Fertility Capability Classification of Some Flood Plain Soils in Kogi State, Central Nigeria

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Abstract: Sustainable crop production and protection of soil resources requires a proper understanding of the soil resources and limitations as well as allocation of land units to uses that are not adversely affected by the limitations posed by the land area. This study was carried out to evaluate some soils of the floodplains near the confluence area of River Niger in Central Nigeria using the Fertility Capability Classification (FCC) approach. Nine soil types identified in a land area covering a total of 18,750 ha of land straddling the floodplains of River Niger and Benue in Kogi State, Central Nigeria were characterized and classified using the USDA soil taxonomy and World Reference Base (WRB) Soil classification methods. The FCC system was used to evaluate the soils based on physical and chemical fertility constraints and limitations for general arable cropping. The starata and sub-starata types of the soils comprised mainly of Loamy topsoils with three of the pedons showing clayey starata types. Classification of the soils into various FCC units reveals that over 80% of the soils are arable with only one soil type – Leptic Cambisol with FCC unit LR^{+++} being non arable due to serious limitations of rock outcrops and very high gravel contents. Most of the soils could be effectively utilized for massive production of the common arable crops in the area if the appropriate tillage, soil fertility and land management strategies are applied.

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1. Introduction

Floodplains have been reported to be fragile ecosystems and their conversion to cropland may result in severe ecological and environmental deterioration and degradation if not appropriately done (Babalola *et al*., 2011). However, increasing demand for food as a result of rapid population expansion in Nigeria necessitates a substantial extension of croplands into some hitherto uncultivated wetlands/floodplains otherwise considered as marginal lands for rain-fed agriculture (Ojanuga, 2006). Basic soil resource information a pre-requisite for planning sustainable agriculture (Ekwoanya and Ojanuga, 2002) and sustainable agriculture requires both direct and indirect knowledge of the capability and nutrient status of the soils to be utilized (Dickson *et al*., 2002). In Nigeria, low soil nutrient reserve due to the predominance of low activity clays and declining soil fertility has been one of the major problems of smallholder farmers, but Mutsaers (1990), opined that soil fertility replenishment strategy that could allow for a sustainable agricultural productivity has not been developed. The need for soil surveys and land evaluation reports prior to crop cultivation and other agricultural land uses have been emphasized (Ogunkunle 1998; Dickson *et al*., 2002; Orimoloye, 2011).

However most land evaluation studies are executed by Pedologists who view the soil as embodiment of pedogenic processes and more emphasis are laid on soil genesis, inherent characteristics and taxonomy; the interpretations of the soil data in land evaluations are based on perceived or expected land developments. The soil fertility capability classification (FCC) system was developed for interpreting soil taxonomy and additional soil attributes in a way that is directly relevant to plant growth (Boul *et al.,* 1975; Sanchez *et al.,* 1982, 2003). It is a technical system of grouping soils with similar limitations, and management problems in terms of nutrient supply capacity of the soils, which has been widely used in the tropics (Sanchez *et al.,* 2003). The FCC considers topsoil parameters as well as specific subsoil properties that are related to plant growth. While the FCC is considered to be a land evaluation system by many, Rossitter (1994) believes it is a soil classification system which does not perform 'ranking of soils'.

The FCC modifiers (letters) can be directly related to individual land qualities therefore in effect, the soil 'name' as given by its FCC class is meaningful for soil fertility management and appears to be a suitable framework for agronomic soil taxonomy, acceptable to both Pedologists and agronomists (Lin, 1989). Through knowledge of FCC classes, farmers and land users can identify fertility, rooting and moisture limitations of land to specific crops and plan their activities to circumvent the drawbacks (Sanchez *et al.,* 2003).

While floodplains in river basins of many parts of the world have been used for agriculture because of their natural fertility (Verhoeven and Setter, 2010), Babalola *et al.* (2011), observed that some promising *Fadama* soils were poorly managed and have been abandoned by cultivators because of soil fertility decline, erosion and desiccation. Land evaluation using a scientific procedure, is essential to assess the potential and constraints of a given land for agriculture purposes and the knowledge of soil limitation arising from land evaluation report therefore aims at providing practical approaches to ameliorating such limitations before or during cropping period (Lin *et al.,* 2005). Appropriate protection and judicious utilization of the floodplains is essential to enable this ecosystem continue to provide livelihood to local community. Also sustainable agricultural production can only be achieved when information on the soil characteristics are carefully collected, assembled and interpreted. This study was carried out therefore to characterize the soils of the floodplains and evaluate the agricultural productivity of the soil using the updated FCC system.

