Soil suitability evaluation of floodplain soils for rice production in Abi Local Government Area of Cross River State

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Abstract- Soils from the floodplain of Abi local Government Area were evaluated. Three profile pits where dug and denoted as AFAFP, EDIFP and IMAFP soil units and samples carefully collected from the horizons into polythene bags for analysis. Parametric and non-parametric methods were used for the suitability evaluation of the soils. The physico-chemical properties showed that bulk density was agronomically favourable for the cultivation of rice (<1.8mg/kg). Porosity was low in AFAFP and IMAFP units while EDIFP unit was high. Moisture content was higher in EDIFP than in AFAFP and IMAFP. Particle size analysis showed high sand fraction in all the soil units. The mean value of pH was higher in AFAFP than in EDIFP and IMAFP soil units. The soils were moderately acidic (5.00 – 6.00). The organic carbon content, total nitrogen, CEC and available P were low for rice cultivation. The exchangeable Ca, Na and K were below the critical limits for the production of rice. Exchangeable Mg was within the critical limit for rice cultivation (<0.5 cmol/Kg). The exchange acidity (EA) was high in the soil (>1.5 cmol/Kg). Base saturation was high in all the soil units. For the suitability evaluation of the soil, the result depicted that the climatic conditions of the soils were highly suitable (S1) for rice cultivation. Soil physical characteristics considered were soil depth, texture and drainage. Soil depth was highly suitable (S1) in AFAFP soil unit and moderately suitable (S2) in EDIFP soil unit while in IMAFP it was not currently suitable (N) for rice production. The soil texture was moderately suitable (S2) in AFAFAFP and EDIFP soil units and not suitable (N) in IMAFP soil unit. Drainage (wetness) was highly suitable (S1) for rice cultivation. For soil fertility characteristics (f), pH was moderately suitable (S2) in all the soil units. Organic carbon, total nitrogen and exchangeable K were not currently suitable (N), CEC, available P, exchangeable Ca and Mg were marginally suitable (S3) in all the soil units. Base saturation was moderately suitable (S2) in AFAFP and EDIFP and highly suitable (S1)in IMAFP soil unit. In the parametric and non- parametric methods of assessment based on the current productivity index, the soils were rated as currently not suitable (N) for rice production with aggregate scores of less than 24. The same trend was observed with that of potential productivity index except that of AFAFP soil unit that showed marginal suitable (S3) with an aggregate score of 34. Therefore to obtain maximum production of rice, improvement of the soils by increasing the organic matter level through the incorporation of organic residues such as farmyard manure, plant residues, and household refuse should be done. Also the application of fertilizer and liming rice plots to raise the level of CEC should also be practiced.

Index Terms- suitability evaluation, floodplain, parametric, non-parametric and rice cultivation

I. Introduction

Suitability evaluation of soils is the characterization of soils of any given place or area for a specific land use type or purpose. The information obtained in any survey carried out on the soil enables the development of land use plans, which is used for evaluations and predictions of the effects of the land use on the environment (Rossiter, 1990). For the purpose of evaluating the suitability of any soils for the production of crops, the requirement of the soil for the crop (s) must be ascertained. In addition, these requirements must wholly be known in the light of the shortcomings that are imposed by the land forms and other features which are part of the soil but may have a significant influence on use that can be made of the soil (FAO, 1978). A quick look at the primary requirements of soil for the production of crops, a number of soil characteristics directly related with the performance of crop yield. The soil Suitability evaluations are based on the awareness of the crop requirements, the prevalent conditions of the soil, qualifies in broad terms to what extent soil conditions match the areas. The FAO guideline on the land evaluation system FAO, (1983) and the one developed by Sys et al, (1985, 1991) are commonly accepted and used for evaluation of soil suitability for cultivation of crops. The system is primarily based on combination of several land qualities as related to individual crop requirements. To develop the land use planning, Mongkolsawat and Paiboonsak (2004) depicted that the evaluation of soils or lands has to provide the alternatives with less marking risk. In the evaluation of suitability of the soil for rice cultivation, land units resulting from the overlay operation of the defined land qualities should be established (Mongkolsawat, et al, 2000).

