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Evaluation of Lower Niger River Floodplain Soils of Bayelsa State, Southern Nigeria for their Agricultural Capabilities

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ABSTRACT

Capabilities and fertility constraints to crop production of the Lower Niger River floodplain soils were assessed using Land Capability Classification (LCC), Land capability Index (LCI), and the Fertility Capability Classification (FCC) systems. The LCC grouped the nine soil mapping units (SMUs) into class II, suited for a wide range of arable crops while LCI grouped ELM1 into class I, ODN1 and TFN1, in class II and ELM2, ELM3, ODN2, ODN3, TFN2, and TFN3, in class III, good to excellent for annual crops. For perennial crops, LCI grouped ELM1, ODN1, and TFN1 into class II, ELM3, ODN2, TFN2, and TFN3, in class III, and ELM2 and ODN3, in class IV, considered good to excellent for perennial crops. The FCC classified ELM1 and ELM2 as Lha-e, ELM3 into Sha-ek; ODN1 into Lha-; ODN2 and ODN3 into Lgha-ek; TFN1 into Lha-ek; TFN2 into SLa-ek; and TFN3 into Sha-e. Wetness, flooding, low nutrient retentive capacity, low exchangeable $Ca^{2+,}$ and Mg^{2+} concentration, soil acidity and Al^{3+} toxicity, texture, drainage, K deficiency, and the likelihood of Fe^{3+} toxicity were identified as limiting fertility characteristics. Whereas limitations identified by the different systems were similar, only LCC identified flooding limitation, LCI, and FCC identified texture and FCC alone identified K^{+} deficiency limitation. Flood control, improved drainage, liming, and adequate fertilization practices including organic matter conservation, were recommended for improved land management.

1.0 Introduction

The economy of Nigeria has, for a long, has been dependent on crude oil. With the dwindling oil resources, governments at all levels are driving to diversify the economy, agriculture being the focus. Arable land for increased food production is one of the most critical resources being considered by states in this agricultural drive. Crop production in the upland soils of Nigeria over the years has remained very popular, while alluvial soils are grossly under-utilized (Udo *et al.,* 2011). Upland soils are facing stiff competition with non-agricultural land uses, especially those related to urbanization and industrialization; hence, the need for greater attention to the floodplain. Floodplain soils worldwide are beneficial for agricultural production, constituting a huge reserve of available nutrients for utilization by crop plants (Akpan-Idiok and Agbaji, 2013). Effiong and Ibia (2009), asserted that the agricultural potentials of alluvial soils had not been fully exploited because of a lack of understanding of their physical and chemical properties and the changes they undergo under intensive cultivation. Floodplain soils cover Bayelsa State's vast land areas with high agricultural potentials, but current information and knowledge on the characteristics, capabilities, and suitability are inadequate and obsolete. Therefore, efficient management of the soils for increased and sustainable crop production is hampered. Consequently, the state faces food insecurity, depending on other states for food needs. This study, therefore, was conducted to evaluate the capabilities of floodplain soils of some selected communities chosen for agricultural intensification in the state to determine their agricultural capabilities for efficient management in sustainable agriculture.

