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CAPABILITY AND SUITABILITY EVALUATIONS OF *FADAMA* SOILS FOR SELECTED CROPS IN THE NIGERIAN SUDAN SAVANNA

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ABSTRACT

Capability and suitability of *fadama* soils for selected crops at Yayu, Gwasamai and Alamari in Katagum Local Government Area (LGA) of Bauchi State were evaluated as a case study of the similar soils in Nigerian Sudan savanna. Soil samples from each identified genetic horizons of profile pit at each site were analysed for some physico-chemical properties. For evaluation, the fertility capability classification (FCC), index of capability (IC) and land suitability classification (LSC) using the limiting condition principle were compared. Results showed that while the FCC and LSC gave similar and more acceptable evaluations, the IC tended to underscore (1.30-3.46%) the capability of soils. The fadama soils at Yayu, Gwasamai and Alamari were classified as Lcge, Leh and Lcegh, respectively using the FCC and found moderately suitable (S2) for all the crops considered. The exceptions were rice and sugarcane at Yayu, and maize at Alamari for which the soils were marginally suitable (S3). Based on the present suitability assessments, maize, wheat and onion cultivation could be suggested for the *fadama* land at Yayu, maize and/or onion for that at Gwasamai, and maize, rice and sugarcane for that at Alamari. Organic manuring to improve the CEC, nutrient status and drainage is suggested. Liming of the soils at Gwasamai and Alamari could be beneficial.

KEY WORDS: Capability; Suitability; *Fadama*; Sudan savanna

INTRODUCTION

The *fadama* land is more productive, greater in agricultural potential, higher in sale value and strikingly different in its ecology and microclimate than the adjacent upland (Singh and Babaji, 1990; Singh, 1997). While Scoones (1992) described the *fadama* as "wetland in dryland", Amborg (1988) called it "a garden, a little paradise" in the vast semi-arid northern Nigeria. Due to characteristic moisture (residual and underground) retention within the rhizosphere for most part of the year, the *fadama* land is cultivated to a host of agronomic and horticultural (vegetables and fruits) crops year round. Due to the attributes described above, *fadama* lands are gaining a lot of popularity among farmers. Consequently, many studies related to physico-chemical properties and/or fertility evaluations of various *fadama* soils (Kparmwang and Esu, 1990; Kparmwang, 1996; Singh, 1997) were undertaken with a view to understand and utilize them better. Results of such evaluations play vital roles in communication of soil information among soil scientists and in evolving ways and means of harnessing the agricultural potential of *fadama* land better.

However, to many farmers, some of these technical information are of no value as they are more interested in the response of soils to management and manipulations (Ogunkunle and Babalola, 1986). Therefore, for the soil information to be useful to farmers, it must be translated into units of practical implication. Capability and suitability assessments provide such information.

Land (capability and suitability) evaluation involves the collection and interpretation of inventories of soil, vegetation, climate and other aspects of land in order to identify and make comparisons of, at least, an optimal and sustained use as well as management alternatives in a known socio-economic setting (ITC, 1979; FDLAR, 1982). Land evaluation, therefore, serves as a tool for proper, judicious and more efficient use of land/soil (Mustapha *et al.*, 2001).

With this realization, the present study was undertaken with the objective of evaluating the capability and suitability for maize, wheat, onion, and rice as well as sugarcane of the *fadamas* at Yayu, Gwasamai and Alamari in Katagum LGA of Bauchi State, Nigeria as a case study of the *fadama* soils in Sudan savanna agroecology of Nigeria.

MATERIALS AND METHODS

The Study Areas

The Yayu, Gwasamai and Alamari areas are situated within the Sudan savanna agroecology in the Katagum LGA (Latitude11° 30′-12° 00′ N, Longitude 9° 30′-10° 35′ E) in the northern part of Bauchi State. The climate of the areas is divided into distinct wet (June-September) and dry (October-May) seasons. The annual rainfall averages about 700 mm while the soil temperature regime is rated isohyperthermic (has little variation in soil temperatures which are high all year round at 50 cm depth). The arable land consists of vast upland and some *fadama* land. While the upland soils belong mostly to the Orders Ultisol and Alfisol, the *fadama* soils are mostly Inceptisols and Entisols. The major crops grown in the areas include sorghum, millet and cowpea in the upland, and rice, wheat and vegetables in the *fadama*.