2. Materials and Methods

Location

The study was based on nine (9) representative pedons identified in a semi-detailed soil survey of an area covering 18,750 ha for National Sugar Development Council (NSDC) project at Koton-Karfe local Government area Kogi State (Anonymous, 2014). The area is located on the floodplains of Rivers Niger and Benue, close to the confluence (Fig 1). The specific study area is located within the coordinates $7^{0}52'02.51^{0}$ N, $6^{0}48'11.15^{0}$E (SW), $7^{0}59'37^{0}$N, $6^{0}47'33.54^{0}$E (NW). $7^{0}58'01.28^{0}$N, $6^{0}56'57.96^{0}$E (NE) and $7^{0}52'55.18''$N, $6^{0}55'38.45''$45E (SE). The climate of the study area is designated as Sub-Humid (AW by Koppen classification) with mean annual rainfall of 1259 mm at Lokoja. Annual temperature ranges from 25-29 ^{0}C. Though this area is within the Derived (Guinea) savannah, the study area is characterized by luxuriant woody shrubs. To a large extent, the area has not been fully exploited for agricultural purpose; peasant farming with crops such as yam, melon, maize grown in mixture is practiced by local farmers. Some swamp rice cultivation was noticed at the depression while substantial numbers of pastoral herdsmen use several parts of the area as water and grazing points for their cattle, sheep and goats especially in the dry seasons. According to the agro ecological zoning of Nigeria, the area lies within agro-ecological zone F (Sub-Humid Niger-Benue Trough) (Ojanuga, 2006). The specific study site is underlain by the laterite capped Nupe sandstones and the sedimentary materials of the Niger-Benue Trough. The soils are significantly influenced by colluvial sediments from the upland and the alluvial deposits of the Rivers Niger and the Benue.

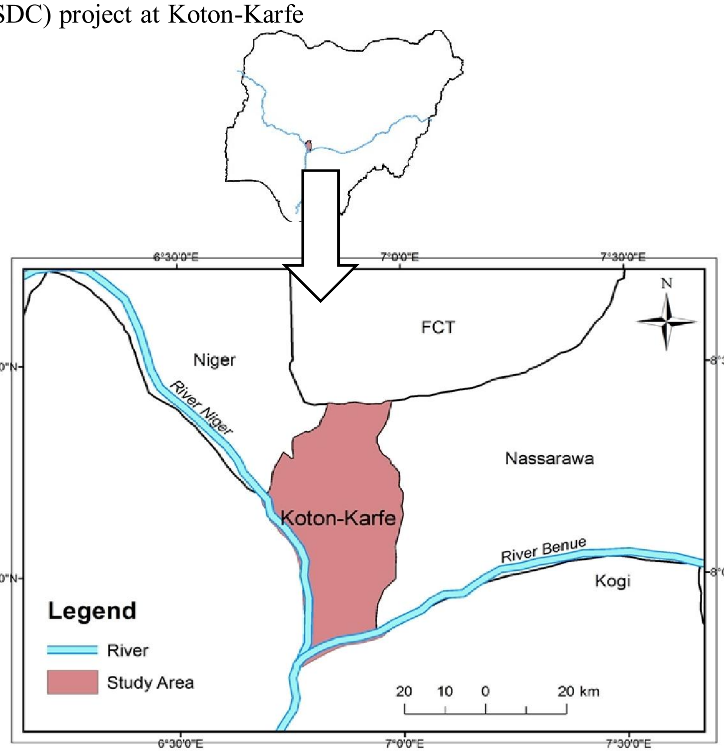

Fig 1: Map of Nigeria showing the study area at Koton-Karfe Local Government Area of Kogi State

Field Study

A semi detailed soil survey was conducted February, 2014 on the study site as part of the pre-feasibility study for the NSDC project. The method of soil survey adopted has been described elsewhere (Orimoloye et al., 2015). The soils were examined with modal profile pits measuring 200 x 150 cm dug up to 180 cm depth. The profiles were described according to standard guidelines (FAO, 1977). Soil examples were collected from the genetic horizons.