2.0. Materials and methods

2.1 Description of the Study Areas, Soil sampling proce-

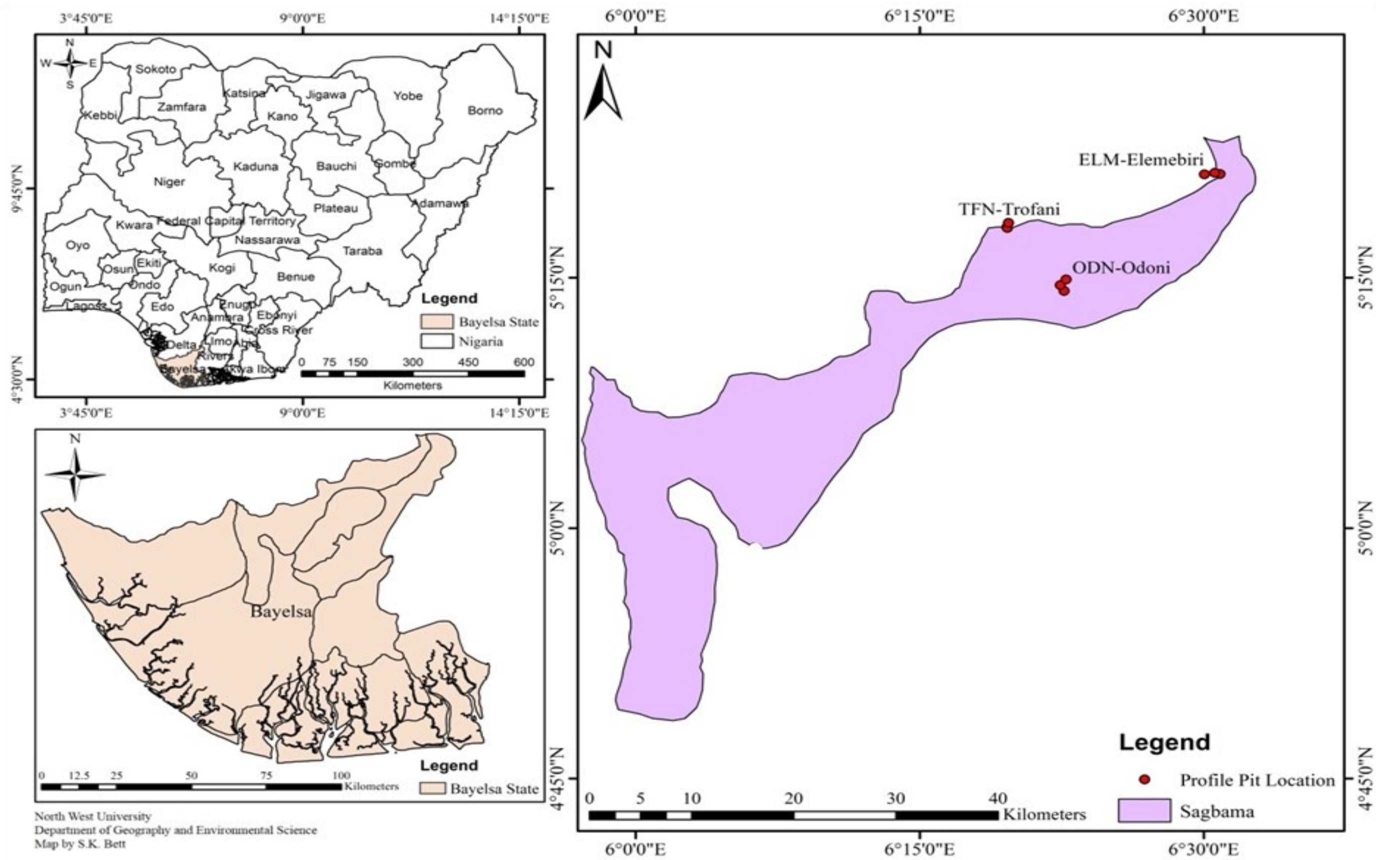

Table 1: Geo-Reference Points of Profile Pits and area covered by Soil Mapping Units

Study Location	Soil Mapping Unit	Geo-reference of Profile Pit	No. of Profile Pits	Land Area (Hectares)
Elemebiri	ELM1	N 05° 21' 11.5" E 006° 30' 02.2"	1	29.0788224
	ELM2	N 05° 21' 12.4" E 006° 30' 51.3"	1	21.2464612
	ELM3	N 05° 21' 22.6" E 006° 30' 51.3"	1	162.139097
Odoni	ODN1	N 05° 14' 12.4" E 006° 22' 37.2"	1	89.943181
	ODN2	N 05° 14'33.3" E 006° 22'25.5"	1	52.099569
	ODN3	N 05° 14’ 53.3" E 006° 22' 43.4"	1	90.573750
Trofani	TFN1	N 05° 18' 01.5" E 006° 19' 36.0"	1	87.610710
	TFN2	N 05° 17' 58.6", E 006° 19' 37.1"	1	51.495672
	TFN3	N 05° 18' 17.1", E 006° 19' 41.2"	1	148.509325

dure and analyses

This study was carried out in Bayelsa State in the Niger Delta region, Southern Nigeria. The study locations lie between latitude 05° 22' 03.9" N and 04° 59' 08.9" N and longitude 006° 30' 21.1" E and 006° 06' 54.1" E. Three locations: Elemebiri by Lower Niger River, Odoniby Nun River and Trofani by Forcados River, all in Bayelsa State in the southern part of Nigeria. . In the study area (Fig 1), the annual rainfall (2000-4500mm), spread over 8 to 10 months each year and is bimodal, peaking at June and September and this field study was carried out between January and March. Food crops are cultivated on the levee crest, levee slope, backslope, and recent alluvial soils on channels of present active rivers. Levee crest soils are no longer flooded during the most flood

plain soils and alluvial soils in the channels of present active rivers are flooded yearly by the Niger River floods.

A detailed soil survey was conducted on agricultural lands from Elemebiri, Odoni, and Trofani using rigid grids. The designation of the soil mapping units (SMUs) were ELM1, ELM2, and ELM3 for Elemebiri, ODN1, ODN2, and ODN3 for Odoni soils, and TFN1, TFN2, and TFN3 for Trofani, Details of the soil mapping units and the land area are as presented in table 1. Soil sampling procedures followed the methods prescribed by the USDA Soil Taxonomy and the World Resource Base. Profile pits were located following standard procedure, dug, described and samples collected for laboratory analyses. Details of the procedures are as reported by Dickson (2018).

Standard laboratory methods were used to determine the physical and chemical properties of the soil samples. Soil texture (particle size analysis) was determined using the Day (1965) method, popularly known as the hydrometer method. Soil pH both in water and $CaCl_2$(1:2 soil-water ratio), was determined using a glass electrode pH meter, and electrical conductivity was determined using a conductivity meter (Estefan *et al.,* 2013). Organic carbon was determined using the modified dichromate oxidation method of Walkley-Black as described by Estefan *et al.* (2013), and the values obtained multiplied by 1.724 to obtain organic matter, total N determined using the macro-Kjeldahl digestion-distillation method as described by Houba*et al.* (1995) and available P by Bray P-1 method (Bray and Kurtz, 1945). Exchangeable acidity was extracted with 1M KCl and determined by titration with NaOH solution using phenolphthalein indicator as described by Anderson and Ingram (1993) and exchangeable Al with 0.01 M HCl (Sumner and Stewart, 1992). Exchangeable cations were extracted with neutral normal ammonium acetate solution as described by Estefan *et al*. (2013) and potassium and sodium in the extract measured by flame photometry and calcium and magnesium by atomic absorption spectrophotometry. Cation exchange capacity (CEC) was by the summation method (Kamprath, 1970).

2.2 Capability Evaluation Methods

Capability evaluation of the soils was done using Land Capability Classification (LCC) system (Klingebieland Montgomery, 1961) which was modified by Ogunkunle and Babalola (1986), Land Capability Index (LCI) by Van Ranst and Verdoodt (2005), and Fertility Capability Classification (FCC) system by Sanchez *et al.* (2003).

2.2.1 Land Capability Classification

The criteria for the LCC system of Klingebieland Mont-

Table 2: Summary of criteria for Land Capability Classification (Adopted from Ogunkunle and Babalola, 1986)

Limitation	**Arable Crops**				**Non-Arable Crops**			
	I	II	III	IV	V	VI	VII	VIII
Slope angle (degrees)	0-2	3-4	4-5	5-10	10-20	20-35	›35	
Wetness	nil	Nil	Slight	slight	Mod	mod	Severe	Severe
Effective Depth (cm)	150	100	60	30	20	20	30	
Texture	Scl/c	Sl/c	Sl/c	Ls/c	Ls/heavy c	Ls/heavy c	Ls/heavy c	Ls/heavy c
ECEC-subsoil Cmol/kg	15	10-15	5-10	2-5	2-5	1-2	0-1	2-5

*Flooding f0- no flooding, f1- flooding for less than 1month, f2- flooding for 1-2months, f3- flooding for 3-6months, f4- flooding for more than 6months gomery (1961) was slightly modified from that modified by Ogunkunle and Babalola, (1986) by the non-inclusion of total soluble salts (ss), and percent, rock outcrop as the environment is the freshwater environment and not rocky. Also, permeability and available water capacity (cm) were excluded (Table 2). Furthermore, due to the particular kind of limitations owing to the peculiar environment, which may likely have different effects on crop performance, subclass designations were modified. Consequently, instead of using erosion (e), excess water (w), root- zone limitation (s), and climate limitation (c), as subclass designations, angle of slope (a), soil texture (t), wetness (w), and nutrient holding capacity (n) were used. Flooding (f) was introduced in this report because the study environment was subject to yearly seasonal floods which affect the farming season and the time of crops harvest.

