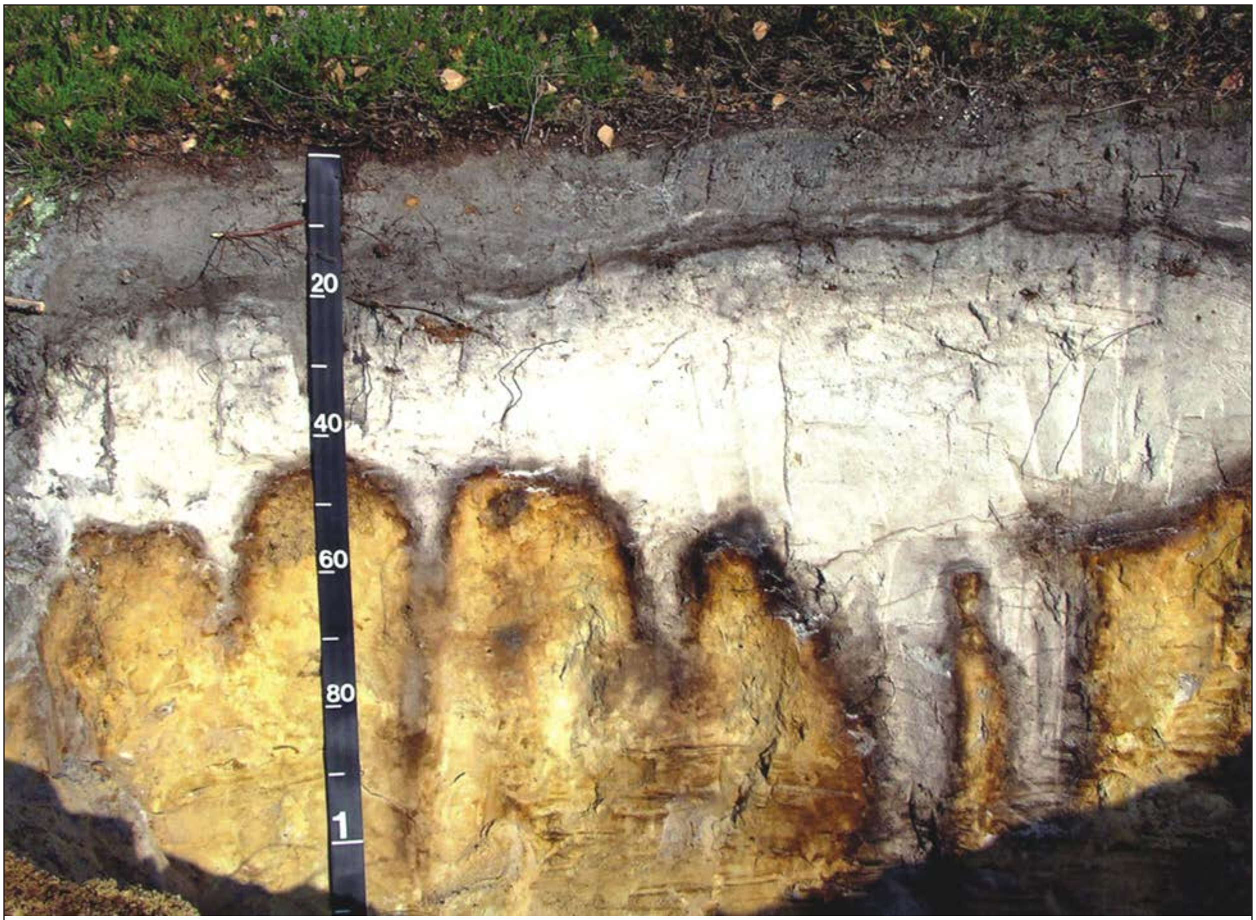

International Journal of Soil Science

ISSN 1816-4978

Academic Journals Inc.

www.academicjournals.com

International Journal of Soil Science 6 (2): 142-149, 2011
ISSN 1816-4978 / DOI: 10.3923/ijss.2011.142.149

Soil Suitability Evaluation and Management for Cassava Production in the Derived Savanna Area of Southwestern Nigeria

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ABSTRACT

The experiment was carried out at Ilaju village in the derived savanna area of South Western Nigeria to evaluate the suitability of the soil for long term cassava production in order to extrapolate to similar soils in the region. Critical nutrient requirement for cassava were collected from past research works. Soil survey was done which on the area to collect soil samples which were analysed and compared with the critical nutrient levels. Three soil series were identified which are Apomu, Gbemi and Matako series. These were classified as Dystric arenosols, Plinthic Ferrasols and Dystric Fluvisols, respectively. The suitability evaluation shows that Dystric arenosols is moderately suitable due to its low nutrient with CEC of 3.92 cmol kg^{1}. The Plinthic Ferrasols is marginally suitable because of its high gravel content and shallow depth (39 cm). Dystric Fluvisols is not suitable due to its seasonal high water table and low CEC (3.48 cmol kg^{1}). Soil management recommendation includes use of organic fertilizer, mulching and leguminous cover cops to enhance soil quality.

