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CAPABILITY GROUPINGS OF SOME NUN RIVER FLOODPLAIN SOILS OF BAYELSA STATE, SOUTHERN NIGERIA

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ABSTRACT

Nine Nun River floodplain soils in Bayelsa State were evaluated using Land Capability Classification (LCC), Land Capability Index (LCI) and Fertility Capability Classification (FCC) systems. The LCC grouped most soil mapping units (SMUs) into class II except NDU3. Odi (ODI1), Koroama (KRM1) and Niger Delta University (NDU1) were grouped in IInf0; ODI2, KRM2 and NDU2 in IIwnf0; ODI3 and KRM3 in IIwnf1 and NDU3 in Vwnf3, respectively. Indicating suitability for wide range of arable crops. The LCI grouped ODI1, KRM1 and NDU1 in class II while ODI2, ODI3, KRM2, KRM3, NDU2 and NDU3, in class III for annual crops. For perennial crops, KRM1 and NDU1 were grouped in class II, ODI1, KRM2 and NDU2 in class III while ODI2, ODI3, KRM3 and NDU3, in class IV, respectively. The FCC grouped ODI1 in La$^-$ and ODI3 into Lga$^-$e. On the other hand, KRM1 was grouped in La$^-$e while KRM2, KRM3 and NDU3 in Lga$^-$ek. The identified limiting fertility constraints were wetness, flooding, low exchangeable K^+, Ca^{2+} and Mg^{2+} concentration, soil acidity as promoted by Al^{3+} toxicity, texture and drainage. LCI and FCC identified texture as a major constraint with LCI placing emphasis on soil colour while FCC identified K^+ deficiency as a limitation. Wetness, flooding, low nutrient capital of exchangeable K^+, Ca^{2+} and Mg^{2+}, soil acidity and Al^{3+} toxicity, texture and drainage were key to land evaluation in the study area. Flood control, improved drainage, liming and adequate fertilization practices including organic matter conservation should be adopted for improved land management.

Key words: land capability index, fertility capability classification, soil mapping units, floodplain

INTRODUCTION

Natural classification systems are very helpful in the understanding of soil properties and behaviour, and are vital for communication between soil and environmental scientists. Agriculturists and other professionals dealing with soils, and their taxonomy often convey very little or no meaningful information to many end users, especially the farmers. In the opinion of Mustapha and Udom (2005), the ultimate interest of most land users is in the response of soils to management and manipulation which are (a) the use to which a piece of land is best suited or its relative suitability for alternative uses, (b) the crops that are most suitable and profitable to be raised on that land, (c) the limitation(s) of the land to a particular use or alternative uses and how such limitation(s) can be overcome. Only land evaluation can inform farmers on how suitable the land is, in terms of soil limitations, crop yield or profit (Olaleye *et al.,* 2008). Conducting a land evaluation involves the integration of a number of factors including soil properties, the ways in which soils react to various farming methods, climatic variables, topography, geology and geomorphology as well as social and technical consideration (Udoh, 2010; Adesemuyi, 2014; Nahusenay and Kibebew, 2015).

Agricultural potentials of alluvial soils have not been fully exploited due to insufficient data on their physical and chemical properties and concomitant changes they undergo under intensive cultivation (Effiong and Ibia, 2009; Ukaegbu *et al.,* 2015; Ukabiala *et al.,* 2021). Floodplains are about the most fertile lowland resources used mostly for rice production as well as dry season vegetable farming, and they can be highly responsive to management (Nnadi *et al.,* 2021). In Bayelsa State of Nigeria occurs a vast land space of floodplain soils with high agricultural potentials but current information on their characteristics, capabilities and suitability are inadequate (Dickson *et al.,* 2020). For any soil survey information to be useful to farmers and other land users in Bayelsa State, it must be translated into units with practical implications for use. The aim of this study, therefore, was to (i) emphasize on the relevance of land evaluation for improved agricultural development in Bayelsa State and indeed, Nigeria in general, (ii) assess the suitability of the floodplain soils for cultivation of various crops. It demonstrates the kind of studies needed in selecting appropriate land evaluation system and the associated criteria for appropriate land characterization in the Niger Delta ecological zone.

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MATERIALS AND METHODS

Description of the Study Areas, Soil Sampling Procedure and Analyses

The study areas are in Bayelsa State, Niger Delta region, Southern Nigeria and 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; Odi by Nun River, Koroama by Taylor Creek and Niger Delta University (Amassoma) by Nun River, all within Bayelsa State were randomly sampled for the study. Map of the area and details of soil study locations are shown (Figure 1). Annual rainfall of the area is in the range of 2000-4500 mm which spreads over 8 to 10 months each year and is bimodal, peaking at Jun. and Sep. Food crops in Bayelsa State are cultivated on the levee crest, levee slope, back slope and on recent alluvial soils on channels of present active rivers. Levee crest soils as defined by Brierley *et al.* (1997) and Skene *et al.* (2002) were no longer flooded. While levee slope, back slope or lower slope and alluvial soils in the channels of present active rivers are flooded yearly by the Niger River floods.

