Current and Potential Soil Suitability for Cassava for Sustainable Production in Varying Soils of Bayelsa State Nigeria

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Abstract: Mangrove swamp deposit, Sombreiro Warri deltaic deposit, and Recent and sub-recent alluvial deposit soils of Bayelsa State were characterized and evaluated for arable crop cassava production. Results showed that there were variations in the soil physicochemical properties. Soils underlain by Mangrove swamp deposit being better than others since it had greater content of organic matter, total nitrogen, Ca and total exchangeable bases. It also recorded higher pH making it less acidic for crop production. The results of the current (actual) suitability map of the soils showed a wide range of moderate to marginal suitability scores for cassava production except in in soils of Otuoke (11.4 to 24.28%) indicating temporary nonsuitable (N1) for cassava production. However, the potential suitability map of the study area revealed that the soils were moderately suitable for cassava. The study also revealed that fertility is a major constraint to the production of cassava and managerial strategies capable of boosting fertility status should be employed for cassava production in this region.

I. Introduction

Meeting the food demand of the global population is the main challenge facing agricultural production and development. This population is expected to reach 9 - 10 billion by the year 2050 and by approximation, 12 billion by 2100 (U.N, 2019). Global food demand is expected to rise up to 60% by 2050, and this rise is expected to be much greater in tropical Africa where Nigeria has its place (Van Ittersum *et al.*, 2016). The global policy agenda for many generations show more concern for sustainable agricultural practices that will support this growing population (Rosegrant and Cline 2003). Perhaps this could be a result of the fact that agricultural productivity is declining because of land degradation driven by inappropriate land use caused by poverty (Lambina *et al.*, 2001).

Cassava is one of the dominant crops in southern Nigeria, and holds paramount importance in food security and livelihood. Cassava serves as buffer against crop failure because it has been known to grow in marginal soils giving it the potential to eliminate food crises and famine (Anikwe and Ejike, 2018). The production of cassava is declining due to their cultivation on moderately and marginally suitable soils, and under low to poor management conditions. Such constraints caused by soil degradation are responsible for the low productivity of the crop. Loss of soil nutrients, waterlogging (Singh, 2016), and contamination (Sam *et al.*, 2016; Chartzoulakis and Bertaki, 2015) are some of the serious environmental problems facing agricultural activities in this area. Such degradations make the previously used soil for the cultivation of these crops unsuitable for their production (Verheye, 2008), and if this usage continues, it may pose a serious threat to food security in this region (Gomiero, 2016; Abd-Elmabod, 2019). There is a need for effective utilization of land resources according to their suitability to achieve sustainable agricultural production (FAO 1976; Elaalem *et al.*, 2010). Allocation of land resources to the use for which they are most suitable is the best approach to ensuring optimum output (Fasina *et al.*, 2007). In this regard, a land evaluation strategy seems to be an effective tool both for sustainable agriculture as well as sustainable land use planning (Shahbazi *et al.*, 2009; Perveen *et al.*, 2012). The main objective of this study is to evaluate the suitability of soils of Bayelsa State for cassava production.

II. Materials and methods

Study Area

This research was carried out in Bayelsa state situated in the Niger Delta, Nigeria. Its geographical coordinates lie within Latitudes 4° 30'to 4° 39`00'' North and longitude 6° 11'to 6° 16`00" East (Figure 1). The area is about 695 km^2 with maximum elevation of 29 meters and minimum elevation of 1 meters above sea level (Figure 3). The area is bounded by River Niger in the north. Bayelsa is known for its high rainfall of about 3,899-4900mm per year. The temperature ranges from 24.7^{0}C (76.4^{0}F) to 27^{0}C (81.4^{0}F) in February. The relative humidity is between 74 to 89%. The area covers the upper deltaic plain that forms a relatively low-lying broad and more gently sloping portion of the Niger Delta basin, comprising small ox-bow lakes, flood plains, alluvial cones, alluvial fans, natural levees of rivers and creeks and back swamps (Mordi, 1986; Ayolagha, 2001; Kamalu et al, 2002). The soils of Bayelsa State Nigeria are derived from geologic materials of Fluvial and alluvial materials (Figure 2) which are recent deposits of alluvium that have been affected only by slight soil forming process such as the incorporation of humus and the development of mottled color owing to poor drainage (Ayolagha, 2001). The study area is within the equatorial rainforest region though the archetype forests around the lake have been replaced by oil palm (*Eliasis guineensis*) grooves Raffia palms (*Farinifera*), and agroforestry species such as Bush mango (*Irvingia gabonensis,*) *Cola* sp., Plantain (*Musa* sp.) and a heavy undergrowth of ferns. However, some have been reduced to a mosaic of small plots of field crops like cassava *Manihot sp*), yams (*Dioscorea esculeta*), cocoyams (*Colocasia esculenta)*, vegetables and agro-forestry. The major occupation of the people is fishing, water transport, sand dredging, and tourism. Other social-economic activities include lumbering, farming agroforestry, limited poultry, cattle, sheep and goat rearing, piggery and cottage industry.