Key words: Soil suitability evaluation shallow soil depth, controlled land use, sustainable production, nutrient requirement for cassava, soil management

INTRODUCTION

Soil suitability evaluation involves characterizing the soils in a given area for specific land use type. The information collected in soil survey helps in the development of land-use plans, evaluates and predicts the effects of the land use on the environment (Rossiter, 1990). The suitability of a given piece of land is its natural ability to support a specific purpose. This may be major kind of land use, such as rain fed agriculture, livestock production, forestry, etc. (Dent and Young, 1981). According to the FAO methodology (1976), this is strongly related to the land qualities such as erosion resistance, water availability and flood hazard that are not measurable. As these qualities derived from the land characteristics, such as slope angle and length, rainfall and soil texture which are measurable or estimable, it is advantageous to use these latter values to study the suitability. Thus, the land characteristics parameters were used to workout land suitability for irrigation, crops and forest.

For assessing the suitability of soils for crop production, soil requirements of crops must be known. Also, these requirements must be understood within the context of limitations imposed by landform and other features which do not form a part of the soil but may have a significant influence on use that can be made of the soil (FAO, 1978). From the basic soil requirements of crops, a number of soil characteristics are directly related to crop yield performance. For most crops, optimal, sub-optimal, marginal and unsuitable levels of these soil characteristics are known and have been quantified. Beyond critical ranges, crops cannot be expected to yield satisfactorily unless special precautionary management measures are taken. Soil suitability classifications are based on knowledge of crop requirements, of prevailing soil conditions and of applied soil management. In other words, soil suitability classifications quantify in broad terms to what extent soil conditions match crop requirements under defined input and management circumstances (FAO, 1976).

Land suitability assessment for agriculture is meant to evaluate the ability of a piece of land to provide the optimal ecological requirements of a certain crop variety. In other words, assessing the capability of land is enabling optimum crop development and maximum productivity. Thus evaluation needs a specification of the respective crop requirements and calibrating them with the terrain and soil parameters (Dent and Young, 1981). The identified limiting factors could be managed to suit the various crop requirements and improve crop productivity. This is a pre-requisite to productivity maximization in the agricultural sector. Optimal crop growth and productivity is based amongst other factors on soil conditions, the climate and agricultural practices. However, it was realized that the following soil parameters: cation exchange capacity; soil organic matter content expressed by the organic carbon content; soil depth and stoniness are amongst the main factors that influence crop adaptability to a given land area (Dent and Young, 1981). Some conservative farming practices could as well accelerate soil chemical and physical degradation and create some of the unfavorable soil. The need for sustainable increase in cassava production per unit area in Nigeria has resulted to more soil being opened up for large scale cassava production (Ande *et al*., 2008). The studied area is being considered for commercial cassava production due to new initiative for more cassava production for exportation in Nigeria. However, it has been observed that continuous cassava production on a particular soil leads to decline in soil fertility, which on the other hand may be due to nutrient loss/imbalance by erosion and crop removal (Howeler, 2002). The starting point toward sustainable management is adequate information on the land resources. Equally important is suitability evaluation but these are not in proper form in Nigeria in spite of several spots studied (Ogunkunle, 2004). One of the strategies for achieving food security as well as sustainable environment remains studying the soil resources to details through the processes of soil characterization and land evaluation for various land utilization types (Esu, 2004). The productivity of Nigerian soils is decreasing, the fragile savanna soils where this study was conducted need to be used in a sustainable way to avoid soil degradation. Lands have been utilized intensively for all purposes at the expense of its suitability capability thereby resulting in land degradation and altering of the natural ecological conservatory balances in the landscape (Senjobi, 2007). Land evaluation provides avenue sustainable land use since land will be used according to its capability. This therefore makes it mandatory to carry out land suitability in order to ensure that the selected site is suitable and capable of sustaining long term production of cassava.

MATERIALS AND METHODS

Description of the study site: The study area covered 57.52 hectares and its situated South West of Ibadan City. It falls within longitudes 7°15′ and 7°30′ North and latitude 3°45′ to 4°00′ East approximately.