Several efforts have been made by many researchers in many parts of the world to evaluate the suitability of soils for specific and other uses including those of Nigeria with particular reference to Abi soils in Cross River State for crop production. For instance, Ogunkule (1993) evaluated suitability of soil at the site of the Nigeria institute for oil palm research (NIFOR) main station for oil palm cultivation from 12 pedons and classified more than half of the pedons as potentially moderately suitable (S2), and saw particle size as the major shortcomings of the study. Similarly Gbadegesin and Nwagu (1990) carried out the suitability evaluation of soils from the forest and savanna ecological zones of southwestern Nigeria for maize production and noted that 65 percent of the forest zone was fairly suitable to suitable and that the whole of savanna zone were fairly suitable to very suitable. In the other hand Ogunwale et al. (2009) assessed the soil suitability of University of Ilorin farm soils in the Southern guinea savanna ecological zone of Nigeria for cowpea and found out that the topography does not restraint the production of cowpea in Ilorin and its environs. whereas Otomi (2009) evaluated the land use along the course of river Ethiope in Abraka, Delta State and stressed in their study that the suitability of the farmland across the banks of the river for some crops like maize, okro, pumpkin and other vegetable crops was as result of the presence of water in the soil. Agbogidi et al. (2007) in another study demonstrated that soil contaminated with crude oil has a highly significant effect of reducing some mineral element composition of maize. They opined that the suitability of the soil for maize production is minimized as a result of the contamination.

But Udoh et al. (2011) who evaluated two alluvial soils in Akwa Ibom state using both the nonparametric and the parametric methods showed that despite the favorable climatic variables and physical characteristics of the soil in the study area, the soils were not highly suitable for rice cultivation. By the non-parametric method, both potentially and currently, all the soils were marginally suitable (S3) for rice cultivation. But by the parametric method, currently, 12.5% of the pedons were marginally suitable (S3) while 87.5% were not suitable (N1) for rice cultivation. Potentially, 50% of the pedons were marginal (S3) while 50% were not suitable (N1) for rice cultivation. In the same vein Olaleye et al, (2008) assessed the representative pedons at the southwestern part of Nigeria used for rice cultivation and reported that the suitability of the pedons for rice cultivation was between marginal (S3) and not suitable (N1). The major challenges they were noted in the pedons were poor soil texture, which resulted to poor water management in addition to low nutrient contents. They observed that the grain yields gotten from the farmers' showed that the current state of two of the soil series, the grain yield of the two rice cultivars ranged between 0.61 and 2.13 t/ha and decreased gradually upward across the two cropping seasons. Abi Local Government Area is one of the localities highly known for serious cultivation of rice for decades now. Many local farmers in the study area engaged in rice production. Continuous cultivation of rice; reduction in crop yields (rice) as a result of continuous cultivation have been noted in the study area. This has been credited to the unsuitable land use behaviour, lack of plant nutrients, among other factors. Rice requires enough water, organic matter content, pH of 3.1 -6.00, good soil structure and texture (). In Abi environs little attention is given to the proper cultivation and soil requirement of this viable crop. Hence the objective of the study was to evaluate the soils of the floodplain for rice production in Abi Local Government Aea.

II. MATERIALS AND METHODS

2.1 Study area

Abi Local Government Area is a riverine area which lies between latitude 6^0 00’ and 5 45’ N and longitude 8°00 and 08 75’. It shares common boundaries with Yakurr Local Government Area in the east and Abia State at the west, Biase Local Government Area at the south and Ebonyi state at the North (figure 1). The study area has a land mass of 285.17sqkm (Cross River State Ministry of Lands and Survey, 2012). The climate of the study area is equatorial in nature and it is consist of wet and dry seasons with an annual rainfall of about 2500mm, annual temperature of about 29°C and a relative humidity of about 60 percent.

2.2 Methodology

Three profile pits were dug for the study and designated has soil units AFAFP, EDFP and IMAFP. Soil samples were collected from genetic horizons of the profile pits for physico-chemical and suitability evaluation. The soil samples were subjected to the standard routine procedures described by Page, Miller and Keeney, (1983), Jou, (1983) and Klute ((1986). For the suitability assessment, non-parametric and parametric methods were used for the evaluation (FAO, 1976, Sys 1985) and also adopted one from Olaleye et al, (2002). For the non-parametric evaluation, the soils were initially placed in suitability classes by matching their characteristics with the established requirements for rice respectively (Ibrahim, Aliyu, Sabo and Yusuf, 2018). The most limiting characteristics dictated overall suitability for each soil unit. The suitability of each factor for each soil unit was classified as highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N) (Ibrahim, Aliyu, Sabo and Yusuf, 2018). In the parametric method of land evaluation, each limiting characteristic was rated as follows: S1(95), S2(85), S3(60), N(40). The index of productivity for each soil unit was calculated using Udoh et al (2006) modified equations: the limiting characteristic was rated and the index of productivity for each soil unit was calculated using Square root method equation:

$IP = A \times \sqrt{B/100 \times C/100 \times \ldots \times F/100}$

Where: A is the overall lowest characteristic rating (nutrient availability) and B, C…F are the lowest characteristic ratings for each land quality group**.** The land characteristics were grouped into climate (c), soil physical property (p), wetness (w), availability of Nutrient (f) (Ibrahim, Aliyu, Sabo and Yusuf, 2018).