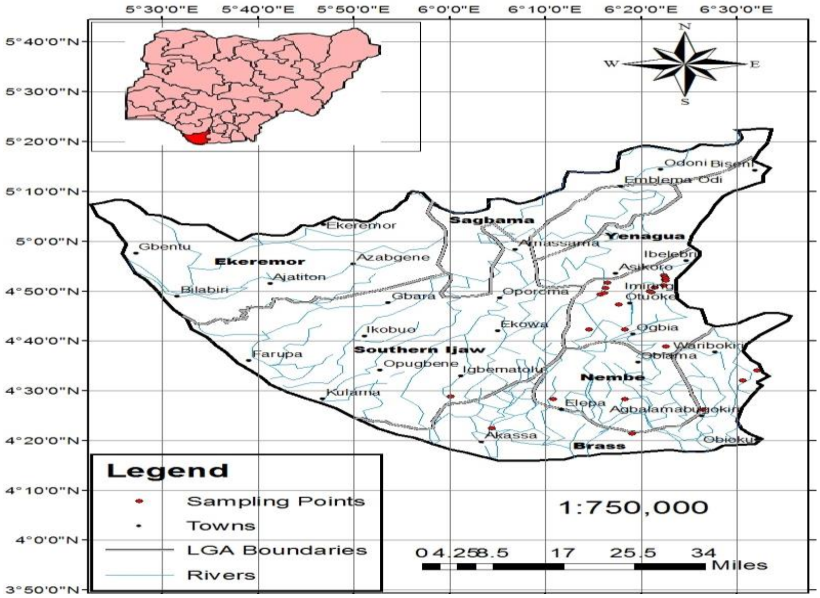

Fig 1: Location map of Bayelsa state

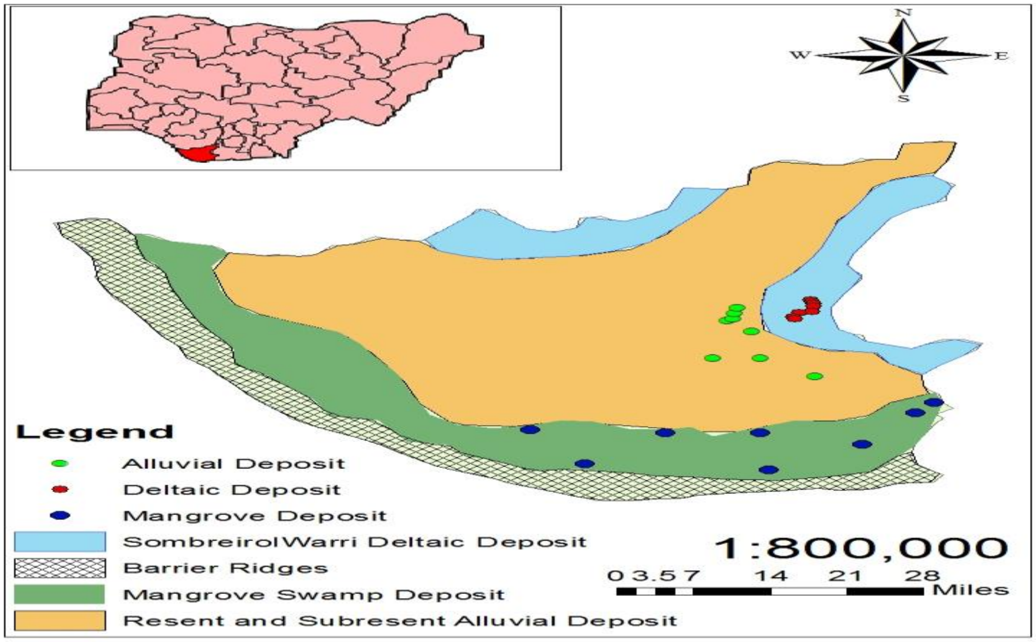

Fig 2: Geology map of Bayelsa

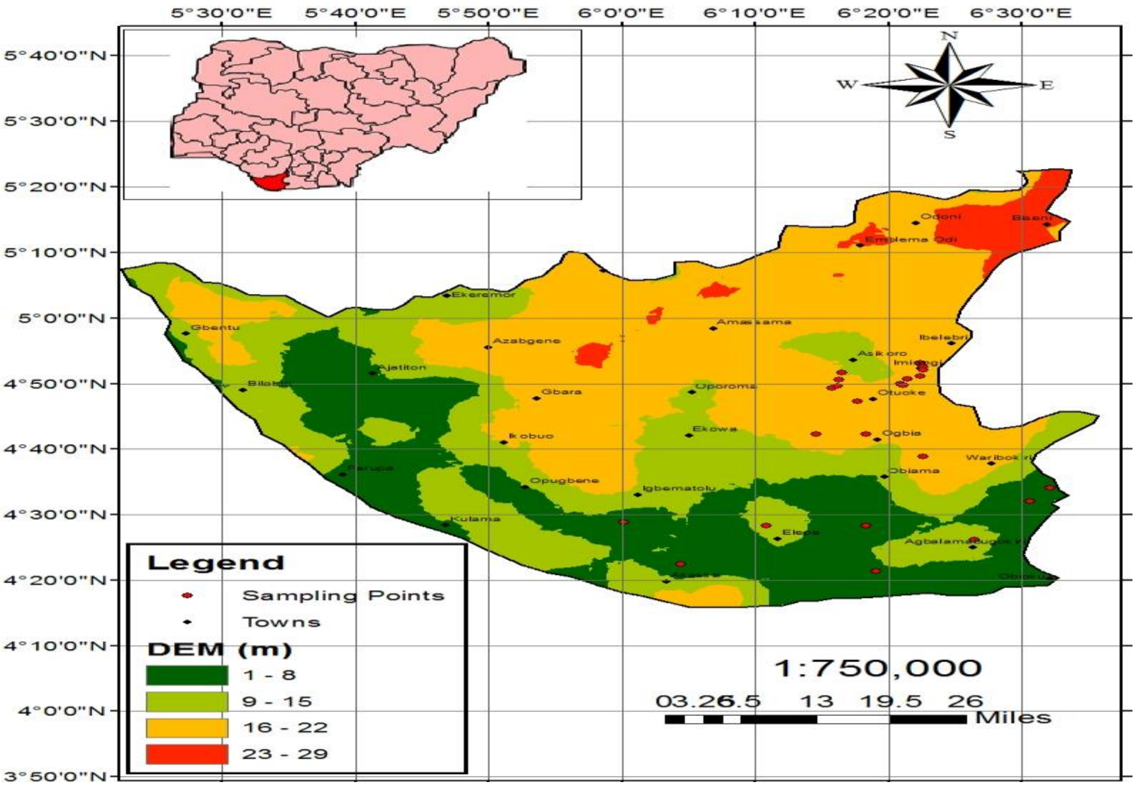

Fig 3: Digital Elevation Model

Field Study

A reconnaissance visit was conducted on the study sites with the aid of location, geological and topographic maps of the study area to identify the different parent materials and geomorphic units. A target sampling technique was adopted and three parent materials namely Sombreiro, Warri Deltaic Deposits, Mangrove Swamp Deposits, and Recent and Sub Recent Alluvium were studied. Eight profile pits were dug in each location. A total of 24 profile pits were used for the study following the standard procedure of profiling (FAO 1983). The samples collected were taken to the laboratory for standard routine analysis.

Laboratory Analysis

Particle Size Distribution was determined by sieve analysis and by hydrometer method (Gee and Or, 2002). Soil pH was determined in water and 0.1 KCl using a pH meter in soil/liquid suspension of 1:2.5 (Hendershot *et al.*, 1993). Organic Carbon was determined using the wet oxidation method (Walkley and Black 1934). Total Nitrogen was determined by kjehdahl digestion method using concentrated H_2SO_4 and a Sodium Copper Sulphate catalyst mixture (Brenner and Yeomans, 1988). Available phosphorus was determined using Bray 2 solution method according to (Olsen and Sommers, 1982). Exchangeable K and Na were extracted using 1N Neutral Ammonium Acetate (NH_4OAC) and determined photometrically using a flame photometer (Thomas, 1982). Exchangeable Magnesium and Calcium were determined using ethelene diaminetetraacetic acid (EDTA) (Thomas, 1982). Exchangeable Acidity was determined titrimetrically (Mclean, 1982). Effective Cation Exchange Capacity (ECEC) was calculated from the summation of all exchangeable bases and exchangeable acidity (IITA, 1982). Percentage Base Saturation (%BS) was determined by computation.

Land Suitability Evaluation