Detailed soil survey was conducted on agricultural lands in Odi, Koroama and Niger Delta University Teaching and Research Farm using rigid grids. One profile pit per mapping unit was sunk with designation of the soil mapping units (SMUs) being ODI1, ODI2 and ODI3 for Odi soils; KRM1, KRM2, and KRM3 for Koroama soils and NDU1, NDU2 and NDU3 for Niger Delta University soils, respectively. Soil sampling procedures followed the methods prescribed by the United States Department for Agriculture (USDA) Soil Taxonomy and the World Reference Base for soil resources classification systems (Madueke *et al.*, 2021). Profile pits were located based on the spread of the three communities with recorded high agricultural activities and land use by the locals. Following standard procedure, profile pits were dug, described and samples collected across pedogenic horizons for laboratory analyses. Details of the procedures were as reported by Dickson *et al.* (2020). Standard laboratory methods were used to determine the physical and chemical properties of the soil as reported by Dickson *et al.* (2020).

Land Capability Evaluation Methods

Three land capability evaluation methods namely Land Capability Classification (LCC) system (Klingebiel and Montgomery, 1961) as modified by Ogunkunle and Babalola (1986), Land Capability Index (LCI) or Soil Index (SI) by Van Ranst and Verdoodt (2005) and Fertility Capability Classification (FCC) system by Sanchez *et al.* (2003) were adopted and used in the study.

Land capability classification

The criteria for the LCC system of Klingebiel and Montgomery (1961) slightly modified by Ogunkunle and Babalola (1986) was further modified by the non-inclusion of total soluble salts (ss), and percent rock outcrop as the environment is freshwater environment and not rocky. Also, permeability and available water capacity (cm) were excluded (Table 1). Furthermore, due to the kind of limitations owing to the peculiarity of the environment that 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 as the study environment was subject to yearly seasonal floods which affect the farming season and the time of crops harvest.

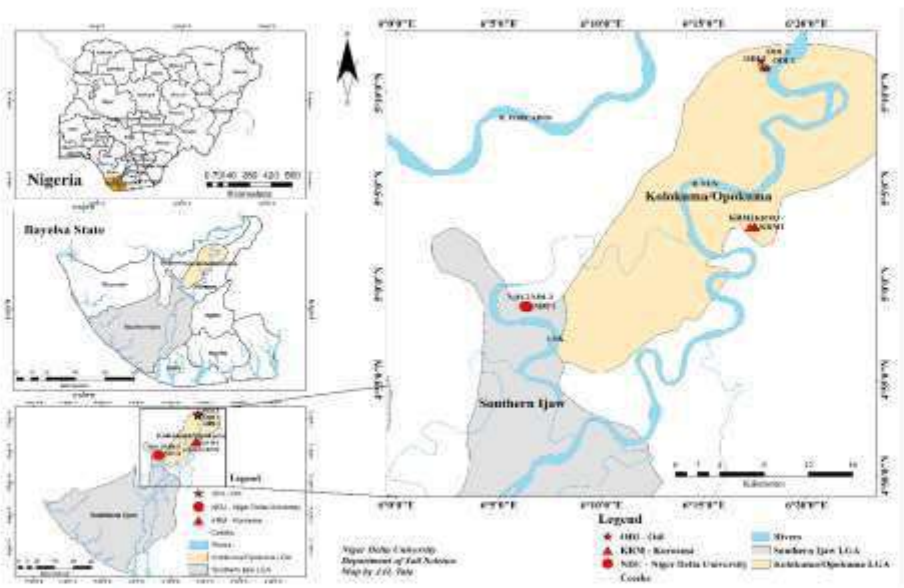

Figure 1: Map of Bayelsa State of Nigeria showing study area with sampling units

Table 1: Summary of criteria for land capability classification (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	Moderate	Moderate	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^{-1})	15	10-15	5-10	2-5	2-5	1-2	0-1	2-5

ECEC - effective cation exchange capacity, scl - sandy clay loam, sl - sandy loam, Ls - loamy sand, c - clay

Land capability index

The LCC (Van Ranst and Verdoodt, 2005) 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. This characterization uses six land capability classes of excellent, high, good, moderate, low and not capable to characterize the capability of the land unit for the production of the desired or selected crops. Land capability was estimated by calculating capability index or soil index, as a product of ratings attributed to six soil characteristics:

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

where LCI is capability index or soil index; *A* is rating for profile development; *B* is rating for texture; *C* is rating for soil depth; *D* is rating for colour/drainage conditions; *E* is rating for pH/base saturation; *F* is 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 exacting crops, moderately exacting crops and less exacting crops.

Fertility capability classification

The fertility capability classification (FCC) system by 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: Strata type (topsoil texture), substrata 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.

RESULTS AND DISCUSSION

Land Capability Classification of the Study Area

Table 2 presents the interpretations of the LCC of the soil mapping units. Out of the eight capability classes in the LCC system, only class II and V were encountered. The ODI1, KRM1 and NDU1 belonged to IInf0 LCC unit; ODI2, KRM2 and NDU2 to the IIwnf0, ODI3 and KRM3 to the IIwnf1, and NDU3 to Vwnf3 LCC. Class II soils were well suitable for a wide range of arable crops with wetness, flooding and low reserve of nutrients including exchangeable Ca^{2+} and Mg^{2+} as limitations. Recommended conservation measures include avoidance of bush burning that is common in the area, drainage to reduce wetness, and liming to increase exchangeable Ca^{2+} and Mg^{2+} and reduce exchangeable Al^{3+}. Also, use of organic soil amendments is suggested to replenish Ca^{2+} and Mg^{2+} (Nwite *et al.*, 2012a), but more comprehensively, *sawah*-based soil and water management strategies which often involve input of organic materials could help to harness the wetness while improving nutrient retentive capacity (Nwite *et al.*, 2012b; Obalum *et al*., 2012; Igwe *et al*., 2013).