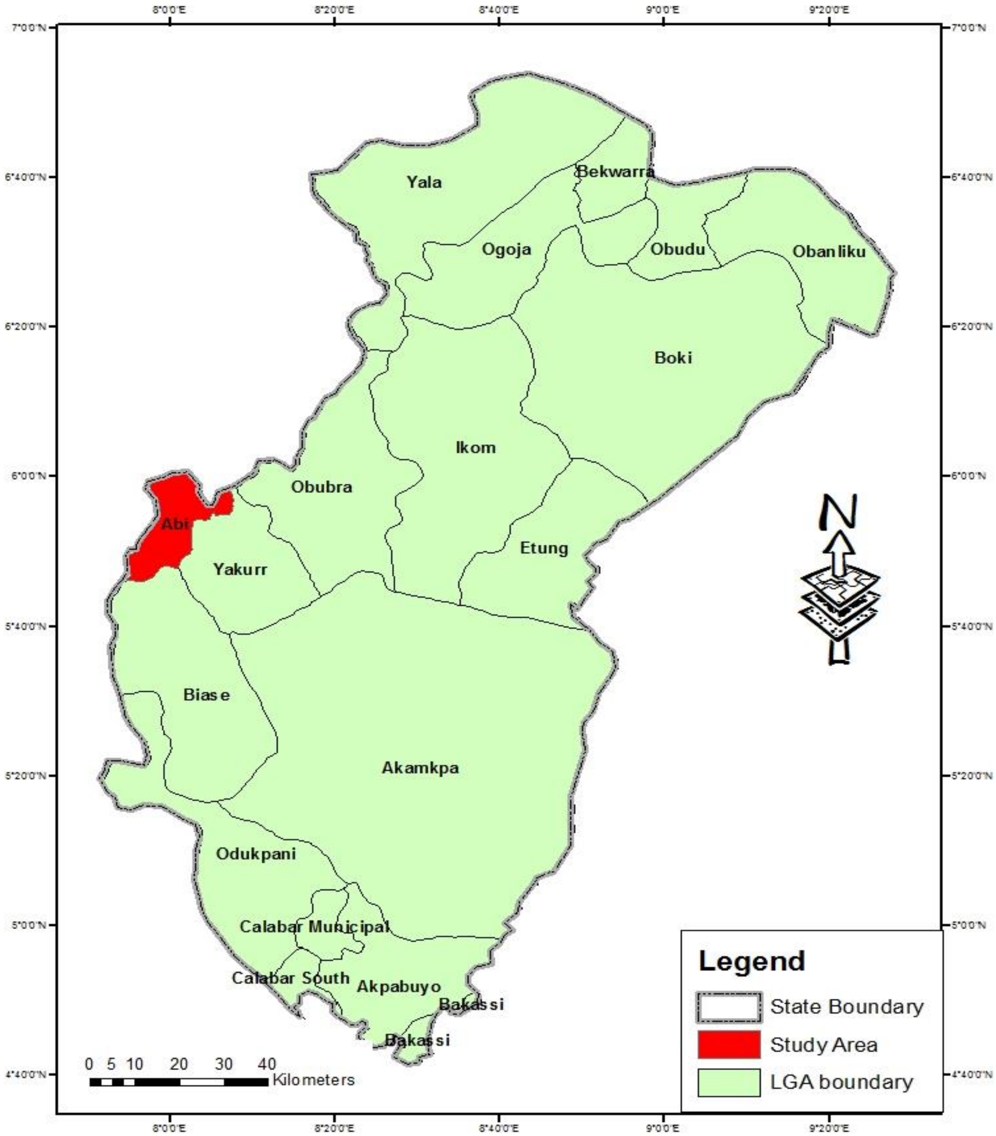

Figure 1: Cross River State showing Abi Local Government Area
Source: Geographic Information System (GIS) laboratory, Department of Geography and Environmental Sciences, University of Calabar

The suitability of the soil units was done separately for each soil unit identified in the study area. Current and potential Index of Productivity of the soil was calculated. In calculating the index of productivity (current index), both the soil chemical properties that can be easily altered such as exchangeable K, Ca, and available P as well as those used for Potential Index of Productivity (IPp), were used for the calculation of the current index of productivity (IPc). Whereas in computing the productivity of Potential Index (IPp), properties that cannot easily be changed such as pH and organic matter (OC) were used as part of the fertility (f) group while those chemical properties that can easily be changed such as exchangeable K, Ca, available P, were not part of the calculation (Ibrahim, Aliyu, Sabo and Yusuf, 2018).