Soil Sampling and Handling

A profile pit (1.0 x 1.5 x 2.0 m or to a lithic or paralithic contact zone) was dug in each of the three *fadama* locations. Soil samples were taken from each identified genetic horizons, dried in air, ground using a porcelain pestle and mortar and passed through a 2-mm sieve.

Laboratory Analyses

The processed soil samples were analysed for the physico-chemical properties included in Table 1 following the procedures described by Page *et al.* (1982). Particle-size analysis was performed by the Bouyoucos hydrometer method after dispersing the soil with 1*N* sodium hexametaphosphate and the textural class determined using the United States Department of Agriculture (USDA) textural class triangle. Soil pH was determined potentiometrically in 1:1 soil-water suspension. The organic carbon (C), total nitrogen (N) and available phosphorus (P) were respectively determined by the Walkley-Black wet combustion, macro-Kjeldahl and Bray-1 methods. Cation exchange capacity (CEC) was determined by the ammonium saturation method using neutral ammonium acetate solution. The filtrate from the CEC determination was saved and analysed for calcium (Ca) and magnesium (Mg) on the atomic absorption spectrophotometer as well as for potassium (K) and sodium (Na) on a flame photometer. Total exchange acidity (TEA) in the filtrate was estimated by NaOH titration.

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Table 1. Physico-chemical properties of some *fadama* soils in Katagum LGA, northern Bauchi State, Nigeria

Location	Depth (cm)	Horizon	pH (water)	Org. C. (gkg^{-1})	Avail. P. ($mgkg^{-1}$)	Exchangeable bases ($cmol(+)\ kg^{-1}$) Ca	Mg	Na	K	TEA	CEC	Total N	BS	Sand	Silt	Clay	Texture
													%				
Yayu	0-15	Ap	6.13	9.6	7.5	1.95	0.6	0.1	0.4	0.60	3.74	0.07	82	35.4	46.7	17.9	L
	15-33	Bt1	6.14	11.6	6.5	2.27	0.5	0.1	0.6	0.56	4.36	0.13	80	41.4	20.7	37.9	CL
	33-63	Bt2	6.17	7.6	6.2	1.67	0.6	0.1	0.3	0.65	3.45	0.10	78	39.4	24.7	35.9	CL
	63-81	Bt3	6.20	7.8	3.4	1.66	0.6	0.1	0.5	0.86	4.24	0.07	68	51.4	26.7	21.9	SCL
	81-156	B4	6.19	7.4	3.2	2.11	0.6	0.1	0.4	0.85	4.82	0.10	67	71.4	12.7	15.9	SL
Gwasamai	0-14	Ap	5.60	12.5	6.8	1.56	0.6	0.1	0.4	0.97	3.62	0.03	74	68.6	6.2	25.2	SCL
	14-31	Bt1	5.78	11.2	5.2	2.30	0.4	0.1	0.4	0.95	4.24	0.24	76	66.6	4.2	29.2	SCL
	31-61	B2	5.82	10.1	5.4	2.29	0.5	0.1	0.1	0.92	3.86	0.17	78	48.6	28.2	23.2	SCL
	61-83	B3	5.85	9.3	2.2	1.67	0.6	0.1	1.2	0.98	4.99	0.17	72	30.6	46.2	23.2	L
	83-128	B4	5.98	11.5	3.2	1.46	0.7	0.1	0.8	0.96	5.14	0.10	65	50.6	32.2	17.2	L
Alamari	0-16	Ap	5.60	12.0	8.2	1.81	0.6	0.1	0.9	0.73	4.33	0.13	78	52.1	22.7	25.2	SCL
	16-46	Bt1	4.99	9.0	6.0	2.21	0.3	0.01	0.8	0.99	4.76	0.13	70	46.1	10.7	42.2	SC
	46-76	Bt2	5.02	11.2	5.0	2.25	0.4	0.2	0.7	0.85	4.72	0.07	75	50.1	18.7	31.2	SCL
	76-106	B3	4.95	9.6	5.0	1.60	0.5	0.1	0.8	0.97	4.17	0.07	72	42.1	30.7	27.2	CL
	106-142	Bt4	5.05	11.6	3.2	2.24	0.4	0.1	0.6	0.83	4.28	0.03	78	52.1	10.7	37.2	SL