Land Capability Indexes of the Study Area

Using the Land Capability as defined by Van Ranst and Verdoodt (2005), the tabulation of the land capability indexes of the SMUs are presented in Table 3. In Table 4 is the summary of the land capability indexes and capability classification of the SMUs.

According to Van Ranst and Verdoodt (2005), the LCC 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, which were further distinguished into annual and perennial crops. The LCC for the humid tropics is a parametric system with assigned nominal numerical values from 20 to 125 (ratings) for different capability classes of the land characteristics. Profile development is a key determining factor in which the capability index or soil index obtained as the numerical values assigned ranges from 55 to 100 (Van Ranst and Verdoodt, 2005). All the SMUs were assigned 95 for having Cambic horizons 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 120 cm, the numerical value of 100 was assigned to all. And regarding the rating for the 'A' horizon development, the value of 120 was assigned because all the SMUs had well developed 'A' horizons, deeper than 20 cm.

The soil characteristics that varied in their ratings in the SMUs studied were ratings for texture, colour/drainage conditions and pH-base saturation, respectively. These were regarded as limiting factors for crop production for the SMUs. Light-textured soils were rated low and heavy-textured soils having < 60% clay like silty clay, silty clay loam and clay loam were rated high (100, 95 and 90, respectively). Therefore, the ratings for texture in the SMUs with silt loam were assigned 85 and those with silty clay loam, 95 and loam, 75; dictating the ratings for texture. The SMUs dominated by sandy loam and loamy sand textures had low rating for texture, while those with silty clay loam as part of the profile had high ratings. The

Table 2: Interpretation of land capability classification of the soil mapping units

SMU	Sub-class	Interpretation
ODI1	IInf0	ODI1 belongs to class II, free from flooding (f0). The major limitations are low nutrient retentive capacity (n), low exchangeable Ca^{2+} and Mg^{2+} and high exchangeable Al^{3+}. Land is suitable for cultivating wide variety of arable crops.
ODI2	IIwnf0	ODI2 belongs to class II, free from seasonal floods (f0). The major limitations are wetness (w) within 50 cm depth, low nutrient retentive capacity (n), low exchangeable Ca^{2+} and Mg^{2+} and high exchangeable Al^{3+}. Land is suitable for cultivating wide variety of arable crops.
ODI3	IIwnf1	ODI3 belongs to class II, with indications of wetness (w) all through the profile. Apart from wetness, flooding (f1) for less than 1 month during the annual floods and low exchangeable Ca^{2+} and Mg^{2+} as well as high exchangeable Al^{3+} are major limitations. Land is suitable for cultivating arable crops when big mounds are raised.
KRM1	IInf0	KRM1 belongs to class II, free from annual flooding (f0) with low nutrient holding capacity (n), low exch. Ca^{2+} and Mg^{2+} as well as high exchangeable Al^{3+} as major limitations. Land is suitable for cultivating wide variety of arable crops.
KRM2	IIwnf0	KRM2 belongs to class II, free from flooding (f0) but wetness (w) with 50 cm depth, low nutrient retentive capacity (n); low exchangeable Ca^{2+} and Mg^{2+} as well as high exchangeable Al^{3+} are the limitations. Land is suitable for cultivating wide range of arable crops with improvement in nutrient holding capacity.
KRM3	IIwnf1	KRM3 belongs to class II. Flooding (f1) for less than 1 month, wetness (w) with 50 cm depth, low nutrient retentive capacity (n), low exchangeable Ca^{2+} and Mg^{2+} as well as high exchangeable Al^{3+} are the limitations. Land suitable for cultivating wide range of arable crops with improvement in nutrient holding capacity including liming.
NDU1	IInf0	NDU1 belongs to class II, free from flooding (f0) but wet, low in nutrient retentive capacity (n), low exchangeable Ca^{2+} and Mg^{2+} as well as high exchangeable Al^{3+} is the limitations. Land suitable for cultivating wide range of arable crops with improvement in nutrient holding capacity
NDU2	IIwnf0	NDU II belongs to class II free of flooding (f0) but wet (w) within 50 cm depth from soil surface. Other limitations are low nutrient retentive capacity (n), low exch. Ca^{2+} and Mg^{2+} as well as high exchangeable Al^{3+}. Land is suitable for cultivating a wide variety of crops with improvement in nutrient retentive capacity by supplying additional nutrients
NDU3	Vwnf3	NDU3 belongs to class Vw due to high degree of wetness. The land is flooded (f3) for 3-6 months each year and there is serious wetness (w) even during the dry months. Nutrient retentive capacity (n) is low as well as exch. Ca^{2+} and Mg^{2+} while exchangeable Al^{3+} level is high which are the limitations. Land is suitable for low land rice production.

SMU - Soil mapping unit, Flooding f0 - no flooding, f1- flooding for less than 1 month, f2- flooding for 1-2 months, f3- flooding for 3-6 months, f4- flooding for more than 6 months, w - wetness, n - nutrient retention capacity

KRM3 rated 91 and NDU2, 93 (Table 4) due to the presence of silty clay loam texture which was used in calculating the ratings for texture in the two SMUs. As 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 whereas, 95 rating is given when the moist colour is yellow (yellower than 5YR), mottling at a depth deeper than 120 cm and is well drained (Bassey *et al*., 2009). All the SMUs 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. For the rating of pH and base saturation, none of the SMUs attained 100 due to low base saturation and variation in pH with the assigned values ranging from 90-98 and LCI.