2.2.2 Land Capability Index

The land capability classification for the humid tropics characterizes the capability of land units in the humid tropics for the production of three groups of crops namely: exacting crops, moderately exacting crops, and less exacting crops (Van Ranst and Verdoodt, 2005). The land capability was estimated by calculating capability index or soil index, being a product of ratings attributed to six soil characteristics:

$$CS = A \, x \, \frac{B}{100} \, x \, \frac{C}{100} \, x \, \frac{D}{100} \, x \, \frac{E}{100} \, x \, \frac{F}{100}$$

Where CS = capability index or soil index

A = rating for profile development
B = rating for texture
C = rating for soil depth
D = rating for colour/drainage conditions
E = rating for pH/base saturation
F = rating for the development of the A horizon

Soils were grouped into capability classes depending on the capability index and their suitability for the production of three groups of crops, namely: exacting crops, moderately exacting crops, and less exacting crops.

2.2 Fertility Capability Classification

The FCC system (Sanchez *et al.*, 2003) is a technical system of grouping soils with similar limitations and management problems in terms of nutrient supplying capacity. The system classifies soils into three categorical levels: Type (topsoil texture), substrate type (subsoil texture), and condition modifiers or fertility constraints. The FCC unit is obtained by the combination of the class designation from the three categorical levels.

3.0. Results and Discussion

Table 3 presents the interpretations of land capability classification of the SMUs.Of the eight capability classes in the LCC system, only class II was encountered in the study area. The class II soils were suited for a wide range of arable crops with limitations ranging from wetness, flooding, low nutrient retentive capacity, low exchangeable Ca^{2+} and Mg^{2+} level, and high exchangeable Al^{3+}. Conservation measures included drainage to improve wetness, liming to increase exchangeable Ca^{2+} and $Mg^{2+,}$ and reduce Al^{3+} as well as increase nutrient capacity. Good management strategies to improve organic matter levels can also improve nutrient retention capacity.

Following the definition of Land Capability Classes by Van Ranst and Verdoodt (2005), the tabulation of the land capability indexes of the SMUs is presented in table 4 while in table 5 is the summary of the land capability indexes and capability classification of the SMUs. The land capability classification for the humid tropics characterizes the capability of land units in the humid tropics for the production of the three groups of crops namely: exacting crops, moderately exacting crops, and less exacting crops (Van Ranst and Verdoodt, 2005)which were further distinguished into annuals and perennials crops. The land capability classification for the humid tropics is a parametric system with assigned numerical values (ratings) to different capability classes of the land characteristics. Profile development is a crucial factor determining the capability index or soil index obtained as the numerical values assigned range from 55 to 100 (Van Ranst and Verdoodt, 2005). For the SMUs being considered, ELM3 and TFN3 were assigned 100 as they fell into A-C profiles, having weak profile development without diagnostic subsurface horizons while ELM1, ELM2, ODN1, ODN2, ODN3, TFN1, and TFN2 were assigned 95 for having cambic horizon with a CEC ‹ 24 cmol (+) kg^{-1} clay. The profile development figures for the SMUs helped in boosting the capability index values obtained. Since all the profiles were deeper than 120cm, the numerical value 100 was assigned to all. And regarding the rating for the development of the 'A' horizon, the numerical value 120 was assigned because all the SMUs had well developed 'A' horizon, deeper than 20cm except ELM2 having 'A' horizon depth of 19 cm and was assigned 110.

The soil characteristics that varied in their ratings were texture, rating for color/drainage conditions, and rating for pH/ base saturation (Table 4) indicating that these factors were limiting to crop production in the SMUs. Light textured soils were rated low and heavy textured soils having ‹ 60% clay-like silty clay, silty clay loam, and clay loam haswere rated high (e.g., 100, 95, and 90, respectively). Therefore, the ratings for texture in SMUs having silt loam texture like ODN1 was assigned 85 while those with silty clay loam, 95; loam, 75; sandy loam, 60 and loamy sand, 50. Whereas the rating for texture in TFN3 was 60 as the profile was dominated by sandy loam and that of ELM3, 52 (Table 4) as loamy sand and sandy loam dominated the profile, that of ELM1 was 95 due to the inclusion of silty clay loam texture in calculating the ratings for texture. For the rating of colour/drainage class, a soil is rated 100 if the moist soil colour is red (5YR and redder), no mottling, and well-drained while 95 ratings are given when the moist colour is yellow (yellower than 5YR), mottling at a depth deeper than 120cm and is the good drain (Udo *et al.*, 2009). But all the SMUs except TFN1 had mottles at depths less than 120 cm and were given the appropriate ratings, ranging from 60-90 for annuals and 40-80 for perennials. The TFN1, mottled at 140 cm depth was given 100. For ELM3 and TFN3, though flooded seasonally and mottling was observed at depths shallower than 120cm, the next horizons were not mottled indicating that the mottling was not the result of rising in groundwater table and was considered in the well-drained group of soils and assigned 100. In the rating for pH and base saturation, none of the SMUs attained 100 because of low base saturation and variation in pH, and the assigned values ranged from 90-98.