Like any other part of Nigeria, Ibadan area has a tropical humic climate characterized by high humidity. The mean annual rainfall distribution (mm) of Ibadan is 1485 mm.

Temperature ranges between 27.9-34.7°C. Humidity range between 73-87, 38-14 and 83-95% at 15, 19 and 21 h, respectively.

Original vegetation characteristics of the area was a semi-deciduous low land rain-forest. The original vegetation had been drastically disturbed and in its place are cultivated crops and secondary vegetation successions like bush-regrowth, thicket derived savanna and secondary forest. The type of land use is majorly arable cultivation with small sizes of maize, coconut, oil palm, cassava and vegetable.

The study area is underlined by pre-Cambrian/upper Cambrian basement complex consisting basically of older granites, gneisses and quartz-schist rocks, which are mostly metamorphic in origin.

Field survey: The project site was surveyed in 2008 using Grid method. This method involved taking of representative soil samples at intervals of 100 m apart. Mini pit was dug to identify soil series and to locate soil boundaries. Representative profile pits were also dug to examine the soil horizons. The soil samples were collected and analyzed using standard procedure. Soil particle size was determined using the hydrometer method (Bouyoucos, 1962) with sodium hexameta-phosphate as the dispersing agent. Total N was determined by the microkjeldah method. Available P was determined organic matter content was determined calorimetrically at 66' mm after the development of molybdenum blue colour. Soil organic carbon was determined by the dichromate oxidation procedure (Walkley and Black, 1934). Exchangeable bases (Ca, Mg, K and Na) was extracted with NH4OHC solution. The soil characteristics were compare with nutrient requirement and critical levels of the parameters for cassava production (Howeler, 1996, 2002).

Laboratory analysis

Soil suitability evaluation: Land Suitability evaluation of the soil was done using the parametric method of Sys *et al.* (1991). The parameters used for the land quality calculation include rainfall, length of growing season, mean temperature, slope, wetness, drainage, texture, volume of coarse.

Materials are soil depth, fertility, cation exchange capacity, base saturation and organic carbon. The sums of these were divided by the number of the parameters considered to determine their values.

Suitability: The soil suitability classification consists of assessing and grouping the land types in orders, classes, subclasses and units base on the crop requirements. The suitability classification was done separately for each soil unit identified in the survey area.

RESULTS

Soil classification: Three soil units were identified viz., Dystric Arenosol, Plinthic Ferrasols and Dystric Fluvisols (FAO, 1972). They were classified at local level as Apomu, Gbemi and Matako series respectively according to Smyth and Montgomery (Bouyoucos, 1962; Murdoch *et al.*, 1976). The first soil unit, Dystric Arenosol was classified based on its low cation exchange capacity and its loamy sand to sand texture (Table 1). The second was classified as Plinthic Ferraslos due to its high content of iron concretions forming Plintithe at 39 cm depth. The dystric fluvisols was located at the valley bottom and has high sand content (90%). Apomu series occupies 63%, Matako- 8% and Gbemi about 29% of the study site.

Apomu series (Dystric Arenosol) occupies the gently undulating lower slope and well drained. Water table is below profile depth. Gbemi series (Plinthic Ferrasols) occupies the middle slope. The colour was dark greyish to dark yellowish brown, having hard pan soil below 39 cm. It is well

Table 1: Average physical and chemical properties in the soil

Soil series	Sand (%)	Silt (%)	Clay (%)	pH in KCl	pH in H_2O	Ca^{++} (Meq/100 g)	Mg^{++} (meq/100 g)	K^{+} (Meq/100 g)	Na^{+} (Meq/100 g)
Apomu	64.6	25.8	9.60	4.40	4.80	1.27	1.63	0.14	0.45
Gbemi	72	20.13	7.86	5.05	5.40	1.04	1.58	0.16	0.32
Matako	90	5.46	4.60	4.68	5.37	1.04	1.64	0.15	0.65

Soil series	H^{+} (Meq/100 g)	CEC (Meq/100 g)	BS (%)	C (%)	N (%)	P (ppm)	Zn (ppm)	Cu (ppm)
Apomu	0.63	3.92	84.59	0.77	0.08	3.31	7	1.92
Gbemi	0.14	3.58	96.02	2.44	0.22	10.58	7	2.33
Matako	0.14	3.62	96.18	0.53	0.05	6.87	7.02	2.52

drained, slightly moist and having surface stones and rock outcrops. Groundwater table is below profile depth. Matako series (Dystric Fluvisols.) occupies the valley bottom area, sited on a slope of about 1-2%. Its parent material is alluvium. The area is not under cultivation, but left to fallow, with the groundwater table below the profile depth but with seasonal high water table.