Based on the calculated capability index or soil index of the SMUs (Van Ranst and Verdoodt, 2005), ODI1, KRM1 and NDU1 were grouped in class II and ODI2, ODI3, KRM2, KRM3, NDU2 and NDU3 in class III for annual crops. While for perennial crops, KRM1 and NDU1 were grouped in class II, ODI1, KRM2 and NDU2 in class III and others (ODI2, ODI3, KRM3 and NDU3) in class IV. From the definition of the capability classes (Table 4), capability class III is rated to be good for annual crops, class II to be high and class I to be excellent. On the other hand, for perennial crops, class IV is rated good, class III, high and classes II and I, rated as excellent. It was, therefore, concluded that the capabilities of the SMUs were good to very good for the production of annual and tree crops. Understandably, oil palm, which roots concentrate within the 0-60 cm depth was found growing in the poorly drained soils like ODI3 during the field investigation, confirming the results of capability classification index (LCI). Most of the SMUs are flooded annually by the Niger River between September and October. This implied that capability classification using LCI did not consider flooding as a limiting factor.

Fertility Capability Classification of the Soils

Presented in Tables 5 and 6 are the detailed interpretation of the FCC of the soils and the summarized interpretation, respectively. Olaleye *et al*. (2008) reported that 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 that the soils were predominantly loamy textured. Of the nine SMUs, ODI1, ODI2 and NDU2 were grouped into the La^{-} unit with ODI3 into the Lga^{-}e unit and KRM1 into the La^{-}e unit. On the other hand, KRM2, KRM3 and NDU3, were grouped into Lga^{-}ek of FCC units, accordingly. Based on fertility classification guide of Sanchez *et al*. (2003), soil fertility limiting factors in the soils included wetness, low nutrient reserve, soil acidity and Al toxicity; Ca^{2+}, Mg^{2+} and K^{+}

Table 3a: Capability classification indexes of the soil mapping units at ODI

Factor	Parameter	Value	Rating	
			AN	PN
		ODI1		
A	Profile dev.	ABC - profile	95	95
B	Texture		78	78
	Ap	Silt loam - no gravel		
	A	Loam - no gravel		
	B1	Loam - no gravel		
	B2	Silt loam - no gravel		
	B3	Loam - no gravel		
	C1	Silt loam - no gravel		
	C2	Silt loam - no gravel		
	C3	Silt loam - no gravel		
C	Soil depth (cm)	200 +	100	100
D	Drainage	Mottling 80-120 cm	90	80
E	pH		90	90
	Ap	6.30		
	A	6.03		
	B1	6.40		
F	Dev. of topsoil		120	120
	-land use	Secondary forest		
	-value/chroma	A-3/3		
	-thickness	> 20		
LCI			72	64
Class			II	III
		ODI2		
A	Profile dev.	ABC - profile	95	95
B	Texture		75	75
	Ap	Loam - no gravel		
	A	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 40-80 cm	75	60
E	pH		90	90
	Ap	5.70		
	A	6.08		
F	Dev. of topsoil		120	120
	-land use	Grassy vegetation		
	-value/chroma	A-3/4		
	-thickness	> 20		
LCI			58	46
Class			III	IV
		ODI3		
A	Profile dev.	ABC - profile	95	95
B	Texture		85	85
	Ah	Silt loam - no gravel		
	Ap1	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		
C	Soil depth (cm)	200 +	100	100
D	Drainage	Mottling 0-40 cm	60	40
E	pH		90	90
	Ah	5.67		
	Ap1	5.89		
	Ap2	6.30		
	B1	6.20		
	B2	6.04		
F			120	120
	-land use	Oil palm farm		
	-value/chroma	A-2/2		
	-thickness	> 20		
LCI			52	35
Class			III	IV

AN - Annuals, PN - Perennials

Table 3b: Capability classification indexes of the soil mapping units at KRM

Factor	Parameter	Value	AN	
			AN	PN
		KRM1		
A	Profile dev.	ABC - profile	95	95
B	Texture		85	85
	A1	Silt loam - no gravel		
	A2	Silt loam - no gravel		
	B1	Silt loam - no gravel		
	B2	Silt loam - no gravel		
	BC	Silt loam - no gravel		
	C	Silt loam - no gravel		
C	Soil depth (cm)	200 +	100	100
D	Drainage	Mottling 80-120 cm	90	80
E	pH		90	90
	A1	5.79		
	A2	5.48		
	B1	6.12		
F	Dev. of topsoil		120	120
	-land use	Fallowed cassava farm		
	-value/chroma	A-3/4		
	-thickness	> 20		
LCI			78	70
Class			II	II
		KRM2		
A	Profile dev.	ABC - profile	95	95
B	Texture		90	90
	Ap	Silt loam - no gravel		
	Ap2	Silt loam - no gravel		
	B1	Silty clay loam - no gravel		
	B2	Silty clay loam - no gravel		
	B3	Silt loam - no gravel		
	C1	Silt loam - no gravel		
	C2	Silt loam - no gravel		
C	Soil depth (cm)	200 +	100	100
D	Drainage	Mottling 40-80 cm	75	60
E	pH		90	90
	Ap	5.55		
	Ap2	6.39		
	B1	6.10		
	B2	6.38		
	B3	6.49		
F	Dev. of topsoil		120	120
	-land use	Secondary bush		
	-value/chroma	A-3/2		
	-thickness	> 20		
LCI			69	55
Class			III	III
		KRM3		
A	Profile dev.	ABC - profile	95	95
B	Texture		91	91
	Ap	Silt loam - no gravel		
	Ap2	Silt loam - no gravel		
	B1	Silty clay loam - no gravel		
	B2	Silty clay loam - no gravel		
	B3	Silty clay loam - no gravel		
	C	Silt loam - no gravel		
C	Soil depth (cm)	200 +	100	100
D	Drainage	Mottling 0-40 cm	60	40
E	pH		90	90
	Ap	5.67		
	Ap2	6.09		
	B1	6.24		
	B2	5.72		
F	Dev. of topsoil		120	120
	-land use	Old plantain farm		
	-value/chroma	A-3/2		
	-thickness	> 20		
LCI			56	37
Class			III	IV

