CHARACTERIZATION AND SUITABILITY CLASSIFICATION OF SOME PLINTHIC LANDSCAPES FOR OIL PALM PRODUCTION IN NIGER STATE, NIGERIA

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ABSTRACT

A rapid reconnaissance survey was carried out to characterize and classify the suitability of some plinthic landscapes for cultivation oil palm (Elaeis guinensis) in Niger State, Nigeria. Two locations, Minna and Ijah-Gbagyi, were selected for the study. In each location, two representative profile pits were dug and described according to FAO guidelines for soil description. Soil samples were collected from genetic horizons for routine laboratory analysis. Suitability evaluation was performed using Square Root method. Results have shown that the color of the soils was dark brown (10YR3/3) which graded to dark yellowish brown (10YR4/4) in the subsoil in Minna, while Ijah-Gbagyi had dark yellowish brown (10YR3/4) overlaying various shades of light yellowish brown in the subsoil. Texture was sandy clay loam over gravely sandy clay in Minna; and gravely sandy loam over gravely sandy clay loam in Ijah-Gbagyi. Both locations had poorly drained substratum due to presence of indurated plinthic materials. Soil reaction was moderately acid (pH 5.9) in Minna to strongly acid (pH 5.3) in Ijah-Gbagyi. Organic carbon, CEC and percent base saturation were all medium to high. Actual suitability evaluation ranked both locations currently not suitable (N1) for oil palm due to limitation of rainfall and its distribution pattern. When irrigation management was imposed as corrective measure, Minna upgraded to moderately suitable (S2) while Ijah-Gbagyi was marginally suitable (S3). On the basis of limitations of climate and soil factors, Minna could be more suitable for cultivation of oil palm.

KEYWORDS: Parametric land evaluation, plinthic soils, oil palm, Nigeria

INTRODUCTION

Land suitability classification is an assessment of land in a particular location to determine it fitness for a specified use in a sustainable way (Boitt *et al*., 2015). In terms of agricultural use, suitability classification is a function of matching crop requirements with soil or land quality/ characteristics to establish the suitability class of a particular land (Singha and Swain, 2016). Classification methodologies are principally grouped into qualitative and quantitative land evaluation (Baja *et al*., 2007). In more recent time, quantitative approach was increasingly being used (Elsheik *et al*., 2010) and hence, adopted for this study. In quantitative evaluation, numeric indicators, ranging from a scale of 0 to 100, are usually assigned in ranking land quality/ characteristics.

Oil palm, a perennial tree crop, originated from West Africa (Poku, 2002), particularly in Nigeria where records of its domestication dated as far back as some 5,000 years (Sridhar and Ade-Oluwa, 2009). Palm oil is a product extracted from the fleshy mesocarp of the palm fruit. It is a major food and non-food ingredient consumed by virtually every household in Nigeria, directly or indirectly, through the use of palm oil related products (Ohimain *et al.*, 2014). Nigeria was once the world leading producer and exporter of palm oil in the sixties, but lost her leading status to Malaysia and Indonesia because of her poor commitment to oil palm production (Nnorom, 2012; Ohimain *et al.*, 2014). The drop in ranking was blamed on neglect of agriculture sector for petroleum products.

Plinthic soils or Plinthosols have a global coverage estimated at some 60 million hectares (WRB/IUSS Working Group, 2014). Plinthosols have a wide distribution in humid savanna grassland of north-central Nigeria including Jos Plateau (Ojanuga, 2006). They are formed from humus-poor iron-rich ferruginous materials, with genetic history of repeated wetting and drying, leading to formation of pisoliths (in form of gravels or concretions). These type of soils are associated with numerous management problems, ranging from low fertility, water-logging or drought (depending on their physiographic locations), to shallow rooting depth (WRB/IUSS Working Group, 2014). Suitability evaluation of this group of soils for tree crops, particularly oil palm, in this part of the country, that is north-central, Nigeria, have not been carried out. On this basis, this work was designed to characterize and evaluate the suitability of some plinthic landscapes for oil palm production, based on a parametric (Square Root) method, in some locations (Minna and Ijah-Gbagyi) in Niger State, North-central Nigeria.