III. Result and Discussion

Physico-chemical properties of the soils

The soil texture was sand clay loam for AFAFP and EDIFP while that of IMAFP was sandy loam .The mean value for bulk density in AFAFP showed 1.64g/cm^3 while that of EDIFP unit showed a mean value of 1.44g/cm^3 and 1.3 g/cm^3 for IMAFP (Table 1). This showed that bulk density is agronomically favourable for the cultivation of rice since it is <1.8g/cm^3.

Porosity was low (<50%) in AFAFP and IMAFP units while EDIFP unit was high. Moisture content was higher in EDIFP (54.8%) than in AFAFP and IMAFP. The particle size analysis depicted that sand fraction was higher in AFAFP and IMAFP (75 & 77.33%). In the other hand silt content was seen to be higher in EDIFP than in AFAFP and IMAFP. The clay content was also higher EDIFP (35.8%) than the other two which indicated that there was illuviation and perturbation **(**Malgwi et al, 2000, & Raij, 2000). The mean value of pH was higher in AFAFP (5.6) than in EDIFP (5.54) and IMAFP (5.30). The soils were moderately acidic (5.00 – 6.00). The organic carbon content was low for rice production being <3% in all soil units (Enwezor et al, 1989). The total nitrogen content was also too low for the cultivation of rice production in the study area (<0.10 mg/kg) (Udo et al, 2009). The available P was seen to be too low for the cultivation rice production being\ (<10 mg/kg) (Uponi & Adeoye, 2000).

Variation in the amounts of exchangeable bases over the soil units was observed in the study area. The mean of exchangeable Ca, Na and K were below the critical limits for the production cultivation of rice. Exchangeable Mg was within the critical limit for rice cultivation (<0.5 cmol/Kg). The exchange acidity (EA) was high in the soil (>1.5 cmol/Kg) and this reflects the acidic content of the soils. The mean values of CEC were low across the soils units.. Being <5 – 15cmol/kg. Base saturation was high in all the soil units (AFAFP= 52.2, EDIFP= 71.8 and IMAFP= 75.64%).

IV. Suitability Evaluation of Soil for Rice Cultivation

When the climatic requirements for rice as advanced by FAO, 1976; Sys, 1985, 1991 in Table 2 were matched with the land quality (mean annual rainfall and temperature) of the study area as shown in Table 3, all the soils were seen to be highly suitable (S1) for rice cultivation (Tables 4). These results revealed that the study area is currently ideal in terms of climate for the cultivation of rice. Soil physical characteristics considered for the cultivation of rice were soil depth, texture and drainage. Soil depth was highly suitable (S1) for AFAFP soil unit and moderately suitable (S2) in EDIFP soil unit while in IMAFP it was not currently suitable (N) for rice. The soil texture was seen to be moderately suitable (S2) for rice cultivation in AFAFAFP and EDIFP soil units and not suitable in IMAFP soil unit (Sys, 1985, 1991). For soil drainage (wetness), the results of matching the crop requirements with land characteristics showed that the soil units were highly suitable (S1) for rice cultivation.

For the soil fertility characteristics (f), pH was seen to be moderately suitable (S2) in all the soil units. The values of organic carbon, total nitrogen and exchangeable K showed that they were not currently suitable (N) for rice production in the study area. While the values of Cation exchange capacity (CEC), available P, exchangeable Ca and Mg were seen to be marginally suitable (S3) in all the soil units for rice cultivation as the values were low when compared with the requirements of rice production (FAO, 1976). In another hand base saturation was seen to be highly suitable (S1) for the cultivation of rice in the study area. These findings showed that fertility of the soil is the major challenge to the suitability of the soils for rice production in the study area. This finding is in line with the findings of Ogunkule (1993); Olaleye (2002) and Oluwatosin (2005) who also noted in their studies that soil fertility is the major limitation to the suitability of Nigeria soils.

In the parametric method of assessment (Table 4), based on the current index of productivity, the soils of all the soil units were classified as currently not suitable (N) for rice production with aggregate suitability scores of less than 24. The same trend was observed with that of potential index of productivity except that of AFAFP soil unit that showed marginal suitable S3 with an aggregate suitability score of 34.