Land suitability evaluation was done based on parametric approaches viz: Storie method (Storie, 1978). Pedons were placed in suitability classes by matching their characteristics with land use requirements or rating of land qualities representing soil conditions for cassava. The current (actual) and potential suitability of the soils was calculated using the formula of the Storie method below: The index was taken as a product of individual ratings:

$$I = A \times \frac{B}{100} X \frac{C}{100} X\ 100 \qquad \text{equation 1}$$

Where: I is index (%) and A, B, C etc. describe ratings allocated to different land characteristics (%). Thereafter, suitability classes were determined by the number and intensity of the limitation(s), and the most unfavorable quality determined the suitability class. Suitability classes S1, S2, S3 and N1 were established.

Data Analysis and **GIS Model**

Microsoft Excel was used to descriptively analyzed data from the laboratory and mean values were presented in charts. The data was also used to calculate the aggregate suitability scores (both actual and potential). The results were digitally encoded in Arc GIS 10.2 software with the GPS data generated from the field study for the production of thematic maps. The Open Street Map was used to develop the shape file for Bayelsa State.

III. Results and discussion

Physical Properties of the Soils studied

Displayed in Figure 4 are the particle size distribution results. Sand-sized particles were dominant over other particle sizes in studied soils. Mean coarse, fine and total sand varied from 286.1-475.6g/kg, 289.2-344.1g/kg and 606.9-823.4 g/kg, suggesting that sand fractions were higher in soils of Subrecent alluvial plains than others. Similar differences among horizons of soils from varying lithologies were recorded in earlier studies by Onweremadu *et al*. (2015). However, greater silt (227.5g/kg) and clay (166.9 g/kg) fractions were found in soils of mangrove swamp deposits. Higher values of silt were obtained by Chris-Emenyonu *et al*. (2020) in soils of dissimilar lithologies in southeastern Nigeria. However, results on clay content were less than 140-580 g/kg reported by Kamalu and Nwonuala (2015) in Ogba soils, possibly due to greater pedogenetic processes involving clay loss in the Sombreiro - Warri Deltaic area. But clay content satisfies the optimum requirement for the production of crops like rice (Sys *et al*.,1991 a and b).