Physical and chemical properties of the soils: Gbemi series (Plinthic Ferrasols) is located at the middle slope position and has a sandy texture. Considering the slope of 3%, adequate soil conservation like mulching is required when the cassava leaves are not yet fully grown to avoid loss by erosion. However, this series has a major limitation to cassava production, which is its 39 cm depth to hard pan. This depth may impede root extension especially with improved varieties that can root up to 1 m below the soil, leading to great reduction in yield. Adequate soil conservation like mulching is required when the cassava leaves are not yet fully grown to avoid loss by erosion. The soil was high in Ca, containing about 1.04 Meq/100 g. It was also moderate in available K and high in available P, which was about 10.58 ppm (Table 1) according cassava nutrient requirement reported by Howeler (1996).

The properties of Apomu soil shows that it is suitable for cassava production. Very essential are its sandy loamy texture coupled with its gentle slope of 3-4%. This texture also allows for easy growth, extension and harvesting of cassava tubers unlike clay texture, where tuberisation may be tedious and requiring more energy. However, when its K requirement was compared with available nutrient, it was found inadequate. It is important to watch out for this since the critical level is 0.15 Meq/100 g (Table 2) and the average amount present in the soil was 0.13 Meq/100 g. The soil was low in N with average N of 0.08%. Average Cation Exchange Capacity (CEC) for this series was 3.92 Meq/100 g soil. Average level of K and P were 0.14 Meq/100 g soil and 3.31 ppm, respectively. These were considered to be low according to nutritional requirement of cassava (Table 1). This would consequently result to reduction in growth of cassava (Howeler, 1996). Thus, to obtain good yield and sustainable production of cassava the available nutrient in the soil should be increased through fertilization (Sittibusayo, 1993).

Matako series is sandy in texture. In terms of cassava production the soil was high in Ca and moderate in K. It contained an average Ca of 1.04 Meq/100 g and K of 0.12 Meq/100 g (Table 1). However, this result was not unconnected with the fact that the soil has been left to fallow for about 3 years. This shows that under proper farming system and management practices, the soil can support production of cassava but because of its physiographic location at a depression it would be susceptible to root rot in the wet season, when the ground water table usually rise close to soil surface.

Table 2 showed the critical levels of soil parameters for cassava production. The soil parameters considered such as (Na, K, Ca and Mg) were above the critical levels except for P in Apomu series which was 3.31 ppm against critical level of 7 ppm.

Table 2: Critical level of soil parameters for cassava (Howeler, 1996)

Parameters	Level	Method of analysis
pH	4,6 and 7,8	1:1 Soil water ratio
Al^{+++}	2.5 (Meq/100 g)	1 N Kd
P	7 (ppm)	Bray extract
	10 (ppm)	Bray-II extract
	8 (ppm0	O/S Oisen-EdTA Ext
	9 (ppm)	North carolina extract
K^{+}	0.15 (Meq/100 g)	NH_4^+acetate
Mg^{+++}	0.09-0.15 (Meq/100 g)	NH_4^+acetate
Ca^{++}	0.06 (Meq/100 g)	NH_4^+ acetate
Conductivity	0.25 (Meq/100 g)	NH_4^+acetate
Na sat.	0.5-0.7 (mm/homs/cm)	Saturation extract
Zn^{++}	2.5%, 1.0 (ppm)	NH_4^+ acetate
Mn^{++}	5.9 (ppm)	North carolina extract
SO_4-S	8 (ppm)	North carolina extract

Table 3: Suitability classification for cassava production

Soil series	Order	Class	Sub-class	Unit
Apomu	S	Suitable	S2 (moderately suitable)	S_2f
Gbemi	S	Suitable	S3 (marginally suitable)	$S_3g\#$
Matako	N	Not suitable	N1 (Currently not suitable)	N_1d

f: Nutrient deficiencies, g: Gravelly, #: Rock out crop, d: Drainage

Suitability classification: Table 3 shows the suitability classification of the three soil series on the experimental site. Apomu series was moderately suitable (S_{2f}), Gbemi was marginally suitable ($S_{3g\#}$), while Matako was not suitable for cassava production (N) due to susceptibility to water logging during the 5-6 months of raining season in the area. The suitability subclass showed that fertility was low while gravel (g) content and presence of rock (#) out crop limits the suitability of Gbemi series.