Based on the calculated land capability index or soil index of the SMUs, ELM1 was grouped into capability class I, ODN1 and TFN1, class II and ELM2, ELM3, ODN2, ODN3, TFN2, and TFN3, class III for annual crops while for perennial crops, ELM1, ODN1, and TFN1 were grouped in class II, ELM3, ODN2, TFN2, and TFN3, class III, ELM2 and ODN3, class IV (Table 5). From the definition of the capability classes (Van Ranst and Verdoodt, 2005), capability class III is suitable for annual crops, class II, high and class I, excellent while

Table 3: Interpretation of LCC units of the Soil Mapping Units

Soil Mapping Unit	LCC Unit	Interpretation
ELM1	IInf0	ELM1 belongs to class II, free from the annual seasonal floods but the soil is low in nutrient retentive capacity, exchangeable $Ca^{2+,}$ and $Mg^{2+,}$ and may require additional supplies through liming. Exchangeable $Al^{3+,}$ on the other hand, is high. The area is good for planting a wide variety of arable crops.
ELM2	IIwnf0	ELM1 belongs to class II, free from the annual seasonal floods but the soil is low in nutrient retentive capacity, exchangeable $Ca^{2+,}$ and $Mg^{2+,}$ and may require additional supplies through liming. Exchangeable $Al^{3+,}$ on the other hand, is high. The area is good for planting a wide variety of arable crops.
ELM3	IIwnf2	ELM3 also belongs to class II. Due to its location on the channel of the Niger River, it is subject to wetness during the flood season and flooding for 1-2 months. Water retentive capacity is low during the dry period. Generally, the nutrient retentive capacity level is a challenge, and exchangeable Ca^{2+} and Mg^{2+} levels are low while exchangeable Al^{3+} is high. A wide variety of arable crops could be planted.
ODN1	IInf0	ODN1 belongs to class II, no flooding, and can be planted with a wide variety of crops but has a low nutrient retentive capacity, low exchangeable $Ca^{2+,}$ and $Mg^{2+,}$ and moderately high exchangeable Al^{3+} level as limitations.
ODN2	IIwnfo	ODN2 belongs to class II, no flooding, and can be planted to a wide variety of crops but low nutrient retentive capacity, low exchangeable $Ca^{2+,}$ and g^{2+}, as well as high exchangeable Al^{3+} are major limitations.
ODN3	IIwnf1	ODN3 also belongs to class II but with wetness and flooding for less than 1 month during the flood season. Low nutrient retentive capacity and low exchangeable Ca^{2+} and Mg^{2+} as well as high exchangeable $Al^{3+}$are limitations. The area could be planted to a wide variety of crops
TFN1	IIf0	TFN1belongs to class II free of flooding and can be used for a wide variety of crops. The major limitations are wetness in the rainy season,
TFN2	IIwnf0	TFN2 belongs to class II, free from flooding. The major limitations are wetness during the rainy season and low nutrient retentive capacity, low exchangeable Ca^{2+} and Mg^{2+} as well as high exchangeable Al^{3+}. Land suitable for the production of a wide range of arable crops
TFN3	IIwnf2	TFN3 belongs to class II, subject to the Niger River seasonal flood through the Forcados River. Apart from flooding, low water retentive capacity during the dry period, low nutrient retentive capacity, low exchangeable Ca and Mg as well as high exchangeable Al are major limitations

for perennial crops, class IV is good, class III, high and classes II and I, excellent.

It could be inferred that the capabilities of the SMUs were good to excellent for the production of annual and tree crops. Understandably, oil palm, whose roots concentrate within the 0-60cm depth was found planted in ELM2 with imperfect drainage during the fieldwork which confirmed the capability classification rating. The ELM3 and TFN3 were placed in capability class III for both In table 6 is the interpretation of FCC units of the SMUs while table 7 summariz-

Table 4: Capability Classification of the Soil Mapping Unit

Factor	Parameter	Value	Rating	
			Annuals	Perennials
	ELM1			
A	Profile development	ABC-profile	95	95
B	Texture		95	95
	Ap	Silt loam-no gravel		
	Ap2	Silt loam-no gravel		
	B1	Silty clay loam-no gravel		
	B2	Silty clay loam-no gravel		
	C1	Silt loam-no gravel		
	C2	Silt loam-no gravel		
	C3	Silt loam-no gravel		
	C4	Silt loam-no gravel		
C	Soil depth cm	200+	100	100
D	Drainage	Mottling 80-120cm	90	80
E	pH		98	98
	Ap	5.46		
	Ap2	5.62		
	B1	5.77		
	B2	5.73		
F	Development of topsoil		120	120
	-land use	Grassy vegetation		
	-value/chroma	A≤ 3/2		
	-thickness	›20		
Cs			97	85
Class			I	II
	ELM2			
A	Profile development	ABC-profile	95	95
B	Texture		75	75
	Ap	Silt loam-no gravel		
	Ap2	Silt loam-no gravel		
	B1	Silt loam-no gravel		
	B2	Silt loam-no gravel		
	B3	Silt loam-no gravel		
	C1	Silt loam-no gravel		
	C2	Silt loam-no gravel		
	C3	Silt loam-no gravel		
C	Soil depth cm	190+	100	100
D	Drainage	Mottling 40-80cm	75	60
E	pH		95	95
	Ap	5.44		
	Ap2	5.74		
	B1	6.61		
	B2	6.04		
	B3	6.07		
F	Development of topsoil		110	110
	-land use	Plantain farm		
	-value/chroma	A≤3/3		
	-thickness	‹20		
Cs			56	45
Class			III	IV

Table 4 Cont.

	ELM3			
A	Profile development	A-C profile	100	100
B	Texture		52	52
	A	Loamy sand-no gravel		
	Ap1	Loamy sand-no gravel		
	Ap2	Sandy loam-no gravel		
	C1	Loamy sand-no gravel		
	C2	Loamy sand-no gravel		
	C3	Sandy loam-no gravel		
	C4	Sandy loam-no gravel		
	C5	Sandy loam-no gravel		
C	Soil depth cm	200+	100	100
D	Drainage	-	100	100
E	pH		95	95
	A	5.52		
	Ap1	7.00		
	Ap2	6.15		
F	Development of topsoil		120	120
	-land use	Grassy vegetation		
	-value/chroma	A-3/6		
	-the thickness (cm)	›20		
Cs			59	59
Class			III	III
	ODN1			
A	Profile development	ABC-profile	95	95
B	Texture		85	85
	Ap	Silt loam-no gravel		
	Ap2	Silt loam-no gravel		
	B1	Silt loam-no gravel		
	B2	Silt loam-no gravel		
	B3	Silt loam-no gravel		
	C	Silt loam-no gravel		
C	Soil depth cm	200+	100	100
D	Drainage	Mottling 80-120cm	90	80
E	pH		95	95
	Ap	5.76		
	Ap2	5.75		
	B1	6.01		
F	Development of topsoil		120	120
	-land use	Plantain farm		
	-value/chroma	A- 2/2		
	-thickness	›20		
Cs			83	74
Class			II	II

Table 4 Cont.