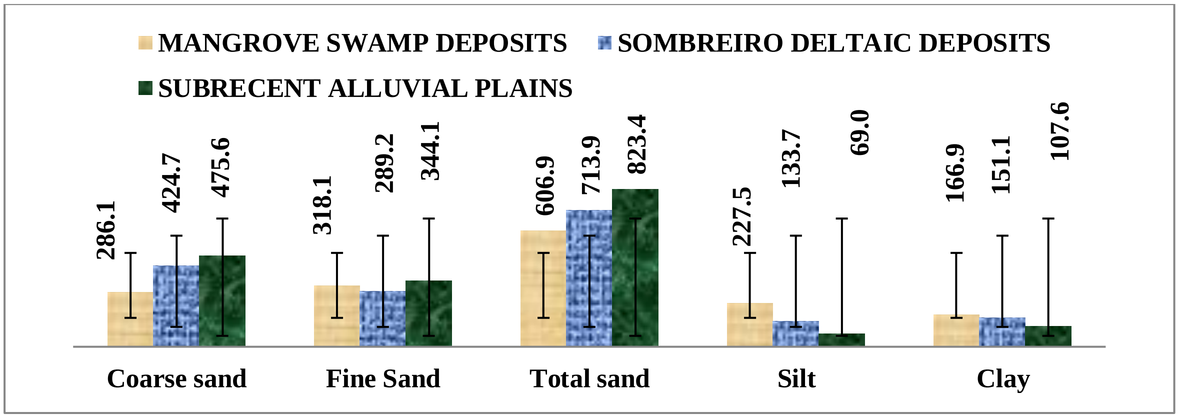

Fig 4: Soil particle sizes (gkg^{-1}) studied

Chemical Properties of the Soils studied

Depicted in Figure 5 to Figure 11 are the chemical properties of the studied soils where the soil pH in water and KCl (Figure 5) varied from 5.5 to 6.3 and 4.5 to 5.4 respectively, suggesting that the soils were generally acidic irrespective of the medium of determination. It also suggests that the soils under sub-recent alluvial plains with lower pH values were more acidic than others. These soil reaction values are classified as highly suitable for most crops (Djaenudin *et al*., 2003). Organic carbon (OC), organic matter (OM) (Figure 7) and total nitrogen (TN) (Figure 8) contents of the soils also varied with higher contents (48.4, 80.5, and 2.5 gkg^{-1} respectively) occurring in soils of mangrove swamp and lowest contents (12.7, 21.8 and 1.1 gkg^{-1} respectively) occurring in sub recent alluvial plains. The total N content of a soil is directly associated with its OC content and its amount on cultivated soils is between 0.03% and 0.04% by weight (Mengel and Kirkby, 1987; Tisdale *et al*., 1995). Values of soil carbon were higher than those obtained in a similar environment by Onweremadu *et al*. (2010) and grossly higher than the results (2.10g/kg) obtained by Mohammed *et al*. (2020) in wetlands of Mambe in Niger State of Nigeria. These values are rated moderate to high and could be attributed to occasional deposition and decomposition of leaf and other plant materials on these soils in line with the findings of Ojanuga (2006). Soil organic carbon content is suitable for most arable and tree crops (Djaenudin *et al*., 2003).

Subsequently, the carbon and nitrogen ratio (Figure 6) was 23.5, 11.2, and 11.5 in a mangrove swamp, sombreiro deltaic deposits, and sub-recent alluvial plains respectively. The values in all the soils apart from the mangrove swamp were lower than the value (20/1) that has been proposed as the threshold between net mineralization and net mobilization (Killham, 1994). Equally, available P (Figure 6) followed a similar trend with TN. It was highest (19.7 mgkg^{-1}) and least (13.1 mgkg^{-1}) in mangrove swamp and sombreiro deltaic deposits respectively. Materechera and Mkhabela (2001) have also reported that Organic matter influences P in soil solution by complexing P from adsorption site in ligand exchange and increasing the mobility of inorganic P, particularly in acid soils, by decreasing chemical activity of iron and aluminum. The FMANR (1990) suggested a critical level value of 8.5 mg/kg for available phosphorus in Nigeria. Soil management via fertilizer use, organic matter, and parent materials haa been reported to influence the level of available phosphorus in the soils (Babalola and Fassina, 2006).