Laboratory Analysis

The soil samples were air dried, crushed and passed through 2 mm sieves for physical and chemical analysis. Particle size distribution was determined using the modified hydrometer method (Bouyoucous, 1951). Soil pH was measured electrometrically in water at 1: 1 soil to liquid (weight/volume) ratio. Organic carbon was determined by the Walkley-Black wet oxidation method (Allison, 1965) and total nitrogen was obtained by the micro-Kjeldahl method (Bremner, 1996). Available phosphorus were extracted with Bray-1solution and the P were determined using the ammonium molybdate-blue method (Bray and Kurtz, 1945). Exchangeable cations (Ca, Mg, K and Na) were extracted with neutral, normal ammonium acetate solution. Calcium (Ca) and Mg were determined by atomic absorption spectrophotometry while K and Na were determined by flame emission photometry. Exchangeable acidity was extracted with a molar solution of KCl and determined titrometrically. Effective cation exchange capacity, exchangeable sodium saturation and based saturation were calculated. Extractable micronutrients namely: copper (Cu), zinc (Zn), iron (Fe) and manganese (Mn) were extracted with 0.1M solution of HCl and the concentrations determined by atomic absorption spectrophotometer.

Soil Classification

Taxonomic classification of the soils which has been reported (Orimoloye et al., 2015) was done according to USDA soil Taxonomy (Soil Survey Staff, 2010) and World Reference Base (WRB) for soil resources (FAO/IUSS/ISRC 2006). The soils were placed into their various Fertility capability class using the Sanchez et al (2003) using the criteria in Fertility capability Classification version 4 (Table 1).

Results And Discussions

Surface soil properties

The physical and chemical properties of the nine representative pedons of the study area are presented in Table 2. Mapping units DRG-A and DRG-B are in the seasonally flooded plains mapping unit B is fairly better drain, mapping units DGR-C, DGR-E,DGR-F and DGR-G are well drained soils, mapping unit DGR-D is very gravelly and is characterized by a rolling mountain ridge with quartzite and ironstone boulders which would not support agricultural activities like planting. Mapping unit DGR-H is a poorly drained soil with features of a backswamp in the floodplains with remarkably distinct red mottles. Mapping unit DGR-I is on clayey lowlands of the floodplains and well supplied with moisture from seasonal overflows from the major rivers though could be said to be fairly well drained with the water table below the profile depth at the time of this study.

Textural properties of the soils (Table 2) revealed that soils of the lowlands exhibit more clayey surface soils than those at the upper slopes. The variation in the composition of the soil separates within the soil profiles and across the landscapes to a large extent reflect the variation in the parent materials.

The surface soils of the area is comprised majorly of loamy sand and sandy loam in the upland areas formed on colluvial and sedentary parent materials. More clayey (sandy clay loam and clay) surface soils are obtained in areas characterized by the lowlands and appears to be a feature originating from the depositional events in the alluvial environment. This illustrates the inherent heterogeneity associated with soils of the floodplains especially when a large scale area is covered (Uzu *et al*, 2007).

The physical impact of soil physical properties on the potentials of these soils for agricultural use will be two fold; first is the difference in the ability of the soils to retain water and nutrients as observed in the drainage state of the soils of the area. Topography affects drainage water and therefore is one of the critical factors in the development of different soils within a given locality (Pai *et al.,* 2007). Apart from the seasonal overflow of the rivers that could predispose the soils of the lowlands to seasonal flooding, some of the waterlogging conditions in the lowlands was occasioned by the clayey surface in comparison to the more well drained soils on the higher elevations. Secondly, the workability and additional tillage cost may be incurred when dealing with soils with higher clay contents on the surface. It has been noted that clay is involved in almost every reaction in soils which affects plant growth. Both chemical and physical properties of soils are controlled to a very large degree by type, content and properties of clay (Raheb and Heidari, 2012). Some of the chemical properties also vary along the physiography. All soils were acidic and their pH increased with depth due to extensive leaching and removal of basic cations from the upper horizons. The pH ranged from 5.9 in DGR-G at the summit which is acceptable to most crops to pH 3.7 on mapping unit DGR-H which has the lowest pH and that is too acidic for some crops. Though the soils has adequate organic carbon which would promote effective growth of plants and also an acceptable amount of nitrogen and phosphorus, Organic carbon was higher in the surface layers and decreased regularly with depth. Contrary to the observations of Takyu *et al*. (2002) and Tsui *et al.* (2004) that organic carbon content, available N and K, extractable Fe and exchangeable Na were the highest in the summit soils, the distribution of nutrients in this study area did not particularly follow physiographic locations of the land. This is most likely due to the depositional nature of the sediments of the floodplains. However it was observed that most of the soils were low in potassium (K) which is an important plant nutrient and need for the development of most arable crops.