Texture: L=Loam ; CL= Clay loam; SCL= Sandy clay loam; SL= Sandy loam; SC= Sandy clay; CL= Clay loam

Table 2. Fertility capability classification of some *fadama* soils in Katagum LGA, northern Bauchi State, Nigeria

Location	Horizon	Type	Modifiers	FCC	Interpretation
Yayu	Topsoil	L			Good water-holding capacity, medium infiltration capacity, removal of the surface soil by erosion or other means will expose a clayey textured subsoil; drainage limited and tillage operations and some crops may be adversely affected unless drainage is improved; low ability to retain nutrients, requires supplementary application of nutrients.
	Substrata	C	ge	LCge	
Gwasamai	Topsoil	L			Good water-holding capacity, medium infiltration capacity; low ability to retain nutrients and may require split application of major plant nutrients; may require liming for acid sensitive crops.
	Substrata	L	eh	Leh	
Alamari	Topsoil	L			Good water-holding capacity, medium infiltration capacity; removal of surface soil by any means will expose undesirable clay-textured subsoil; low ability to retain nutrients, may require supplementary application of nutrients; drainage limited and tillage operation and some crops may be adversely affected unless drainage is improved; may require liming for acid-sensitive crops.
	Substrata	C	egh	LCegh	

Capability Assessments

The FCC and IC systems were employed for assessing the capability of the soils for rainfed and irrigated agriculture based on their soil physico-chemical properties. The FCC system evaluates the fertility/fertility limitations other than N deficiency (Sanchez *et al.*, 1982). The system recognizes three categories: Type, Substrata type and Modifiers. The Type evaluates the texture of plough layer or surface 20cm, whichever is shallower and assigns 'S' to sandy topsoils (loamy sands and sands), 'L' to loamy topsoils (<35% clay but not loamy sand/sand), 'C' to clayey topsoil (>35% clay), and 'O' to organic soil (>30% organic matter to a depth of 50cm or more). The Substrata type views the texture of the subsoil and assigns 'S', 'L' and 'C' as in the Type, and 'R' to rock or other lithic contacts. The Modifiers, usually in lower case letters such as g=drainage, e=nutrient retention and h=pH, describe the major fertility limitations.

The IC of the *fadama* soils was determined using the method of Sys and Frankart (1971) as modified by Ogunkunle and Babalola (1986). It was determined using the formula:

$$IC\ (\%) = A \times B \times C \times D \times E \times F \times G \times H \times 100$$

where, IC = Index of capability, A = index related to profile development, B = index related to texture, C = topsoil depth, D = drainage, E = base saturation, F = organic matter content of the A horizon, G = CEC of the upper 50cm of A horizon, and H = slope gradient

Suitability Assessment

The suitability of the *fadamas* for maize, wheat, onion, and rice and sugarcane was evaluated using the limiting condition principle. In this method, suitability of the soils was matched with the crop requirements, and a suitability index obtained for the particular factor. Texture, drainage, pH, organic carbon content, base saturation, and soil depth, considered the most important soil factors, were used for the evaluation. The least favourable assessment found limiting was taken as the land suitability class (FAO, 1983).

RESULTS AND DISCUSSION

Capability and suitability assessments were based on the physico-chemical properties of the *fadama* soils included in Table 1.

Fertility Capability Classification

The summary of the FCC for the *fadama* soils in Table 2 indicates that they had good water holding capacity but medium infiltration capacity. This is as a result of the generally loamy texture of the topsoils and the clayey (for Yayu and Alamari) or sandy clay loam texture of the subsoil.

The low CEC values possibly owing to low organic matter (Table 1) and/or presence of low activity clays indicate that the chemical activities, such as the plant nutrients adsorption and retention could be low. The findings further corroborate the earlier reports (Agboola *et al.*, 1997; Fagbami, 1997; Mustapha *et al.*, 2001) that the tropical soils are generally of poor quality because of their low nutrient reserve and low CEC due, in part, to the preponderance of low activity kaolinitic clays and low organic matter. Therefore, the farmers working with these soils are advised to judiciously practice organic manuring and split application of major nutrients (especially N) containing fertilizers.