Basic cation contents were very low. Its variation was in a range of 1.8 to 4.0cmol/kg, 0.9 to 1.1cmol/kg, 0.1 to 0.2cmol/kg and 0.2 to 0.7cmol/kg for Ca, Mg, K and Na (Figure 8 and 9) respectively. Ca was more dominant than others. Equally, total exchangeable bases were higher (5.8 cmolkg^{-1}) in soils of mangrove swamp deposits (Figure 8) and lowest (3.1 cmolkg^{-1}) in soils of sub-recent alluvial plains. According to the rating of FAO (2004), basic cations varied from low possibly because of leaching losses, plant uptake and the nature of parent materials as reported by Ahukaemere (2018). Furthermore, higher results of concentrations of aluminium, hydrogen, and total exchangeable acidity (TEA) (1.4, 1.8 and 5.0cmol/kg respectively) were found in soils of sombreiro deltaic deposits and the lowest scores of them (0.9, 0.9 and 1.8cmol/kg respectively) were found in soils of sub recent alluvial plains respectively (Figure 8). Aluminium saturation (A/sat) and exchangeable sodium percentage (ESP) distribution were in the range of 10.8cmol/kg to 14.2 and 2.2 to 7.7cmol/kg respectively with soils of sombreiro deltaic deposits having the least contents. Effective cation exchange capacity (ECEC) and active cation exchange capacity (ACEC) were highest in soils underlain by sombreiro deltaic deposits (Figure 10) and lowest in soils underlain by sub-recent alluvial plains. Percentage base saturation (Figure 11) of the soil followed decreasing trend of mangrove swamp deposits (57.4%)> sub-recent alluvial plains (44.5%) > sombreiro deltaic deposits (37.2%). Acid sand soils of southern Nigeria are known to have higher exchangeable acidity (average of 5.32 cmol/kg) and lower base saturation, less than 40% (Ojanuga *et al*., 1981). Accordingly, electrical conductivity (EC) and sulphate (SO_4-S) (Figure 10) followed decreasing order of mangrove swamp deposits (5.2mmhos/cm and 15.9mg/kg respectively)> sombreiro deltaic deposits (4.1 mmhos/cm and 6.9 mg/kg respectively) > sub recent alluvial plains (1.0 mmhos/cm and 2.7 mg/kg respectively). The EC values were more than 1.0 mmhos/cm recorded in the study conducted by Agbenin (2003) in southern Nigeria, who also reported fluctuations in the electrical conductivity of wetland soils.