DISCUSSION

Apomu series which was a light textured soil was classified as moderately suitable due to its medium level of soil chemical characteristics in comparison with the nutrient requirement for cassava production (Table 4). However, this soil possesses a limitation, which was low fertility, especially macronutrients (N, P and K) which are close to the critical level. This however, does not preclude its use for sustainable production of cassava, since the soil fertility and nutrient level can be greatly improved with the use of inorganic and organic fertilizers. This result was similar to results of Ande *et al.* (2008) in their research on similar savanna soils in south western Nigeria. It has also been confirmed that cassava produce maximally on light to medium texture and fertile soil (Howeler, 2002). Sulphate fertilizers should be avoided so as not to raise the level of soil acidity above present level. Gbemi series was generally low in nutrient, though this can be improved. But its depth to hard pan of 39 cm as well as the presence of rock outcrop makes it permanently not suitable for cassava production (Table 3). This is because no foreseeable change will long increase the soil depth to hard pan, which is a crucial limitation to root development and extension of cassava. This does not indicate that the soil cannot be used for other purposes, it can be used for maize, vegetables production or other shallow rooted crops where root extension may not reach the depth of 39 cm (Murdoch *et al.*, 1976).

Table 4: Approximate classification of soil chemical characteristics according to the nutritional requirement of cassava (Howeler, 2002)

Soil parameter	Very low	Low	Medium	Very high	High
pH*	<3.5	3.5-4.5	4.5-7.0	7.0-8.0	>8
Organic matter# (%)	<1.0	1.0-2.0	2.0-4.0	>4.0	
Al saturation			<75.0	75.0-85.0	>85.0
Na saturation			<2.0	2-10	>10.0
P (ppm)	<2.0	2.0-4.0	10.0-14.0	>15.0	
K (Meq/100 g)		<0.10	0.10-0.15	0.15-0.25	>0.25
Ca (Meq/100 g)	<0.25	0.25-1.0	1.0-5.0	>5.0	
Mg (Meq/100 g)	<0.2	0.2-0.4	0.4-1.0	>1.0	
S (ppm)	<20	20.0-40.0	40.0-70.0	>70.0	
B (ppm)	<0.20	0.20-0.50	0.50-1.0	1.0-2.0	>2
Cu (ppm)	<0.10	0.10-0.30	0.30-1.0	1.0-5.0	>5.0
Mn (ppm)	<5.0	5.0-10.0	10.0-100.0	100.0-250.0	>250.0
Fe (ppm)	<1.0	1.0-10.0	10.0-100.0	>100.0	
Zn (ppm)	<0.5	0.50-1.0	1.0-5.0	5.0-50.0	>50.0

pH: pH in H_2O

The soil of Matako series can support the growth of cassava but may be susceptible to root rot, as observed on the fields with high water table especially during the rainy season. This is a major limitation in that the area being a depression behaves as water course during the wet season. The soil should be considered for vegetable production during dry season if cost of irrigation is reasonably low.

Management: Generally, it can be seen that physical factors affect soil suitability greatly for sustainable production of cassava. The soil of Apomu series should be monitored for nutrient balance, since majority of the nutrient elements are close to critical levels, especially Ca, K and P. This is especially important if cassava is to be grown on a yearly basis, due to its high nutrient extraction ability (Sittibusayo, 1993). However, it has been found that cassava adapts well to low levels of available P, but requires fairly high levels of K, especially when grown for many years on the same plot (Howeler, 1994). Hence, it is also recommended that controlled fallow and land use should be introduced which involves crops like sun hemp and centrocema be ploughed into the soil to improve soil nutrient and its water holding capacity (Kumar *et al*., 2010). The use of fortified organic manure may also be employed, which could improve soil structure and nutrient level (Ayoola *et al*., 2008). Soils with pan like Gbemi soils should be avoided for cassava production. Such soils may hinder root development and result to withering. This is very important because some improved varieties of cassava may extend their root up to a depth of 1 m (Ande *et al*., 2008). The valley bottom soils of Matako series can be used for seasonal farming such as vegetables and spices, but should not be considered for cassava production because of its high water table which cause root rot as well as its capability to hold nutrient. The sandy nature would also limit its use for irrigation during dry season. The sandy texture was also reported as limiting factor for surface irrigation for crop production on Shapoor plain in Iran (Albaji *et al*., 2008).

CONCLUSION

The soil of Apomu series is considered suitable but fertility monitoring is very necessary to avoid low yield. Gbemi is marginally suitable because of its shallow soil depth while Matako is not suitable due to seasonal high water table as a result of its location in a depression on the field. Sustainable production of cassava on a long term basis requires good soil conservation practices such as mulching to avoid the damaging effects of soil erosion. Good farming systems and operations such as bush fallow and ridging should be practiced to allow for soil nutrient replenishment. These measures are very important to avoid soil degradation and nutrient loss and/or imbalance.

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