MATERIALS AND METHOD

Study Area

Niger State, Nigeria, lies between latitudes 8° 10' and 11° 31' N and longitudes 4° 30' and 7° 15' E in the Guinea savanna of zone of Nigeria. The state is covered by two major rock formations, that is, the sedimentary rocks (SR) to the south and basement complex rocks (BCR) to the north. To the west is some areas covered by Sokoto Basin (Fig. 1). The locations selected for the study were Minna (latitude 9° 25′ N; longitude 6° 22′ E, on 177 m above mean sea level) and Ijah-Gbagyi (latitude 9° 16′ N and longitude 7° 15.327′ E, on 466 m above mean sea level). The annual rainfall varies from 1600 mm in the south to about 1200 mm in the north usually spread between the months of May and October (Lawal *et al*., 2012).

The study locations fall under sub-humid-Minna-Kaduna-Kafanchan High Plains consisting of gently undulating high plains developed on Basement Complex Rocks made up of granites, migmatites, gneisses and schists. Inselbergs of "Older Granites" and low hills of schists rise conspicuously above the plains. Beneath the plains, bedrock is deeply weathered and constitutes the major soil parent material. The soils derived from the weathered rocks are deep, weakly to moderately structured sand to sandy clay with gravelly and concretionary layers in the upper layer or beneath the surface layer (Ojanuga, 2006). The dominant soils have been classified as Typic Plinthustalfs (Lawal *et al*., 2012; 2013; 2014). A wide range of crops such as grains, roots and tubers, legumes and vegetables are grown within the study areas, among them are maize, sorghum, rice, soybean and yam.

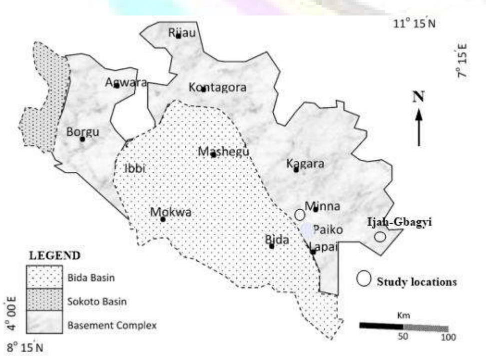

Figure 1: Geological map of Niger State, Nigeria, showing the study locations

Field Work

The choice of the two locations (Minna and Ijah-Gbagyi), for this study was facilitated by previous works of Lawal *et al*. (2012; 2013). In each location, two representative profile pits were dug and described according to guidelines of Food and Agricultural Organization (FAO, 2006). Soil samples were collected, air-dried, gently crushed and passed through a 2 mm-sieve for routine laboratory analysis. The processed soil samples were analyzed for particle size distribution and some chemical properties following the procedures outlined by the International Soil Reference and Information Centre and Food and Agricultural Organization (ISRIC/FAO, 2002). Particle size analysis was determined by Bouyocous hydrometer method while soil pH in water (1:1) suspension was determined with pH meter. Organic carbon (C) was by Walkley-Black method. Exchangeable bases: calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) were extracted with neutral ammonium acetate (1N NH_4OAc) solution and amounts Ca and Mg in solution were measured by atomic absorption spectrophotometer while K and Na were measured by flame photometer. Cation exchange capacity (CEC) was determined by the neutral 1 N NH_4OAc saturation method, while percent base saturation was by calculation.

Land Suitability Evaluation

The land suitability evaluation for oil palm was carried out using Square Root method. Land requirements for oil palm are shown in Table 1. Data from field observations and laboratory characterization were used in the evaluation. Key environmental factors used were climate, soil physical characteristics and drainage, topography of the land, nutrient availability and nutrient retention capacity. Index of suitability for each soil unit was calculated using the Square Root equation (Khiddir, 1986) below:

$$I = R_{min} \text{ x } \sqrt{\frac{A}{100} \text{X} \frac{B}{100} \text{X} \frac{C}{100} \text{X} \ldots}$$

Where I is the index (%) of suitability, Rmin is the minimum rating of the environmental factors and A, B, C … are other factor ratings besides the minimum. The overall suitability was assigned by converting the index values to their corresponding land suitability classes (Table 2).