		ODN2		
A	Profile development	ABC-profile	95	95
B	Texture		85	85
	Ap	Silt loam-no gravel		
	Ap2	Silt loam-no gravel		
	B1	Silt loam-no gravel		
	B2	Silt loam-no gravel		
	BC	Silt loam-no gravel		
	C1	loam-no gravel		
	C2	loam-no gravel		
C	Soil depth cm	200+	100	100
D	Drainage	Mottling 40-80cm	75	60
E	pH		93	93
	Ap	5.64		
	Ap2	6.70		
	B1	5.38		
	B2	6.11		
F	Development of topsoil		120	120
	-land use	Grassy vegetation		
	-value/chroma	A- ¾		
	-thickness	›20		
Cs			68	54
Class			III	III
	ODN3			
A	Profile development	ABC-profile	95	95
B	Texture		88	88
	A	Silt loam-no gravel		
	Ap1	Silt loam-no gravel		
	Ap2	Silt loam-no gravel		
	B1	Silt loam-no gravel		
	B2	Silty clay loam-no gravel		
	B3	Silty clay loam-no gravel		
	C1	loam-no gravel		
	C2	loam-no gravel		
C	Soil depth cm	200+	100	100
D	Drainage	Mottling 0-40cm	60	40
E	pH	5.67	95	95
	Ap	6.45		
	Ap2	5.97		
	B1	6.07		
	B2	6.45		
	B3	5.91		
F	Development of topsoil		120	120
	-land use	Grassy vegetation		
	-value/chroma	A- 3/2		
	-thickness	›20		
Cs			57	38
Class			III	IV

Table 4 Cont.

	TFN1			
A	Profile development	ABC-profile	95	95
B	Texture		85	85
	Ap	Silt loam-no gravel		
	A	Silt loam-no gravel		
	B1	Silt loam-no gravel		
	B2	Silt loam-no gravel		
	B3	Silty clay loam-no gravel		
	C	Silt loam-no gravel		
C	Soil depth cm	200+	100	100
D	Drainage	Mottling 80-120cm	95	95
E	pH		93	93
	Ap	5.64		
	A	5.75		
	B1	5.88		
F	Development of topsoil		120	120
	-land use	Grassy vegetation		
	-value/chroma	A-3/4		
	-thickness	›20		
Cs			86	86
Class			II	II
	TFN2			
A	Profile development	ABC-profile	95	95
B	Texture		79	79
	Ap	Loamy sand-no gravel		
	A2p	Silt loam-no gravel		
	B1	Silty clay loam-no gravel		
	B2	Silt loam-no gravel		
	C1	Silt loam-no gravel		
	C2	Loam-no gravel		
C	Soil depth cm	200+	100	100
D	Drainage	Mottling 40-80cm	75	60
E	pH		93	93
	Ap	6.16		
	A2p	6.15		
	B1	5.98		
	B2	6.80		
F	Development of topsoil		120	120
	-land use	Oil palm farm		
	-value/chroma	A- 3/3		
	-the thickness (cm)	›20		
Cs			63	51
Class			III	III

Table 4 Cont.

	ELM3			
A	Profile development	A-C profile	100	100
B	Texture		52	52
	A	Loamy sand-no gravel		
	Ap1	Loamy sand-no gravel		
	Ap2	Sandy loam-no gravel		
	C1	Loamy sand-no gravel		
	C2	Loamy sand-no gravel		
	C3	Sandy loam-no gravel		
	C4	Sandy loam-no gravel		
	C5	Sandy loam-no gravel		
C	Soil depth cm	200+	100	100
D	Drainage	-	100	100
E	pH		95	95
	A	5.52		
	Ap1	7.00		
	Ap2	6.15		
F	Development of topsoil		120	120
	-land use	Grassy vegetation		
	-value/chroma	A-3/6		
	-the thickness (cm)	›20		
Cs			59	59
Class			III	III
	ODN1			
A	Profile development	ABC-profile	95	95
B	Texture		85	85
	Ap	Silt loam-no gravel		
	Ap2	Silt loam-no gravel		
	B1	Silt loam-no gravel		
	B2	Silt loam-no gravel		
	B3	Silt loam-no gravel		
	C	Silt loam-no gravel		
C	Soil depth cm	200+	100	100
D	Drainage	Mottling 80-120cm	90	80
E	pH		95	95
	Ap	5.76		
	Ap2	5.75		
	B1	6.01		
F	Development of topsoil		120	120
	-land use	Plantain farm		
	-value/chroma	A- 2/2		
	-thickness	›20		
Cs			83	74
Class			II	II

Table 4 Cont.

		ODN2		
A	Profile development	ABC-profile	95	95
B	Texture		85	85
	Ap	Silt loam-no gravel		
	Ap2	Silt loam-no gravel		
	B1	Silt loam-no gravel		
	B2	Silt loam-no gravel		
	BC	Silt loam-no gravel		
	C1	loam-no gravel		
	C2	loam-no gravel		
C	Soil depth cm	200+	100	100
D	Drainage	Mottling 40-80cm	75	60
E	pH		93	93
	Ap	5.64		
	Ap2	6.70		
	B1	5.38		
	B2	6.11		
F	Development of topsoil		120	120
	-land use	Grassy vegetation		
	-value/chroma	A- ¾		
	-thickness	›20		
Cs			68	54
Class			III	III
	ODN3			
A	Profile development	ABC-profile	95	95
B	Texture		88	88
	A	Silt loam-no gravel		
	Ap1	Silt loam-no gravel		
	Ap2	Silt loam-no gravel		
	B1	Silt loam-no gravel		
	B2	Silty clay loam-no gravel		
	B3	Silty clay loam-no gravel		
	C1	loam-no gravel		
	C2	loam-no gravel		
C	Soil depth cm	200+	100	100
D	Drainage	Mottling 0-40cm	60	40
E	pH	5.67	95	95
	Ap	6.45		
	Ap2	5.97		
	B1	6.07		
	B2	6.45		
	B3	5.91		
F	Development of topsoil		120	120
	-land use	Grassy vegetation		
	-value/chroma	A- 3/2		
	-thickness	›20		
Cs			57	38
Class			III	IV

Table 4 Cont.