Table 1: Fertility capability soil classification system, version 4 (Sanchez *et al.,* 2003)

FCC class and short description	Symbol	Definitions and some interpretations
Type: texture is the average of plow layer or 0 –20 cm depth, whichever is shallower	S	Sandy topsoil: loamy sands and sands
	L	loamy topsoil: < 35% clay but not loamy sand or sand
	C	clayey topsoil: >35% clay
	O	organic soil: >12% organic C to a depth of 50 cm or more (histosols and histic groups)
Substrata type: used if textural change is encountered within top 50 cm	S	sandy subsoil: texture as in type
	L	loamy subsoil: texture as in type
	C	layey subsoil: texture as in type
	R	rock or other hard root-restricting layer within 50 cm
	R^-	as above, but layer can be ripped, plowed or blasted to increase rooting depth
Condition modifiers: in plowed layer or top 20 cm, whichever is shallower, unless otherwise specified; grouped into modifiers related to soil physical properties, soil reaction (pH), soil mineralogy and soil biological properties.		
Modifiers related to soil physical properties Waterlogging (gley): anaerobic condition, chemical reduction, denitrification; N_2O and CH_4 emissions	G	aquic soil moisture regime; mottles < 2 chroma within 50 cm for surface and below all A horizons or soil saturated with water for >60 days in most years
	g+	prolonged waterlogging; soil saturated with water either naturally or by irrigation for >200 days/year with no evidence of mottles indicative of Fe3 + compounds in the top 50 cm; includes paddy rice soils in which an anaerobic crop cannot be grown without drainage; continuous chemical reduction can result in slower soil N mineralization and Zn deficiencies in rice
Strong dry season (dry): limits year-round cropping, interrupts pest cycles, Birch effect	D	ustic or xeric soil moisture regime: dry >60 consecutive days/year but moist >180 cumulative days/year within 20– 60 cm depth
	d^+	aridic or torric soil moisture regime: too dry to grow a crop without irrigation
Low soil temperatures	T	cryic and frigid (< 8 jC mean annual), non-iso soil temperature regimes, where management practices can help warm topsoils for short-term cereal production
	t^+	permafrost within 50 cm gelisols; no cropping possible
Gravel/ rock outcropping	r^+	r+ = 10–35%
	r^{++}	r r+ +z35% (by volume) of gravel size coarse fragments (2– 25 cm in diameter) anywhere in the top 50 cm of the soil
	r^{+++}	more than 15% rock outcroppings
Slope	%	Where desirable place range in % slope (i.e., 0–15%; 15–30%; >30%)
High erosion risk	SC, LC, CR, LR, SR, >30%	soils with high erodibility due to sharp textural contrasts (SC, LC), shallow depth (R) or steep (>30%) sloper455
Modifiers related to soil reaction Sulfidic (cat clays)	C	pH < 3.5 after drying; jarosite mottles with hues 2.5Y or yellower and chromas 6 or more within 60 cm sulfaquents, sulfaquepts, sulfudepts
	A	>60% Al saturation within 50 cm, or < 33% base saturation of