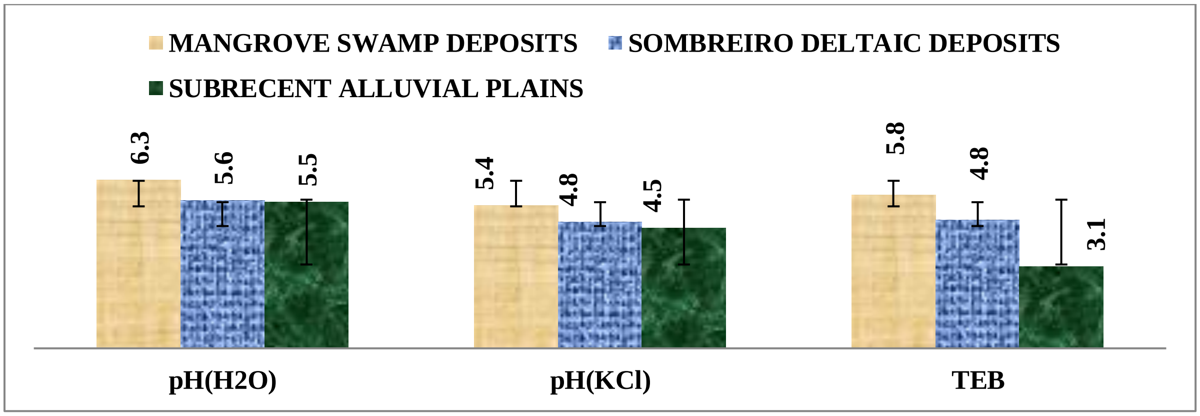

Fig 5: pH and total base saturation (TEB) of the soils studied

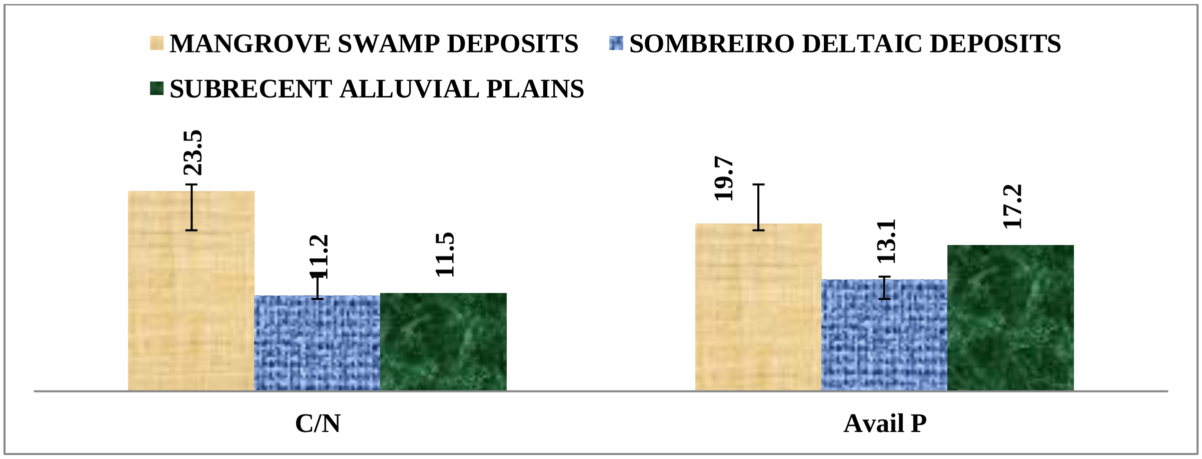

Fig 6: carbon/nitrogen and available posphorus of the soils studied

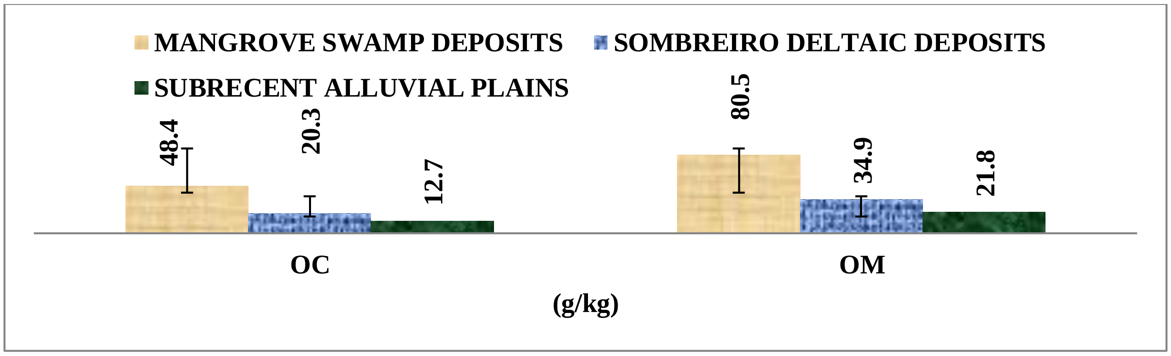

Fig 7: Organic carbon and organic matter content of the soils studied

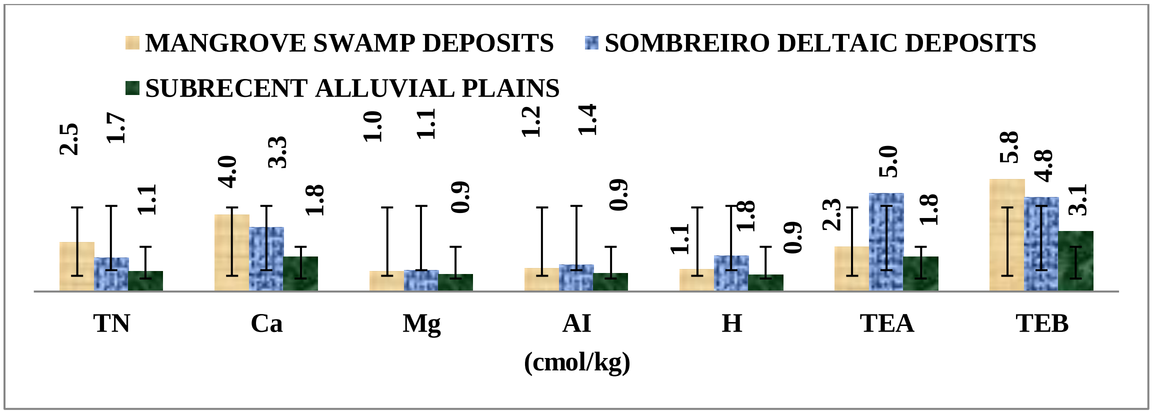

Fig 8: Total nitrogen (TN), total exchangeable acidity (TEA), total exchangeable bases (TEB) and soil elements studied