	TFN1			
A	Profile development	ABC-profile	95	95
B	Texture		85	85
	Ap	Silt loam-no gravel		
	A	Silt loam-no gravel		
	B1	Silt loam-no gravel		
	B2	Silt loam-no gravel		
	B3	Silty clay loam-no gravel		
	C	Silt loam-no gravel		
C	Soil depth cm	200+	100	100
D	Drainage	Mottling 80-120cm	95	95
E	pH		93	93
	Ap	5.64		
	A	5.75		
	B1	5.88		
F	Development of topsoil		120	120
	-land use	Grassy vegetation		
	-value/chroma	A-3/4		
	-thickness	›20		
Cs			86	86
Class			II	II
	TFN2			
A	Profile development	ABC-profile	95	95
B	Texture		79	79
	Ap	Loamy sand-no gravel		
	A2p	Silt loam-no gravel		
	B1	Silty clay loam-no gravel		
	B2	Silt loam-no gravel		
	C1	Silt loam-no gravel		
	C2	Loam-no gravel		
C	Soil depth cm	200+	100	100
D	Drainage	Mottling 40-80cm	75	60
E	pH		93	93
	Ap	6.16		
	A2p	6.15		
	B1	5.98		
	B2	6.80		
F	Development of topsoil		120	120
	-land use	Oil palm farm		
	-value/chroma	A- 3/3		
	-the thickness (cm)	›20		
Cs			63	51
Class			III	III

Table 4 Cont.

	TFN3			
A	Profile development	A-C profile	100	100
B	Texture		60	60
	A	Sandy loam-no gravel		
	Ap1	Sandy loam-no gravel		
	Ap2	Sandy loam-no gravel		
	C1	Sandy loam-no gravel		
	C2	Sandy loam-no gravel		
	C3	Sandy loam-no gravel		
	C4	Sand-no gravel		
C	Soil depth cm	200+	100	100
D	Drainage	Mottling -	100	100
E	pH		90	90
	A	5.74		
	Ap1	5.98		
	Ap2	5.55		
F	Development of topsoil		120	120
	-land use	Grassy vegetation		
	-value/chroma	A 3/3		
	-thickness	›20		
Cs			60	60
Class			III	III

Table 5: Summary of Land Capability Index and Capability Classification of the Soil Mapping Units for Annual and Perennial Crops

Soil Mapping Unit	Annual Crops		Perennial Crops	
	Land Capability Index	Land Capability Class	Land Capability Index	Land Capability Class
ELM1	97	I	85	I
ELM2	56	III	45	IV
ELM3	59	III	59	III
ODN1	83	II	74	II
ODN2	68	III	54	III
ODN3	57	III	38	IV
TFN1	86	II	86	II
TFN2	63	III	51	III
TFN3	60	III	60	III

Table 6: Interpretation of FCC units of the Soil Mapping Units

Soil Mapping Unit	FCC Unit	Interpretation
ELM1	Lha-e	loamy textured soil with good water holding properties, having fertility constraints, especially Ca^{2+} and Mg^{2+}, moderate acidity, having more than 20% Al saturation (50cm), may require liming for Al-sensitive crops, N deficiency likely may require additional supply during the growing season.
ELM2	Lha-e	loamy textured soil with good water holding characteristics, having fertility constraints, low ECEC of less than 4 cmol/kg and moderate acidity with more than 20% Al saturation at 50cm depth, may require liming for Al-sensitive crops, N deficiency likely and may require supplies during the growing season
ELM3	Sha-ek	Loamy sand or sandy loam textured soil with high infiltration, low water holding capacity, low nutrient holding capacity (ECEC less than 4 cmol/kg, low exchangeable K+ in some layers within 50cm depth, moderate acidity (Al saturation of more than 20% at 50cm depth), may require liming for Al-sensitive crops, N deficiency most likely, requiring supply during each planting season.
ODN1	Lha-	Loamy textured soil with good water holding characteristics, acidity between 5 and 6 in the top layer, having Al saturation of more than 30% at 50cm depth, above the critical value of 20% (Ibanga and Udo 1996) requiring liming for Al-sensitive crops, N deficiency is most likely requiring supply for each planting season.
ODN2	Lgha-ek	loamy textured soil with greying characteristics due to low chroma of 2 for more than half the surface 50cm depth, moderate acidity (Al saturation more than 30% at 50cm depth), may require liming for Al-sensitive crops, low exchangeable K^{+} of less than 0.2 in the surface layer, N deficiency likely requiring supply for each planting season.
ODN3	Lgha-ek	loamy soil showing wetness with mottles all through the profile and greying characteristics with mottles with chroma of 2 or less within 50cm depth, moderate acidity (Al saturation more than 20% at 50cm depth), may require liming for Al-sensitive crops, N deficiency most likely requiring supply for each planting season.
TFN1	Lha-ek	loamy soil having good water holding characteristics, with fertility constraints, low ability to supply P, Ca^{2+} and Mg^{2+}, moderate acidity (Al saturation more than 30% at 50cm depth), may require liming for Al- sensitive crops, N deficiency most likely, requiring supply for each planting season.
TFN2	SLa-ek	sandy soil changing to loam with good water holding characteristics, moderate acidity (Al saturation more than 20% at 50cm depth), may require liming for Al- sensitive crops, low ability to supply K^{+}, $Ca^{2+,}$ and Mg^{2+}, N deficiency most likely, requiring supply for each planting season.
TFN3	Sha-e	Sandy textured soil with high infiltration rate and low water holding capacity, having moderate acidity (Al saturation more than 20% at 50cm depth), low ability to supply Ca^{2+} and Mg^{2+} may require liming for Al- sensitive crops, N deficiency most likely, requiring supply for each planting season.