		CEC (BS7) determined by sum of cations at pH 7 within 50 cm, or < 14% base saturation of CEC (BS8.2) by sum of cations at pH 8.2 within 50 cm, or pH < 5.5 except in organic soils (O)
	a^-	10–60% Al saturation within 50 cm for extremely acid-sensitive crops such as cotton and alfalfa
No major chemical limitations (includes former h modifier)	No symbol	< 60% Al saturation of ECEC within 50 cm and pH between 5.5 and 7.2
Calcareous (basic reaction): common Fe and Zn deficiencies	B	free CaCO3 within 50 cm (fizzing with HCl), or pH>7.3
Salinity	S	>0.4 S m_ 1 of saturated extract at 25 jC within 1 m; salids and salic groups; solonchaks
	s^-	0.2– 0.4 S m_ 1 of saturated extract at 25 jC within 1 m (incipient salinity)
Alkalinity	N	>15% Na saturation of ECEC within 50 cm; most solonetz
	n^-	6 –15% Na saturation of ECEC within 50 cm (incipient alkalinity)
Modifiers related to soil mineralogy		
Low nutrient capital reserves (K deficiencies)	K	< 10% weatherable minerals in silt and sand fraction within 50 cm, or siliceous mineralogy,or exchangeable K < 0.20 cmolc kg_ 1 soil, or exchangeable K < 2% of sum of bases, if sum of bases is < 10 cmolc kg_ 1 soil
High P fixation by Fe and Al oxides (>100 mg kg_ 1 P added to achieve adequate soil test levels); Ci soils have excellent structure but low water holding capacity; Ci subsoils retain nitrates	I	dithionite-extractable free R2O3: clay ratio >0.2, or >4% citrate dithionite-extractable Fe in of topsoil, or oxisols and oxic groups with C type, or hues redder than 5YR and granular structure
Modifiers related to soil mineralogy	i^-	as above, but soils have been recapitalized with P fertilizers to supply long-term P to crops; soil test >10 mg kg_ 1 P by Olsen method
	i^+	as above; potential Fe toxicity if soils waterlogged for long time (g+) or adjacent uplands have i modifier
Amorphous volcanic (X-ray amorphous); high P fixation by allophane (>200 mg kg_ 1 P added to achieve adequate soil test levels); low N mineralization rates	X	within 50 cm pH>10 (in 1 M NaF), or positive to field NaF test, or andisols and andic subgroups, except vitrands and vitric great groups and subgroups; other indirect evidences of allophane dominance in the clay size fraction, or >90% P retention (Blakemore et al., 1981 method)
	x^-	P retention between 30% and 90%; medium P fixers
Cracking clays (vertic properties): very sticky plastic clay, severe topsoil shrinking and swelling	V	>35% clay and >50% of 2:1 expanding clays, or coefficient of linear expansibility >0.09 or vertisols and vertic groups
High leaching potential (low buffering capacity, low ECEC)	E	< 4 cmolc kg_ 1 soil as ECEC, or < 7 cmolc kg_ 1 soil by sum of cations at pH 7, or < 10 cmolc kg_ 1 soil by sum of cations +Al3 ++H+ at pH 8.2
Modifier related to soil biological properties (new)		
Low organic carbon saturation (soil organic matter depletion, C sequestration potential)	M	< 80% total organic C saturation in the topsoil (Van Noordwijk et al., 1998) compared with a nearby undisturbed or productive site the same soil, which is equal to 100% or < 80% 333 mM KMnO4-extractable topsoil organic carbon saturation (Blair et al., 1997) compared with a nearby undisturbed or productive site of the same soil, which is equal to 100%

Table 2: selected physical and chemical characteristics of the soil mapping units of Dangerri study area