RESULTS AND DISCUSSION

Soil/land characteristics and management implications

Information on land characteristics/ land quality are presented in Table 3. Mean annual rainfall for Minna and Ijah-Gbagyi was 1284 mm and 1016 mm (Lawal *et al*., 2012; 2013) respectively. Daily temperature for Minna rarely falls below 22 ^{O}C with monthly mean of 34 ^{O}C (Ojanuga, 2006; Adeboye *et al*., 2011), while Ijah-Gbagyi had average of 33 ^{O}C (Lawal *et al*., 2013), which was marginally suitable for oil palm cultivation. Length of dry months for the two locations was 5-6 months, above the critical duration period of 4 months established as normal for optimum performance of oil palm (Djaenudin *et al*., 2003).

The soils of Minna have dark brown (10YR3/3) color at the surface which graded to dark yellowish brown (10YR4/4) in the subsoil. Ijah-Gbagyi have dark yellowish brown (10YR3/4) overlaying various shades of light yellowish brown in the subsoil. The texture is sandy clay loam at the surface over gravely sandy clay at subsoil, while Ijah-Gbagyi have gravely sandy loam over gravely sandy clay loam subsurface. The gravely nature of soils in both locations may create difficulties particularly in rooting. According to Babalola and Lal (1977), gravels pose problems to root penetration and proliferation. Poor to imperfect drainage conditions at the substratum in both locations might be linked to accumulation and subsequent cementation of the gravely layer by clay, starting from the depth of 29 to 73 cm from surface. Since oil palm is sensitive to wet conditions, with implications in poor growth and yields (Arshad, 2014), drainage should be taken into consideration during the rainy seasons. Management problems associated with plinthic soils particularly on water-logging or drought have been pointed out earlier in this report.

Mean soil pH values were 5.9 and 5.3 for Minna and Ijah-Gbagyi respectively, and was fit for cultivation of oil palm. According to Djaenudin *et al*. (2003), oil palm is tolerant to acid soils with pH range of 4.2 to 6.0. Organic C was medium in Minna to high in Ijah-Gbagyi, which was unusual for plinthic soils. Medium to high organic carbon in the soils may imply practice of low intensity farming in both locations. Thus, maintaining the status of organic matter in these soils may immensely preserve the high cation retention capacities and nutrient reserves of the soils. Currently, cation exchange capacity of the soils was high, 18.64 and 13.05 cmol kg^{-1} for Minna and Ijah-Gbagyi respectively. Base saturation was high (90 %) in Minna and medium (67 %) in Ijah-Gbagyi, suggesting dominance of basic cations in the exchange surfaces of the soils (Atoforati *et al*., 2012).

Land Suitability Classification by Land Characteristics

Results of suitability evaluation after matching land characteristics (Table 3) with environmental requirements of oil palm (Table 1) are presented in Table 4. The actual suitability considers the land in its original condition without any improvement measures imposed at the time of evaluation (Arshad, 2014). In this context, the current status of both locations was found not suitable (N1) for oil palm. The indices of productivity (IPc) were 20.4 % and 10.9 % respectively for Minna and Ijah-Gbagyi. These values were below 25 % established as the critical limit (Van Ranst and Verdoodt, 2005). Major limitations for both locations are climatic factors: rainfall and length of dry months which exceeded 4 months established as critical for normal growth of oil palm (Djaenudin *et al*., 2003). Shallowness of the soils in Ijah-Gbagyi constituted to be additional limiting factor for oil palm.

The potential suitability of any parcel of land refers to its suitability after improvement measures have been made on the land (Arshad, 2014). In this regard, since soil depth cannot be manipulated, rainfall/duration can be augmented by irrigation. By imposing irrigation, the two locations potentially become suitable with index values of 55.3 and 29.4 % respectively for Minna and Ijah-Gbagyi. Thus, Minna graded to moderately suitable (S2) and Ijah-Gbagyi was marginally suitable (S3).

CONCLUSION AND RECOMMENDATIONS

On the basis of the parametric approach used in classifying these landscapes, results revealed that both locations, in their natural status are not suitable for the cultivation of oil palm. To make these plinthic landscapes suitable, irrigation must be practiced to augment water deficit. Aside from irrigation, since oil palm cannot perform optimally under poor drainage condition, poor internal drainage characteristics of these soils should be closely managed. Minna had higher potentials for oil palm cultivation. It is more likely to give higher yields compared to Ijah-Gbagyi which was characterized with shallow soil depth as additional limitation.