The presence of clays in the subsoils at Yayu and Alamari (Table 1) could make the area good for the flooded rice. However, hard pans may tend to develop in their subsoil, especially with the use of heavy machineries. Fortunately, such a practice is uncommon presently.

Index of Capability

Table 3 contains the scores for the properties and the overall index of capability for each of the soil units studied. The IC scores were very low ranging from 1.30-3.46%. Among the sites, the IC scores for Gwasamai and Alamari *fadamas* were similar (3.07 and 3.46%, respectively) and higher than that for the Yayu *fadama* (1.30%). It is pertinent to note that the *fadamas* rating low by the IC, rated medium by the FCC. Apparently the IC is more stringent as was also observed by Ogunkunle and Babalola (1986). This calls for further investigation into the applicability of the system so that it may not unnecessarily underscore the capability of soils being evaluated.

Suitability Assessment

The characteristics presented in Table 1 were used in assessing the suitability of the *fadama* soils. The requirements and limits of land characteristics for the crops considered as

Table 3. Index of capability (IC) scores for some *fadama* soils in Katagum LGA, northern Bauchi State, Nigeria

Factor*	Score for the *fadama* unit at		
	Yayu	Gwasamai	Alamari
A	1.0	1.0	1.0
B	0.9	0.8	0.9
C	1.0	1.0	1.0
D	0.6	0.8	0.8
E	1.0	1.0	1.0
F	0.2	0.4	0.4
G	0.2	0.2	0.2
H	0.6	0.6	0.6
IC(%)	1.30	3.07	3.46

***Factor:** A = index related to profile development, B = index related to texture, C = topsoil depth, D = drainage, E = base saturation, F = organic matter content of the A horizon, G = CEC of the upper 50cm of A horizon, H = slope gradient.

Table 4: Rating of land use requirements for maize, wheat, groundnut, onion, rice and sugarcane

Soil characteristics	Rating S1	S2	S3	N
Maize				
Texture	sl,scl	sicl,cl	si,sl,sc	hc,ls,s
Drainage	WD	MWD	ED	VPD
pH(1:1 water)	6.5-7	5.8-6,7-7.5	5.5-5.8	<5.5,>8
CECcmol(+)kg^{-1}	>12	9-12	5-8	<5
Org C. (gkg^{-1})	>10	10-5	5-2	<2
BS (%)	>50	50-30	30-20	<20
Soil depth (cm)	>120	50-120	30-50	<30
Wheat				
Texture	l,cl,sil	c,scl	si,ls	sl,cs
Drainage	WD	MWD	SPD	VPD
pH(in water)	6-8.2	5-6,8.2-8.3	5.2-5.6,8.3-8.5	<5.2,>8.5
CEC(cmol(+)kg^{-1}	>10	10-5	5-2	<5
Org. C.(gkg^{-1})	>50	50-35	35-20	<2
BS (%)	>100	70-100	40-70	<20
Soil depth (cm)	>100	70-100	40-70	<40
Ec (ds/m)	0-3	3-5	5-6	>6
ESP (%)	0-20	20-35	35-45	>45
Onion				
Texure	L,sc,scl	c	s	Si,hc
Drainage	WD	MWD-SPD	PD	VPD
pH(in water)	6-7.8	5.8-6,7.8-8.0	5.5-5.8,8.0-8.2	<5.5,>8.2
CEC(cmol(+)kg^{-1}	>20	15-20	10-15	<10
Org.C.(gkg^{-1})	>12	12-8	8-5	<5
BS (%)	>35	35-25	25-20	<20
Soil depth (cm)	>100	70-100	40-70	<40
Rice/ Sugarcane				
Texture	c,sc,sic	L,scl,cl	hc	S
Drainage	PD,VPD	MWD,SPD	WD	VWD,ED
pH(in water)	5.5-7.5,7.5-7.8	4.5-5.5,7.8-8.0	4-4.5,>8.0	<4.0
CEC(cmol(+)kg^{-1}	>12	9-12	5-8	<5
Org. C(gkg^{-1})	>15	10-15	5-10	<5
BS (%)	>50	50-35	35-20	<20
Soil depth (cm)	>100	70-100	40-70	<40
Ec (ds/m)	0-2	2-4	4-6	>6
ESP (%)	0-20	20-30	30-40	>40

Texture: sl= sandy loam, sicl=silty clay loam, cl= clay loam, si= silt, sc= sandy clay, hc= heavy clay, ls= loamy sand, s= sand, l= loam, sil= silty loam, cs= coarse sand, c= clay, scl= sandy clay loam, sic= silty clay.