Mapping Units	location	Soil name USDA	Soil name WRB	Horizon	Depth (cm)	Sand	Silt	Clay	Texture	pH (H_2O)	Org.C	Total. N	Av.P $mgkg^{-1}$	ExchK	ECEC	B.Sat
						$g\ kg^{-1}$					$g\ kg^{-1}$			$cmol\ kg^{-1}$		(%)
DGR-A	Lower slope /Valley	Fluvaquentic Eutrudept	Gleyic Fluvisol	A	0-17	100	240	660	C	5.0	15.52	1.32	3.14	0.38	6.82	96.33
				B	17-43	160	200	640	C	4.6	11.49	1.14	1.87	0.05	4.47	86.58
				Bg	43-76	160	120	720	C	4.5	8.06	1.03	1.52	0.09	5.42	83.76
DGR-B	Valley bottom	Fluventic Eutrudept	Haplic Fluvisol	A	0-11	200	500	300	CL	4.9	27.61	1.45	8.59	0.23	13.26	98.04
				AB	11-25	200	360	440	C	4.9	7.66	1.18	2.08	0.07	15.21	98.29
				B1	25-50	100	360	540	C	5.1	4.23	1.58	2.25	0.07	17.90	97.32
DGR-C	Middle slope	Kanhaplic Haplaustalf	Haplic Lixisol	A	0-28	800	60	140	SL	5.4	9.47	24.34	4.97	0.16	12.47	97.75
				ABt	28-44	740	60	200	SCL	5.1	13.90	12.38	12.09	0.05	14.74	98.64
				Bt1	44-66	760	40	200	SCL	5.1	4.84	9.03	11.54	0.06	13.93	98.28
DGR-D	Hill crest	Lithic Haplustept	Leptic Cambisol	Ac	0-21	760	120	120	SL	5.9	26.60	2.19	30.60	0.28	12.35	98.22
				Ac	21-49	730	110	160	SL	5.6	11.69	1.57	7.30	0.18	10.62	97.74
				BC1	49-79	560	120	320	SCL	4.5	7.46	1.76	3.97	0.17	13.78	89.40
DGR-E	Upper/ middle slope	Typic Kanhaplaustalf	Haplic Lixisol	A	0-32	820	120	60	LS	4.9	5.84	1.36	18.93	0.04	5.18	92.28
				AB	32-55	800	130	70	SCL	4.9	3.43	1.29	22.11	0.02	1.60	87.50
DGR-F	Upper slope	Rhodic Haplaustalf	Nitic Lixisol	A	0-16	860	70	70	LS	5.4	20.35	0.57	20.35	0.07	3.67	95.10
				AB	16-39	830	70	200	LS	5.6	24.12	0.55	24.12	0.04	2.23	86.55
				Bt1	39-68	750	20	230	SCL	5.2	6.16	0.67	6.16	0.06	3.52	90.91
DGR-G	Middle slope	Arenic Haplaustalf	Vetic Lixisol	A1	0-20	870	60	70	LS	5.0	7.05	0.96	6.25	0.06	2.66	93.22
				A2	20-32	870	60	70	LS	5.4	2.82	1.13	4.47	0.09	1.93	89.64
				B1	32-56	850	90	60	LS	5.5	2.42	1.02	4.56	0.05	1.28	81.25
DGR-H	Back swamp	Aquic Dystrudept	Stagnic Fluvisol	A1	0-14	470	200	330	SCL	3.8	21.76	2.58	2.25	0.09	11.76	25.51
				A2	14-28	290	160	550	C	3.7	15.11	1.35	2.00	0.05	12.14	11.04
				B1	28-48	620	110	270	SCL	3.9	4.03	1.35	1.68	0.02	6.20	9.03
DGR-I	Valley bottom	Fluventic Dystrudept	Haplic Fluvisol	A	0-10	210	250	540	C	4.0	31.64	2.64	2.00	0.22	12.52	70.45
				B1	10-50	50	170	780	C	4.5	6,45	1.45	1.60	0.07	20.16	53.37
Miscellaneous	Marsh/water	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 3: Classification of the soils of Dangerri study area into FCC Units