AN - Annuals, PN - Perennials

Table 3c: Capability classification indexes of the soil mapping units at NDU

Factor	Parameter	Value	Rating AN	Rating PN
		NDU1		
A	Profile dev.	ABC-profile	95	95
B	Texture		93	93
	Ap	Silt loam-no gravel		
	B1	Silty clay loam-no gravel		
	B2	Silty clay loam-no gravel		
	B3	Silty clay loam-no gravel		
	C1	Silt loam-no gravel		
	C2	Silt loam-no gravel		
C	Soil depth (cm)	200 +	100	100
D	Drainage	Mottling 80-120 cm	90	80
E	pH		90	90
	Ap	5.58		
	B1	5.69		
	B2	6.07		
	B3	5.92		
F	Dev. of topsoil		120	120
	-land use	Fallowed farmland		
	-value/chroma	A-3/3		
	-thickness	< 20		
LCI			86	76
Class			II	II
		NDU2		
A	Profile dev.	ABC - profile	95	95
B	Texture		90	90
	Ap	Silt loam - no gravel		
	Ap2	Silt loam - no gravel		
	B1	Silty clay loam - no gravel		
	B2	Silty clay loam - no gravel		
	B3	Silt loam - no gravel		
	C	Silt loam - no gravel		
C	Soil depth (cm)	200 +	100	100
D	Drainage	Mottling 40-80 cm	75	60
E	pH		90	90
	Ap	5.64		
	Ap2	5.92		
	B1	6.06		
	B2	6.01		
F	Dev. of topsoil		120	120
	-land use	Fallowed farmland		
	-value/chroma	A-4/4		
	-thickness	> 20		
LCI			69	55
Class			III	III
		NDU3		
A	Profile dev.	ABC - profile	95	95
B	Texture		85	85
	A1	Silt loam - no gravel		
	A2	Silt loam - no gravel		
	AB	Silt loam - no gravel		
	B1	Silt loam - no gravel		
	B2	Silt loam - no gravel		
	C	Silt loam - no gravel		
C	Soil depth (cm)	200 +	100	100
D	Drainage	Mottling 0-40 cm	60	40
E	pH		90	90
	A1	5.42		
	A2	5.72		
	AB	5.90		
	B1	6.03		
F	Dev. of topsoil		120	120
	-land use	Grass land		
	-value/chroma	A-3/3		
	-thickness	< 20		
LCI			52	35
Class			III	IV

AN - Annuals, PN - Perennials

deficiency as well as N deficiency. Table 5 highlights the acid nature of these soils as indicated by 89% (ODI2, ODI3, KRM1, KRM2, KRM3, NDU1, NDU2 and NDU3) of SMUs included the FCC condition modifier ‘h’, revealing medium to strong 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 plow layer. An Al saturation of between 10 and 60% within the plow layer is harmful to Al-sensitive crops, and may require liming. Sanchez *et al.* (2003) reported that Al toxicity is 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. Ukaegbu *et al.* (2015) also reported similar results on soils supporting oil palm plantations in the coastal plain sands of Imo State, Nigeria. According to Izac and Sanchez (2001), soils with low (< 10%) reserves of weatherable minerals in their sand and silt fractions constituted low nutrient capital reserves in the integrated natural resources management (INRM) context and 36% of soils of the tropics fall into this category. Notably, the only other source of nutrient capital reserves is organic matter, which contains all the nitrogen and much of the phosphorus and sulphur capital of tropical soils (Obalum *et al.,* 2017).

Low nutrient reserve at 56% in the soils was captured by the FCC system by the inclusion of the condition modifier ‘e’ which means that values of exchangeable cation exchange capacity (ECEC) at the surface layers of such soils were less than 4 cmol kg^{-1}. The low nutrient reserve coupled with high concentration of Al^{3+} and Fe^{3+} revealed that the exchange complex was dominated by Al^{3+} and Fe^{3+}. The ECEC values signified that the soils were dominated by 1:1 type of clay with low ability to retain nutrients. Hence, fertilizer application to these soils should be split. Furthermore, the condition modifier ‘k’ was included in 44% (KRM2, KRM3, NDU1 and NDU3) of the soils indicating that the affected soils were deficient in K^+; and the K values were below the 0.2 cmol kg^{-1} critical value for Nigerian soils with a rating of < 95.