es the FCC interpretation of the SMUs. The textural classes of 67% of the SMUs (ELM1, ELM2, ODN1, ODN2, ODN3, and TFN1) was loam, ELM3 and TFN3 (22%), sand and TFN2 (11%), sand in the surface strata, and loam in the substrata. The ELM1 and ELM2 SMUs were classified as Lha-e, ELM3 as Sha-ek; ODN as Lha-; ODN2 and ODN3 as Lgha-ek; TFN1 as Lha-ek; TFN2 as SLa-ek; and TFN3 as Sha-e in the FCC system. Based on the fertility classification guide (Sanchez *et al.,* 2003), soil fertility limiting factors in the soils included low nutrient reserve, soil acidity, and Al toxicity, wetness, K deficiency, and the likelihood of Fe toxicity.

annual and perennial crops in this rating. Since the two SMUs are flooded annually by the Niger River flood between September and October, they are not suitable for raising perennial crops.

According to Olaleye*et al.* (2002), the FCC system focused attention on surface soil properties most directly related to the management of field crops and is best used as an interpretative classification in conjunction with the more inclusive natural soil classification. Using the FCC system in the classification of the soils in the study area revealed the soils to be predominantly loamy textured (Tables6 and 7). The ELM3 and TFN3 soils located on the channel of present actively flowing Niger River and Forcados River, respectively, were sandy textured while TFN2 on the backslope of River Forcados was sandy in the surface layer and loamy in the succeeding layers. The dominance of sand in ELM3 and TFN3 indicated that the SMUs have a high infiltration rate and low water holding capacity with the possibility of moisture stress during dry months. Udo *et al*. (2009), reported that inland depression and floodplain (wetland) soils of Akwa Ibom State were dominantly sandy which was attributed to excessive rainfall experienced in the area. In this study, textural diversity between and within the SMUs was ascribed to different sources of water-borne sediments and the flow rate of the floodwater at the time of deposition of the parent materials. The parent materials of ELM3 and TFN3 were deposited during the high flood period since they are recent alluvial soils from the channels of the presently active Niger River and Forcados River. Only large particles could be deposited during the high flood with current flowing swiftly; thus, their texture was sand dominated. The finer soil particles in suspension were transported for a longer period over greater distances and deposited at a low flood period when there was less turbulence. The dominance of sand in the surface layer of TFN2was ascribed to a different parent material deposited in the surface layer of the SMU from the rest of the horizons.

From tables6 and 7, the acid nature of these soils was revealed by FCC as 89% (ELM1, ELM2, ELM3, ODN1, ODN2, ODN3, TFN1, and TFN3) of SMUs included the condition modifier 'h', indicating strong to medium acidity. This corroborated the Al saturation results as all the pedons included the condition modifier 'a-', implying that the pedons have Al saturation of between 10 and 60% within the plough layer. An Al saturation of between 10 and 60% within the plough layer is harmful to Al- sensitive crops and may require liming. These results agreed with the findings of Ukeagbu*et al*. (2015) on soils supporting oil palm plantations in the coastal plain sands of Imo State, Nigeria. Sanchez *et al*. (2003) earlier reported that Al toxicity was most prevalent in the humid tropics and acid savanna soils and high concentration of Al correlated with low nutrient capital reserves. Aluminum toxicity is caused by excess amounts of Al^{3+} in soil solution. Its adverse effects are poorly developed root systems, drought, lodging, and nutrient deficiencies (Meriga*et al.,* 2010).

Low amounts of Ca and Mg were recorded in the soils, which is commonly associated with high Al. According to Izac and Sanchez (2001), soils with low (less than 10%) reserves of weatherable minerals in their sand and silt fraction constituted low nutrient capital reserves. Other sources of the nutrient capital reserve include organic matter, which contains all the nitrogen and much of the phosphorus and sulphur capital of tropical soils.

Another striking limitation in these soils was the low nutrient reserve, and the likelihood of Al^{3+} and Fe^{3+} toxicity in all the SMUs were high due to the high concentration of these nutrients. Low nutrient reserve in the soils was captured by the FCC system by the inclusion of the condition modifier 'e' in 89% of the SMUs which means ECEC values of the surface layers of such soils were less than 4 cmol/kg. The low nutrient reserve, coupled with a high concentration of Al^{3+} and Fe^{3+} revealed that Al3+ and Fe3+ dominated the exchange complex. The ECEC values signified that the soils were dominated by low activity clay with little ability to retain nutrients. Hence fertilizer application to these soils should be split. Organic matter plays a vital role in sustaining soil fertility, and its management should be given top priority. Furthermore, the condition modifier 'k' was included in 56% (ELM3, ODN2, ODN3, TFN1, and TFN2) of the soils indicating that the affected soils were deficient in K^+ and the K values were below the critical value (0.2 cmol/kg) for Nigerian soils. A similar observation was made by Udo (2001)and Udo (2009). Udo (2001) reported low K reserve as one of the fertility indicators of wetland soils. Brady and Weil (2005) asserted that though K comparatively is found in high levels in most mineral soils, the quantity of K held in an easily exchangeable condition at any one time is small. As a confirmation, many mica flakes were observed during the fieldwork, and mineralogical analysis results indicated the presence of muscovite and other K-bearing minerals in relatively high amounts. The low K reserve in the SMUs could, however, be linked to the dominance of low activity clay (kaolinite) in the soils (Dickson, 2018) and the near absence of ferromagnesian minerals.

The Fertility Capability Classification (FCC) of the soils (Tables 6 and 7) included the condition modifier 'g' for 22% of the soils (ODN2 and ODN3), indicating wetness, greying or prolonged water saturation. The wetness quality makes the affected SMUs unsuitable for the cultivation of deep-rooted crops like oil palm owing to a possible defective oxygen supply. However, shallow crops and short-season crops could be raised in them.