Pedon/ Soil type	Type	Sub Type	Condition modifiers r	e	g	k	m	n	FCC Class	Size (%)	Interpretation	Management options
DGR-A	C	_	_	*	_	*	_	_	Cek	19.36	Clayey topsoil, and exchangeable K <2% deficiency, low ECEC.	Appropriate tillage and fertilizer application
DGR-B	L	C	_	*	_	*	m	n^-	$LCekmn^-$	4.75	Loamy topsoil,<35% clay, K deficiency, low organic carbon, low ECEC, >15% Na saturation within 50cm.	Fertility management preferably with organic fertilizers
DGR-C	L	_	_	*	_	*	*	*	Lekmn	4.95	Loamy top soil K deficient, >15% Na saturation of ECEC, high organic carbon.	Appropriate fertilizer application.
DGR-D	L	R	r^{+++}	_	_	*	_	_	$LRr^{+++}k$	15.02	Loamy subsoil, K deficient, hard root restricting layer,>15% rock outcropping, low ECEC.	Non-arable due to high gravel content and rock outcrop. Could be used for recreation or animal rearing
DGR-E	L	_	_	*	_	*	_	n	Lekn	7.24	Loamy topsoil, K deficient,>15% Na saturation ECEC.	Application of organic soil amendments
DGR-F	L	_	_	_	_	*	_	*	Lkn	4.72	Loamy topsoil, K deficient,>15% Na saturation ECEC.	Application of appropriate fertilizers
DGR-G	L	_	_	*	*	_	_	_	Leg	5.60	Loamy topsoil, low CEC and risk of waterlogging	Drainage, liming and application of soil amendments
DGR-H	L	C	_	*	*	*	*	*	LCegkmn	8.53	Loamy/ clayey loam topsoil, low ECEC, waterlogged, K deficient, high organic carbon.	Appropriate tillage, drainage, liming and fertility management
DGR-I	C	_	_	*	_	*	_	*	Cekn	7.99	Clayey topsoil, low ECEC, K deficient.	Tillage, liming and fertilizer application
Miscellaneous	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	22.01	Inaccessible Marshy/ waterlogged during the field survey	Drainage, or could be exploited for aquaculture

FCC Classification of soil units

The allocation of the representative pedons/mapping units into various FCC units according to the Sanchez *et al* (2003) Fertility Capability Classification system are shown in Table 3. FCC units are according to the fertility related limitations. DGR-A and DGR-I are characterized by clayey starata types and subtypes which will require appropriate tillage before most arable crops can be planted. DGR-B and DGR-H have somewhat clayey sub-types below sandy clay loam surface soils which also requires proper tillage for most crops. These lowland soils are somewhat poorly drained and will in addition to tillage require drainage operations otherwise, cropping could be restricted to the seasons of the year when there is less moisture from precipitation and when the Rivers Niger and Benue are not likely to be flooded. However, if perennial high value crops like sugarcane (which is being proposed for the area) is to be grown, then flood control measures and structures need to be in place. Apart from the high rainfalls experienced in certain times of the year, there are and Benue have major dams like Kainji and Jebba on River Niger as well as Lagdo (Cameroun) on the Benue which may release excess waters ocassionally and crop losses due to flooding may occur. DGR-C, DGR-E, DGR-F and DGR-G are not prone to flooding. They are well drained and have loamy starata types. Cost of tillage would be less but they are less fertile than the soils of the floodplains. DGR-D is however characterized by shallow soils with intermittent boulder rubbles and outcrops of the laterite capped sandstones. This unit is considered non-arable and could be used to build farm houses, cattle ranch or other farm infrastructures. It could also be developed for recreation purposes.

Almost all the soils except mapping units have been under fallow at the time of this study and all are found to be deficient in potassium (K) reserves. This is probably because the K is a soluble nutrient which can easily be leached by the excess water in the lowlands while the sandstones which are the parent rock of the upland soils is inherently low in K (Ojanuga, 2006). Gleying properties were observed in DGR-H and DGR-I in addition to acidic soil reactions that may necessitate liming when acid sensitive crops are being considered. On the alternative, since DGR-A, DGR-H and DGR-I are acidic, with enough clay content on the surface and are prone to water-logging, swamp rice (*Oryza sativa*) which is acid tolerant and can thrive well in hydromorphic conditions could be considered as alternative crops in these mapping units.

Conclusion

The soils in the Dangerri study area with the exception of mapping unit DGR-D are mostly arable if some degrees of nutrient deficiencies and soil physical conditions they have are properly managed. The main limitations are low K reserve, low ECEC, poor drainage and some heavy surface texture. Nutrient deficiencies can be corrected with appropriate organic and inorganic fertilizers. Other management strategies such as drainage, flood control, liming and possibly sub-soiling would mitigate the major limitations to crop production in this area. Arable crops and vegetables that are acid tolerant could be cultivated in this area. Mapping unit DGR-D though has a loamy topsoil, but is highly rocky with unfavourable slope gradients and surface gravel concentration is non arable and may be considered for other uses. Application of potassium (K) rich fertilizer and drainage practices would be encouraged for healthy performance of many arable crops in the Dangerri development area.

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