The FCC of the soils, shown in Table 5, included the condition modifier ‘g’ for 44% of the soils (ODI3, KRM2, KRM3 and NDU3), indicating wetness, gleying or prolonged water saturation each year. The wetness quality makes the affected SMUs unsuitable for deep-rooted crops due to the defective oxygen supply. In this category is oil palm thought to naturally prefer wet environments (Okolo *et al*., 2019). However, shallow-rooted crops and short-season crops could be raised except on NDU3.

Cultivation of shallow rooted and short-season crops on NDU3 is possible only if the excess water is removed via artificial drainage. Organic matter obviously was crucial in sustaining soil fertility and its’ management should be given top priority.

Table 4: Land capability indexes of the soil mapping units

SMU	Annual crops		Perennial crops	
	Land capability index	Land capability class	Land capability index	Land capability class
ODI1	72	II	64	III
ODI2	58	III	46	IV
ODI3	52	III	35	IV
KRM1	78	II	70	II
KRM2	69	III	55	III
KRM3	56	III	37	IV
NDU1	86	II	76	II
NDU2	69	III	55	III
NDU3	52	III	35	IV

SMU - Soil mapping unit

Comparison of the Various Capability Classification Systems

Land capability classification placed all the levee crest soils (ODI, KRM1 and NDU1) into IInf0, the levee slope soils (ODI2, KRM2, and NDU2) into IIwnf0, and of the flood plain soils, (ODI3 and KRM3) were placed in IIwnf1 and NDU3 into a special class, VWnf3 (Table 2). Land Capability Index (LCI) of Van Ranst and Verdoodt (2005) classified ODI1, KRM1, and NDU1 in class II and ODI2, ODI3, KRM2, KRM3, NDU2 and NDU3 in class III for arable crop production. For permanent crops, KRM1 and NDU1 were grouped in class II, ODI1, KRM2, and NDU2, in class III and ODI2, ODI3, KRM3 and NDU3 in class IV (Table 4). The FCC included KRM1 in La$^-$e unit, ODI2 and NDU2 in La$^-$, KRM2, KRM3 and NDU3 in Lga$^-$ek unit, and ODI1, ODI3 and NDU1 in La$^-$, Lga$^-$e and La$^-$k, respectively (Tables 5 and 6). The systems obviously have close relationship but no absolute agreement to a point where all the systems consider one soil best and another worst. This observation agrees with the report of Ogunkunle and Babalola (1986) and Dickson *et al*. (2020) in Nigeria. Dickson *et al*. (2020) compared LCC, LCI and FCC systems for nine SMUs and reported that as the approaches differ, one may not expect absolute agreement among the systems but the assessments of the capability of the soils relative to one another was similar between any two systems, though LCI and FCC seem to have closer relationship.

The LCC in this study 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', as a basis for the classification hence the symbol 'f' was very prominent, knowing fully well that the parent materials of the SMUs are alluvium. On the other hand, LCI did not consider flooding hence ODI2 that is not flooded was placed in class IV.

Table 5: Fertility capability classification units of the soil mapping units

SMU	FCC unit	Interpretation
ODI1	La$^-$	Loamy (L) soil with good water holding characteristics, having fertility constraints, low ability to supply P (i), Ca^{2+} and Mg^{2+}, Al saturation more than 20% (a$^-$) at 50 cm depth, may require liming for Al- sensitive crops, N deficiency most likely, may require N supplies during each cropping season.
ODI2	La$^-$	Loam (L) with good water holding characteristics, having fertility constraints with low ability to supply Ca^{2+} and Mg^{2+},moderatelyacid, Al saturation of more than 20% (a$^-$) at 50 cm depth, may require liming for Al- sensitive crops, N deficiency most likely, requiring N supplies in each cropping season.
ODI3	Lga$^-$e	Loam (L) with good water holding characteristics, mottling (g) all through the profile, soil saturated with water (f2) for more than 60 days in most years; moderate acidity, Al saturation of more than 20% (a$^-$) at 50 cm depth, may require liming for Al-sensitive crops, low ECEC (e)N deficiency most likely, requiring N supplies in each cropping season.
KRM1	La$^-$e	Loam (L) with good water holding characteristics, having fertility constraints with low ability to supply Ca^{2+} and Mg^{2+}, moderately acid with Al saturation of more than 20% (a$^-$) at 50 cm depth, may require liming for Al-sensitive crops, N deficiency most likely, requiring N supplies in each cropping season.
KRM2	Lga$^-$ek	Loam with good water holding characteristics, soil is saturated with water for more than 60 days in most years, having fertility constraints with low ECEC and ability to supply K^+, Ca^{2+} and Mg^{2+}, moderately acid, Al saturation of more than 20% at 50 cm depth, may require liming for Al-sensitive crops, N deficiency most likely, requiring N supply during each planting season.
KRM3	Lga$^-$ek	Loam with good water holding characteristics, most likely saturated with Water for more than 60 days in most years, having fertility constraints with low ECEC and ability to supply Ca^{2+} and Mg^{2+}, moderately acid, Al saturation of more than 20% at 50 cm depth, ma
NDU1	La$^-$k	Loamy soil with good water holding characteristics, with moderate acidity, Al saturation of more than 20% at 50 cm depth, may require liming for Al- sensitive crops, low ability to supply P, Ca^{2+} and Mg^{2+}, N deficiency most likely, requiring N supply during each planting season.
NDU2	La$^-$	Loam with good water holding characteristics, with moderate acidity, Al saturation of more than 30% at 50 cm depth, may require liming for Al- sensitive crops, low ability to supply P, Ca^{2+} and Mg^{2+}, N deficiency most likely, requiring N supply during each planting season.
NDU3	Lga$^-$ek	Loamy soil saturated with water for more than 60 days in most years, having fertility constraints, low ECEC, buffering capacity and ability to supply P, K^+, Ca^{2+} and Mg^{2+}, moderate acidity, Al saturation of more than 30% at 50 cm depth, may require liming for Al- sensitive crops, N deficiency most likely, requiring N supply during each planting season.