The effectiveness of Land Capability Classification, Land Capability Index and Fertility Capability Classification in evaluating the capabilities of the Soil Mapping Units was compared. The results of this study (Table 8) indicated that Land Capability Classification allocated the levee crest soils from Elemebiri and Odoni into IInf0 while that from Trofani into IIf0; The levee slope soils were placed in IIwnf0 while the flood plain soils from Odoni (ODN3) was placed in IIwnf1. The Elemebiri (ELM3) and Trofani (TFN3) of alluvial soils in the channels of present active rivers, were placed in IIwnf2. Land Capability Index (LCI) of Van Ranst and Verdoodt (2005), placed ELM1 into class I for both arable and permanent crops production, ODN1 and TFN1, in class II and ELM2, ELM3, ODN2, ODN3, TFN2, and TFN3, ODI2, ODI3, KRM2 in class III for arable crops production. For permanent crops, ODN1 and TFN1 were placed in class II, ODN2, TFN2, and ELM3 in class III, and ELM2 and ODN3 in class IV. Furthermore, Fertility Capability Classification (FCC) included ELM1 and ELM2 in Lha-e

Table 7: Summary of Interpretations of Fertility Capability Classification of the Soils

SMU	Type	Sub stra-ta	Condition Modifiers								FCC Unit
			G	e	h	i	x	k	B	a^-	
ELM1	L		-	+	+	-	-	-	-	+	Lha-e
ELM2	L		-	+	+	-	-	-	-	+	Lha-e
ELM3	S		-	+	+	-	-	+	-	+	Sha-ek
ODN1	L		-	-	+	-	-	-	-	+	Lha$^-$
ODN2	L		+	+	+	-	-	+	-	+	Lgha-ek
ODN3	L		+	+	+	-	-	+	-	+	Lgha-ek
TFN1	L		-	+	+	-	-	+	-	+	Lha-ek
TFN2	S	L	-	+	-	-	-	+	-	+	SLa-ek
TFN3	S		-	+	+	-	-	-	-	+	Sha-e

Table 8: Comparison of the various Capability Classification Systems

SMU	LCC	LCI		FCC			
		ELM1	IInf0		Arable Crops I	Permanent crops I	Lha-e
ELM2	IIwnf0	III	IV	Lha-e			
ELM3	IIwnf2	III	III	Sha-ek			
ODN1	IInf0	II	II	Lha-			
ODN2	IIwnf0	III	III	Lgha-ek			
ODN3	IIwnf1	III	IV	Lgha-ek			
TFN1	IIf0	II	II	Lha-ek			
TFN2	IIwnf0	III	III	SLa-ek			
TFN3	IIwnf2	III	III	Sha-e			

class, ODN1 in Lha-, ODN2, and ODN3 in Lgha-ek class, ELM3, TFN1, TFN2, and TFN3 in Sha-ek, Lha-ek, and SLa-ek, respectively (Table 8). The systems have a close relationship but no absolute agreement to a point where all the systems consider one soil best and another worst. This observation agreed with the report of Ogunkunle and Babalola (1986), in Nigeria who compared Land Capability Classification (LCC), Fertility Capability Classification (FCC), Index of Classification (IC) and Irrigation Capability Classification (ICC) systems for 13 SMUs, and reported that as the approaches differ, one may not expect absolute agreement among the systems. However, it is expected that the assessments of the capability of the soils relative to one another were similar between any two systems. They concluded that LCC and FCC were very similar and more efficient than ICC and IC, which were also less similar.

In this study, LCC classified the soils as well suited for a wide range of arable crops with limitations ranging from wetness, flooding, low nutrient retentive capacity, low exchangeable Ca^{2+} and Mg^{2+} level, and high exchangeable Al^{3+}, irrespective of location on the landscape. The LCC considered flooding 'f' greatly, as a basis for the classification hence the symbol 'f' was very prominent. It is necessary to note that the parent materials of all the SMUs are alluvium. On the other hand, LCI did not consider flooding hence the appearance of ELM3 and TFN3 flooded seasonally by the Nun and Forcados rivers, respectively, placed in class III for arable and permanent crops while others, ELM2 and ODI2, though not flooded, were placed in class IV. The LCI considered texture, colour/drainage, and pH-base saturation as the limiting characteristics to crop production for the SMUs. However, only LCI considered the appropriateness of the soil mapping units for the cultivation of annual and perennial crops in clear terms. Neither was flooding considered an essential characteristic in the FCC system nor location on the landscape. What was considered prominently by the FCC system as the soil fertility limiting characteristics was textural distribution in the profile, nutrient reserve status, soil acidity, and Al toxicity, wetness, K deficiency, and the likelihood of Fe toxicity. Apart from the fact that the FCC system classified the soils as predominantly loamy, 94% of the SMUs were considered to have high soil acidity and Al toxicity. One major challenge of the use of FCC is the designations used which at a glance did not convey the relative capability of soils. Generally speaking, though the systems have a close relationship, there was no absolute agreement among them, and none can be considered best.

Concerning the criteria employed in the evaluation systems and the capability classifications (Table 8), it is evident that some criteria are more relevant than others in allocating capability groupings of the SMUs. Soil texture, drainage/wetness, and nutrient status stand out as the main criteria common to all systems. Flooding, though very important in the study area, was applied prominently in allocating the soils to capability groups by the LCC system only. Although topography (angle of the slope) and soil effective depth are typical to in all the systems, their variation in the area of study was not so much of a great impact in deciding capability groupings. These results indicated that the criteria of relevance to land capability evaluation are site-specific.

Conclusion

The land capability and fertility constraints of nine SMUs were assessed using land LCC, LCI, and FCC systems. The soil fertility limiting factors identified by the three capability assessment methods were similar, which generally included, wetness, low nutrient retentive capacity, and soil acidity. Whereas only the LCC identified flooding as a fertility limiting factor, the LCI and FCC systems identified textural limitations, implying that sandy SMUs have the likelihood of water stress during dry periods. Only FCC identified K deficiency in the SMUs. Flood control, improved drainage, liming, and adequate fertilization practices are recommended to enhance increased and sustainable crop production on the soils along with organic matter conservation to improve nutrient retentive capacity.

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