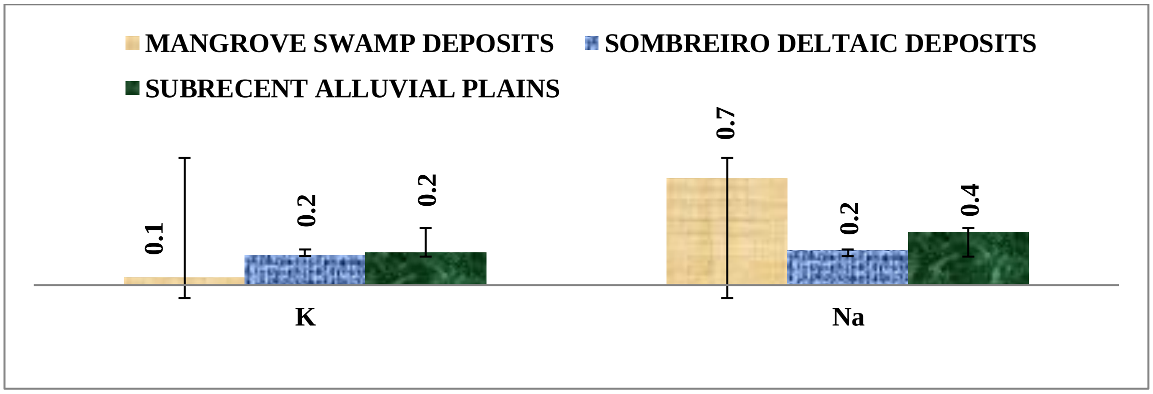

Fig 9: Potassium and sodium concentrations of the soils studied

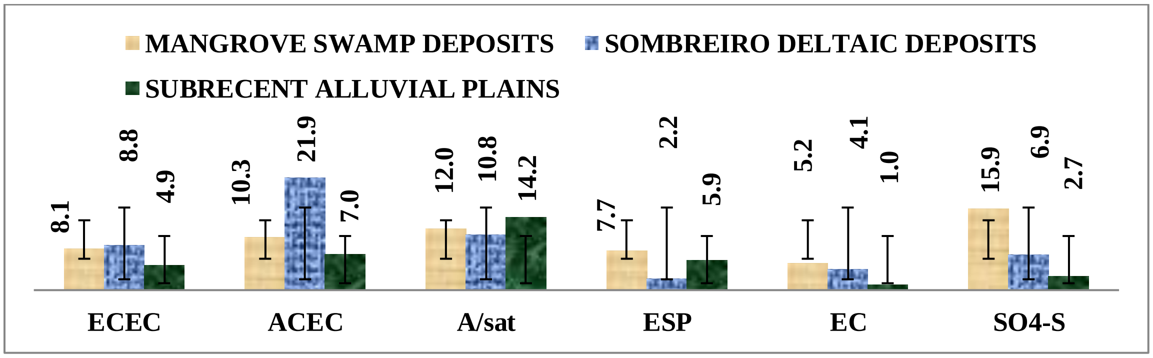

Fig 10: Effective Cation Exchange Capacity (ECEC), Active Cation Exchange Capacity (ACEC), Aluminium Saturation (Al/sat), Exchangeable Sodium Percentage (ESP), Electrical Conductivity (EC) and Sulphate (SO_4-S) content of the soils studied

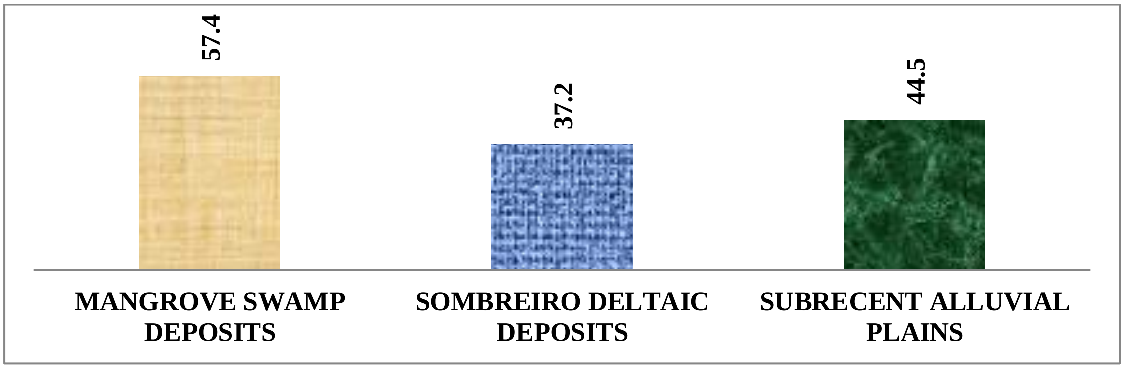

Fig 11: Percent base saturation (B sat) of the soils studied

	Mangrove			
Soil Units	Beach Ridge	Spur	nland Valley	Mangrove Fringe
Actual Suitability (IPc)	20.8(N1)	48.0(S3)	43.0(S3)	54.0(S2)
Potential Suitability (IPp)	64.5(S2)	57.7(S2)	64.5(S2)	64.5(S2)
	Sombreiro Warri Deposit			
Soil Units	Levee	Mudflat	Terrace	Backswamp
Actual Suitability (IPc)	33.6(S3)	45.2(S3)	29.3(S3)	11.4(N1)
Potential Suitability (IPp)	58.6(S2)	57.7(S2)	64.0(S2)	41.9(S3)
	Recent and Sub Recent Alluvial Deposits			
Soil Unit	Plain	PenePlain	Upland Sedentary	Upland Ridge
Actual Suitability (IPc)	47.0(S3)	58.59(S2)	47.6(S3)	34.3(S3)
Potential Suitability (IPp)	58.6(S2)	71.1(S2)	58.6(S2)	58.6(S2)

Table 1: Land Suitability Evaluation for Cassava (*manihot spp*) production

(Guided by Sys 1991c)

Land suitability assessment for cassava (*manihot spp*) production in the study area

The soils of Pene Plain (Table 1) of recent and sub-recent alluvial deposits had the highest actual and potential suitability scores (IPc) of 58.59 (S2) and 71.1 (S2) respectively. The increase in the potential suitability scores also revealed that fertility is a major constraint to crop production and this can be solved through proper management practices.

The Kriged maps of actual and potential suitability for cassava production in the study area were shown in Figure 4 and 5. The map in Figure 4 revealed that a larger portion of the study area was covered by an aggregate score of 47.83 to 58.59%. This showed that large parts of the study area were moderate to marginally suitable for cassava production whereas the lowest aggregate score observed in soils of Otuoke (11.4 to 24.28%) indicated that the soils were present nonsuitable (N1). However, when the fertility constraint was removed (Figure 5), most parts of these areas showed potentially, moderate suitability for cassava production with the least and the highest aggregate score of 41.9 and 71.1% respectively. Several soil suitability studies have also found out that soils of tropical savanna regions are mostly not rated highly suitable (S1) (Olowolafe and Patrick, 2001; Maniyunda *et al*., 2007; Ande, 2011) and were associated with the high rate of soil weathering and degradation affecting soil qualities.