Drainage: WD= Well-drained, MWD= Moderately well-drained, FD= Fairly-drained, SPD= Slightly poorly-drained, PD= Poorly-drained, ED= Excessively-drained.

Rating: S1= Suitable, S2= Moderately suitable, S3=Marginally suitable, N=Not suitable.

given in Table 4 were adapted from FAO (1976), Yayock *et al.* (1988) and Sys *et al.* (1993).

The suitability classification rating given in Table 5 show that the *fadama* soil at Yayu was moderately suitable (S2) for all the crops considered except rice and sugarcane for which it was marginally suitable (S3). Moderately poor drainage and low organic matter, both rating s2, were the dominant factors responsible for lowering the overall crop suitability ratings of *fadama* soil at Yayu to S2.

The *fadama* at Gwasamai was rated marginally suitable (S3) for wheat and moderately suitable (S2) for all the other crops considered. The Gwasamai *fadama* soil is best suited for maize and onion production. The drainage (s2) and pH (s2-s3) were the dominant limiting conditions. An improvement in their conditions may enhance the suitability rating.

The *fadama* at Alamari was rated moderately suitable (S2) for all the crops considered. Drainage and pH, both rating s2, appear to be limiting factors for maize, wheat and onion production. Besides these, the texture (s2) may pose problem in wheat production. The limiting conditions for rice and sugarcane are soil texture and drainage, both rating s2.

Table 5. Suitability classification of some *fadama* soils in Katagum LGA, northern Bauchi State using the limiting condition principle

Soil property	*Fadama* location		
	Yayu	Gwasamai	Alamari
Maize			
Texture	s1	s1	s1
Drainage	s2	s2	s2
pH (in water)	s1	s2	s2
Organic C.	s2	s1	s1
Base saturation	s1	s1	s1
Soil depth	s1	s1	s1
Overall suitability	**S2**	**S2**	**S2**
Wheat			
Texture	s1	s2	s2
Drainage	s2	s2	s2
pH (in water)	s1	s3	s2
Organic C.	s2	s1	s1
Base saturation	s1	s1	s1
Soil depth	s1	s1	s1
Overall suitability	**S2**	**S3**	**S2**
Onion			
Texture	s1	s1	s1
Drainage	s2	s2	s2
pH (in water)	s1	s2	s2
Organic C.	s2	s1	s1
Base saturation	s1	s1	s1
Soil depth	s1	s1	s1
Overall suitability	**S2**	**S2**	**S2**
Rice and Sugarcane			
Texture	s2	s2	s2
Drainage	s2	s2	s2
pH (in water)	s1	s1	s1
Organic C.	s3	s2	s2
Base saturation	s1	s1	s1
Soil depth	s1	s1	s1
Overall suitability	**S3**	**S2**	**S2**

However, drainage may not be much of a problem for lowland rice.

CONCLUSION AND RECOMMENDATIONS

Of the two systems of land capability assessment, the Fertility Capability Classification (FCC) put the *fadamas* in medium while the Index of Capability (IC) in low category. The latter appears to have underscored the capability rating and is possibly more stringent.

With respect to suitability for crops like maize, wheat, onion, rice and sugarcane, the Land Suitability Classification (LSC) placed the *fadamas* in the moderately suitable (S2) category. Exceptions were rice and sugarcane at Yayu and wheat at Gwasamai for which the soils were found to be marginally suitable (S3). Drainage and pH rated s2 for maize, wheat and onion; therefore, they could be major limiting factors in their production. Soil texture may be a limiting factor for wheat at places. Similarly, soil texture and drainage could be limiting in rice and sugarcane production in some areas.

The low organic carbon and cation exchange capacity of the *fadama* soils suggest low plant nutrients availability and retention capacities. Thus there is a need for organic manuring. This will not only improve the nutrient supply capacity, but will also increase the CEC.

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