SMU - Soil mapping unit, FCC - Fertility Capability Classification

Table 6: Comparison of the various capability classification systems

SMU	Land Capability Classification (LCC)	Land Capability Index (LCI)		Fertility Capability Classification (FCC)
		Arable crops	Permanent crops	
ODI1	IInf0	II	III	La-
ODI2	IIwnf0	III	IV	La-
ODI3	IIwnf1	III	IV	Lga-e
KRM1	IInf0	II	II	La-e
KRM2	IIwnf0	III	III	Lga-ek
KRM3	IIwnf1	III	IV	Lga-ek
NDU1	IInf0	II	II	La-k
NDU2	IIwnf0	III	III	La-
NDU3	Vwnf3	III	IV	Lga-ek

w - wetness, n - nutrient retentive capacity, f0 - no flooding, f1 - flooding for less than 1 month, f2 - flooding for 1-2 months in a year, L - loamy, g - gley, a - 10 to 60% Al saturation, e - low ECEC; k - K deficient

Furthermore, the NDU3, flooded for 3 to 6 months or more yearly was classified by LCC into the unsuitable for cultivation class. Vwwas grouped into class IV, along with ODI3, and KRM3 by LCI. The LCI considered texture, colour/drainage and pH-base saturation as the limiting characteristics to crop production for the SMUs. What was considered prominently by the FCC system as soil fertility limiting characteristics were textural distribution in the profile, nutrient reserve status, soil acidity, Al toxicity, wetness, K deficiency and the likelihood of Fe toxicity. Aside the fact that the FCC system classified the soils as predominantly loamy, 89% of the SMUs were considered having high soil acidity and Al toxicity. One major challenge of the use of FCC is the designations which at a glance did not convey the relative capability of soils. Generally speaking, though the systems have close relationships, they have no absolute agreement and none can be considered best.

Concerning the criteria employed in the evaluation systems and the capability classifications (Table 6), 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 stands 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 only by the LCC system while LCI alone emphasized on soil colour. Although, topography (angle of slope) and soil effective depth are common to all the systems, their variations in the area of study are not so much as to have great impact in deciding capability groupings. These results confirm the report of Ogunkunle and Babalola (1986) for Nigerian soils that the criteria of relevance to land capability evaluation are site-specific.

CONCLUSION

The three qualitative land evaluation systems applied to the Nun River floodplain soils indicated 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 most influentialto all systems. Though the systems have close relation-ships between themselves, however, they have no definitive similarity and, therefore, none can be considered best against the other. Though the LCI and FCC showed closer relationship. This study, however, recommends the FCC as most suitable for Bayelsa State soils as it showed a much stronger and detailed presentation based on the soil type.

CONFLICT OF İNTEREST

The authors declared that, for this research article, they have no potential or perceived conflict of interest.

AUTHORS' CONTRIBUTION

The contribution of the authors to the present study is not equal. However, all the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

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REFERENCES

Adesemuyi E.A. (2014). Suitability assessment of soils for maize (*Zea mays*) production in a humid tropical area of south-western Nigeria. *Int. J. Adv. Res.,* **2 (2),** 538-546. https://doi.org/10.1.1.1064.9201

Bassey U.U., Utip K.E., Inyang M.T. and Idungafa M.A. (2009). Fertility assessment of some inland depression and floodplain (wetland) soils in Akwa Ibom State. *Agro-Science,* **8 (1),** 44. https://doi.org/10.4314/as.v8i1.44108

Brierley G.J., Ferguson R.J. and Woolfe K.J. (1997). What is a fluvial levee? *Sediment. Geol.,* **114 (1-4),** 1-9. https://doi.org/10.1016/S0037-0738(97)00114-0

Dickson A.A., Kutu F.R. and Aruleba J. (2020). Evaluation of lower Niger river floodplain soils of Bayelsa State, southern Nigeria for their cropping capabilities. 44th Conference of Soil Science Society of Nigeria on Climate-Smart Soil Management, Soil Health/Quality and Land Management: Synergies for Sustainable Ecosystem Services, Enugu, **44,** 364-379. https://doi.org/10.36265/colsssn.2020.4451

Effiong G.S. and Ibia T.O. (2009). Characteristics and constraints of some river flood plains soils to crop production in southeastern Nigeria. *Agric. J.,* **4 (2),** 103-108. http://www.medwelljournals.com/fulltext/aj/2009/103-108.pdf

Igwe C.A., Nwite J.C., Agharanya K.U., *et al.* (2013). Aggregate-associated soil organic carbon and total nitrogen following amendment of puddled and *sawah*-managed rice soils in southeastern Nigeria. *Arch. Agron. Soil Sci.,* **59 (6)**, 859-874. https://doi.org/10.1080/03650340.2012.684877

Izac A.M.N. and Sanchez P. A. (2001). Towards a natural resource management paradigm for international agriculture: The example of agroforestry research. *Agric. Sys.,* **69 (1-2),** 5-25. https://doi.org/10.1016/S0308-521X(01)00015-4