IV. Conclusions

From the findings, most of the physicochemical properties of soils of Mangrove swamp deposits were better than others. Based on the current (actual) suitability for cassava production, the soils were moderate to marginally suitable whereas potentially, it was moderately suitable. Thus, the production of cassava in this area will be more appropriate if proper management practices that will improve the fertility of this region are put in place.

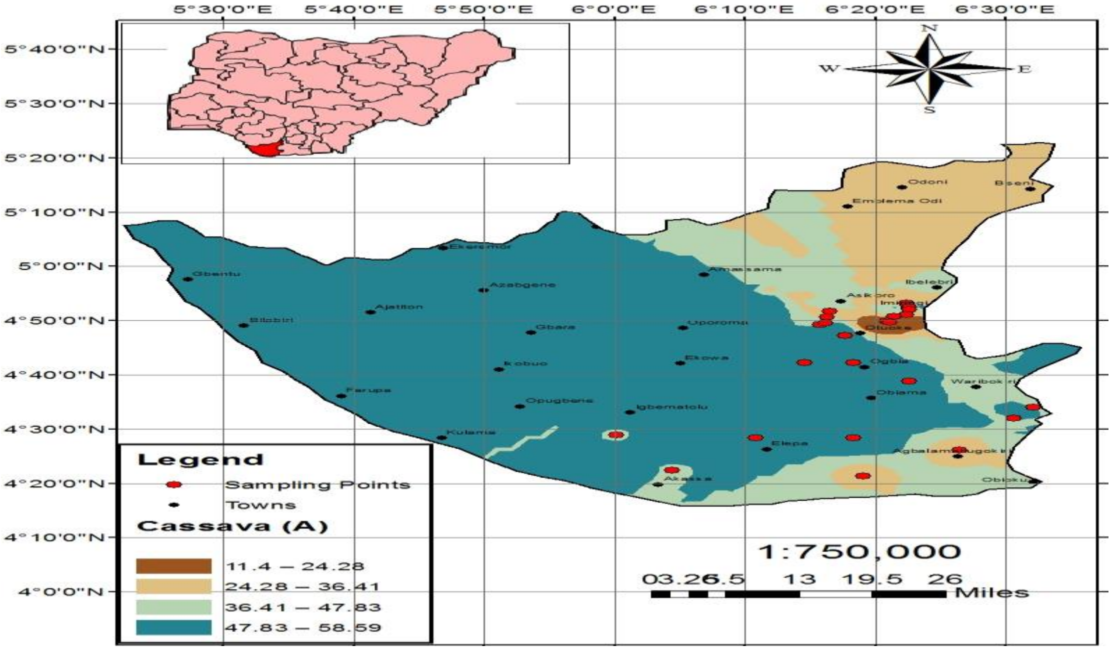

Fig 12: Suitability (Actual) Map of Cassava production in the study area

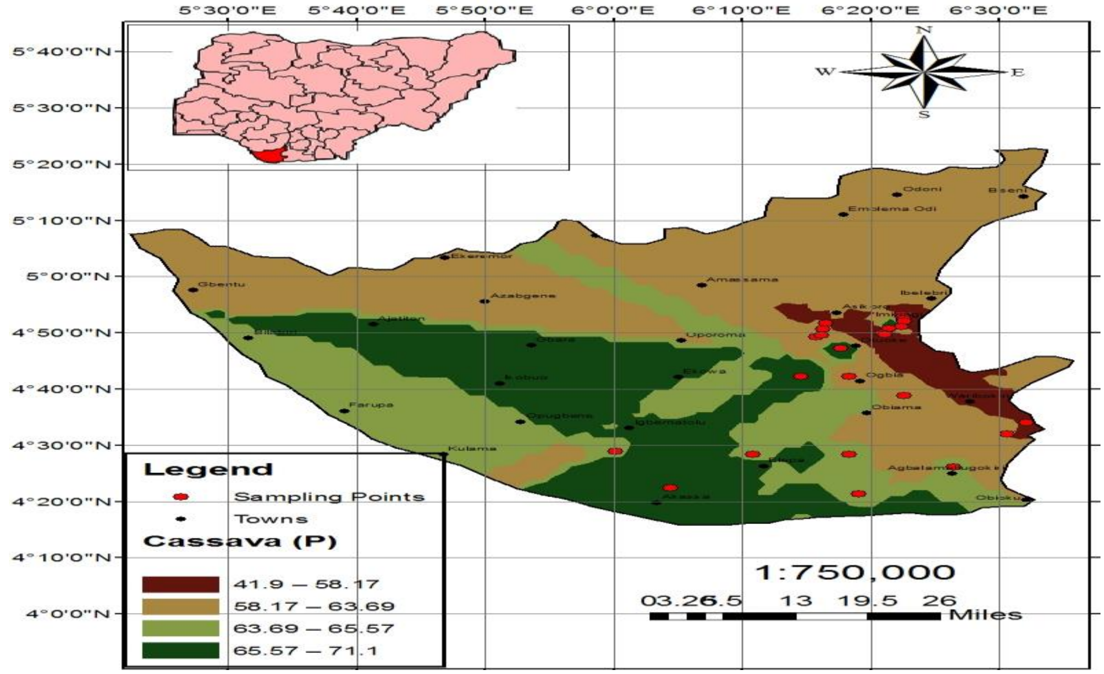

Fig 13: Suitability (Potential) Map of Cassava production in the study

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