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Table 1: Requirements for growth of oil palm (*Elaeis guinensis*)

Land use requirements / Land characteristics	Land suitability class			
	S1	S2	S3	N
Temperature regime (tc)				
Annual average temperature	25-28	22-25 28-32	20-22 32-35	< 20 > 35
Water availability (wa)				
Average annual rainfall (mm)	1700-2500	1450-1700 2500-3500	1250-1450 3500-4000	< 1250 > 4000
Dry months	< 2	2-3	3-4	> 4
Oxygen availability (oa)				
Drainage	Good, moderate	Moderate, poor	Poor, moderate, rapid	Very poor, rapid
Rooting conditions (rc)				
Soil texture (surface)	Fine, slightly fine, medium	-	Slightly coarse	Coarse
Coarse material (%)	< 15	15-35	35-55	> 55
Soil depth (cm)	> 100	75-100	50-75	< 50
Nutrient retention (nr)				
CEC-clay (cmol kg^{-1})	> 16	≤ 16	-	-
Base saturation (%)	> 20	≤ 20	-	-
pH H_2O	5.0-6.0	4.2-5.0 6.5-70	< 4.2 > 7.0	- -
Potassium	> 1.5	1.2-1.5	< 1.2	-
Organic C (g kg^{-1})	> 8.0	≤ 8.0	-	-
Toxicity (xs)				
Salinity (ds/m)	< 2	2-3	3-4	> 4
Erosion hazard (eh)				
Slope (%)	< 8	8-16	16-30	> 30
Erosion hazard (eh)	Very low	Low-moderate	Severe	Very severe
Flood hazard (fh)				
Flooding	F0	F1	F2	> F2
Land preparation (lp)				
Surface stoniness (%)	< 5	5-15	15-40	> 40
Rock out crops (%)	< 5	5-15	15-25	> 25

NB: S1 = highly suitable; S2 = moderately suitable; S3 = marginally suitable; N = not suitable
Source: Modified from Djaenudin *et al*. (2003)

Table 2: Index values for the different land suitability classes

Land Index (%)	Suitability Class	Definition
100-75	S1	highly suitable
75-50	S2	moderately suitable
50-25	S3	marginally suitable
25-12.5	N1	Currently not suitable
12.5-0	N2	Permanently not suitable

Table 3: Land quality/ characteristics of the study locations

Land quality/characteristics	Location	
	Minna	Ijah-Gbagyi
Mean annual rainfall (mm)	1284	1016
Average length of dry season (months)	6	6
Temperature (mean annual) ^{o}C	33.5	33
Slope (%)	< 2	3
Drainage	Imperfectly drained	Imperfectly drained
Flooding	F0	F0
Soil depth to gravely/indurated layer (cm)	83	36
Texture	SCL/SC	SL/SCL
Surface Stoniness (%)	0	< 3
Rock out crops (%)	0	0
Soil reaction (pH)	5.9	5.3
Organic carbon (g kg^{-1})	10.68	30
Cation exchange capacity (cmol kg^{-1})	18.68	13.05
Base saturation (%)	90	67

NB: SCL = sandy clay loam, SC = sandy clay, SL = sandy loam, F0 = flood free.

Table 4: Suitability ratings of land characteristics of the study location for oil palm production

	Minna		Ijah-Gbagyi	
Factor	Actual	Potential	Actual	Potential
Topography (t):				
-Slope	100	100	100	100
Drainage (w):				
-wetness	85	100	85	100
-Flooding hazard	100	100	100	100
Climate (c):				
-Rainfall	60	100	40	100
-Temperature	60	60	60	60
Length of dry season (months)	40	100	40	100
Soil physical characteristics (s):				
-Texture	100	100	100	100
-Soil depth	85	85	40	40
Surface stoniness	100	100	95	95
Rock out crop	100	100	95	95
Nutrient availability (f):				
-Soil reaction (pH)	100	100	100	100
-Potassium				
Nutrient retention (n):				
-Organic carbon	100	100	100	100
-Cation exchange capacity (CEC)	100	100	85	85
-Base saturation	100	100	100	100
Suitability Index (%)	**20.4**	**55.3**	**10.9**	**29.4**
Suitability Class*	**N1c**	**S2c**	**N1sc**	**S3s**

NB: N1 = currently not suitable, S2 = moderately suitable, S3 = marginally suitable, c = climatic limitation, s= soil limitation.

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