Klingebie A.A. and Montgomery P.H. (1961). Land-capability classification (No. 210). Soil Conservation Service, United States Department of Agriculture, Washington DC. https://books.googleusercontent.com/books/content

Madueke C.O., Okore I.K., Maduekeh E.C., *et al.* (2021). Characterization and land evaluation of three tropical rainforest soils derived from the coastal plain. *Agro-Science,* **20 (2),** 25-36. https://doi.org/10.4314/as.v20i2.5

Mustapha S. and Udom G.N. (2005). Capability and suitability evaluations of fadama soils for selected crops in the Nigerian sudan savanna. *Glob. J. Agric. Sci.,* **4 (2),** 119-124. https://doi.org/10.4314/gjass.v4i2.2259

Nahusenay A. and Kibebew K. (2015). Land suitability evaluation in Wadla Delanta Massif of north central highlands of Ethiopia for rainfed crop production. *Afr. J. Agric. Res.,* **10 (13),** 1595-1611. https://doi.org/10.5897/AJAR2014.9248

Nnadi A.L., Ugwu V.U., Nwite J.C., Obalum S.E., Igwe C.A. and Wakatsuki T. (2021). Manurial amendments and source of water for supplemental irrigation of sawah-rice system influenced soil quality and rice yield. *Agro-Science*, **20 (1),** 95-102. DOI: https://dx.doi.org/10.4314/as.v20i1.15

Nwite J.C., Essien B.A., Anaele M.U., Obalum S.E., Keke C.I. and Igwe C.A. (2012a). Supplementary use of poultry droppings and rice-husk waste as organic amendments in southeastern Nigeria. 1. soil chemical properties and maize yield. *Libyan Agric. Res. Centre J. Int.,* **3 (2)**, 90-97

Nwite J.C., Obalum S.E., Igwe C.A., Ogbodo E.N., Keke C.I., Essien B.A. and Wakatsuki T. (2012b). *Sawah* rice system, a technology for sustainable rice production and soil chemical properties improvement in Ebonyi State of Southeastern Nigeria. *World J. Agric. Sci.,* **8 (4),** 351-358

Obalum S.E., Chibuike G.U., Peth S. and Ouyang Y. (2017). Soil organic matter as sole indicator of soil degradation. *Environ. Monit. Assess.*, **189 (4)**, Article 176. DOI: 10.1007/s10661-017-5881-y

Obalum S.E., Oppong J., Nwite J.C., Watanabe Y, Buri M.M., Igwe C.A. and Wakatsuki T. (2012). Long-term effects of lowland *sawah* system on soil physicochemical properties and rice yield in Ashanti Region of Ghana. *Spanish J. Agric. Res.,* **10 (3),** 838-848. http://dx.doi.org/10.5424/sjar/2012103-566-11

Ogunkunle A.O. and Babalola O. (1986). Capability groupings of some soils in the lowlands of Benue River. In: Chude V.O. (ed.), Proc. 14th Ann. Conf. Soil Sci. Soc. Nigeria, Makurdi, pp. 46-62

Okolo C.C., Okolo E.C., Nnadi A.L., Obikwelu F.E., Obalum S.E. and Igwe C.A. (2019). The oil palm (*Elaeis guineensis* Jacq): nature's ecological endowment to Eastern Nigeria. *Agro-Science*, **18 (3),** 48-57. https://dx.doi.org/10.4314/as.v18i3.9

Olaleye A.O., Akinbola G.E., Marake V.M., Molete S.F. and Mapheshoane B. (2008). Soil in suitability evaluation for irrigated lowland rice culture in southwestern Nigeria: Management implications for sustainability. *Comm. Soil Sci. Plant Anal.,* **39(19-20),** 2920-2938. https://doi.org/10.1080/00103620802432824

Sanchez P.A., Palm C.A. and Buol S.W. (2003). Fertility capability soil classification: a tool to help assess soil quality in the tropics. *Geoderma,* **114 (3-4),** 157-185. https://doi.org/10.1016/S0016-7061(03)00040-5

Skene K.I., Piper D.J. and Hill S.P. (2002). Quantitative analysis of variations in depositional sequence thickness from submarine channel levees. *Sedimentol.,* **49 (6),** 1411-1430. https://doi.org/10.1046/j.1365-3091.2002.00506.x

Udoh B.H. (2010). Variation in soil types and characteristics as influenced by topography within an agricultural managemnt unit in south-eastern Nigeria. *J. Appl. Agric. Res., 2*, 105-111

Ukabiala M.E., Kolo J., Obalum S.E., Amhakhian S.O., Igwe C.A. and Hermensah. (2021). Physicochemical properties as related to mineralogical composition of floodplain soils in humid tropical environment and the pedological significance. *Environ. Monit. Assess.* **(2021) 193:** 569. https://doi.org/10.1007/s10661-021-09329-y

Ukaegbu E.P., Osuaku S.K. and Okolo C.C. (2015). Suitability assessment of soils supporting oil palm plantations in the coastal plains sand, Imo State Nigeria. *Int. J. Agric. Forest.,* **5 (2),** 113-120. https://doi.org/10.5923/j.ijaf.20150502.04

Van Ranst E. and Verdoodt A. (2005). *Land Evaluation Method Part II: Qualitative Method*. International Centre For Physical Resources Laboratory of Soil Science. Ghent: Ghent University