Table 1
Description of physico-Chemical properties of the soils for cassava and rice cultivation

	Soil Depth	BD	Porosity	MC	Particles size distribution sand %	silt %	Clay %	pH	OC	TN	Avail P	Exchangeable bases Ca	Mg	Na	K	EA	CEC	BS %	Textural class
AFAFP unit																			
Mean	200	1.64	35	29.4	75	7	18	5.6	1.47	0.04	1.51	2.06	1.06	0.05	0.07	2.78	6.34	52.2	
SD.		0.89	3.19	6.74	3.58	1.26	2.82	0.21	0.68	0.01	0.29	0.19	0.10	0.01	0.02	0.95	0.84	7.18	SCL
Cv %		54	9	23	5	18	16	4	46	30	20	9	15	13	26	32	13	4	
EDIFP unit																			
Mean	150	1.44	54	54.8	45.6	16.7	35.8	5.54	2.00	0.05	2.45	6.36	2.48	0.07	0.10	3.61	12.54	71.18	
SD		0.34	7.31	8.14	9.71	7.30	10.25	0.15	1.15	0.03	0.47	0.72	0.37	0.01	0.02	0.42	1.42	2.24	SCL
Cv %		24	21	15	20	45	29	9	57	64	19	11	14	20	16	12	11	3	
IMAFP unit																			
Mean	40	1.3	32	36.33	77.33	10.33	14.33	5.30	2.68	0.08	2.93	3.73	1.63	0.11	1.05	1.65	6.88	75.64	
SD		0.45	3.11	8.18	8.18	6.94	2.87	0.09	0.2	0.1	0.19	0.38	0.12	0.2	0.2	0.15	1.12	2.03	SL
Cv%		34	10	23	23	67	20	2	8	7	7	10	8	19	19	9	5	3	

AFAFP= Afafanyi Flood plain\, EDIFP= Ediba Flood plain, Imabana Flood plain

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Table 2
Established Land requirements for Rice

	S1	S2	S3	N1
	100%	85%	60%	40%
Climate condition				
(Soil physical characteristics)				
Annual rainfall	110 - 1500	960 - 1100	500 – 900	200 - 500
Mean temperature	>25	22-25	20-22	8-20
Texture	Loam	clay loam	clay	any
Soil depth	>150	100 - 150	80 -100	<80
Drainage	well drained	moderately drained	poorly drained	very poorly drained
Fertility Status (f)				
pH	7 – 6	6.0 – 5.0	<5.0	any
OC	> 60	60 – 43.1	43.1	any
CEC	>25	13 - 25	6 – 12	<6
Base saturation	>75	50 – 75	30 – 50	<30
Available P	> 15	6 – 15	< 5	any
Exchangeable K	> 0.31	0.30 – 0.11	0.11	any
Exchangeable Ca	12 - 6	6 – 3	< 3	any
Exchangeable Mg	12 – 6	6 – 3	< 3	any

Suitability classes: S1= 75 – 100, S2 = 50 – 74, S3 = 49, N1= 15 – 24, N2 = 0- 14
Adopted from FOA, 1976, 1983, Sys, 1985 and Oleye et al, 2002)

Table 3
Land qualities and characteristics of the soils at present

Parameters	AFAFP	EDIFP	IMAFP
Climate condition(C)			
Annual mean rainfall	2500	2500	2500
Annual mean temperature	29^0C	29^0C	29^0C
Soil physical characteristics (s)			
Drainage	well drained	well drained	well drained
Soil Depth	200	150	40
Soil texture	sand clay loam	sand clay loam	sand clay
Fertility status (F)			
pH	5.60	5.54	5.30
CEC	6.34	12.54	6.88
Base saturation	52.2	71.18	75.64
Available P	1.51	2.45	2.93
Organic carbon	1.47	2.00	2.68
Exchangeable Ca	2.16	6.36	3.73
Exchangeable Mg	1.06	2.48	1.63
Exchangeable K	0.07	0.10	0.11

Key: AFAFP – Afafanyi floodplain, EDIFP – Ediba floodplain, IMAFP – Imabana floodplain

Table 4
Suitability class scores for rice production in Abi Local Government Area

Soil characteristics	AFAFP	EDIFP	IMAFP
Climate condition			
Annual rainfall	S1 (100)	S1 (100)	S1 (100)
Annual temperature	S1 (100)	S1 (100)	S1 (100)
Physical condition			
Soil depth	S1 (100)	S2 (85)	N (40)
Texture	S2 (85)	S2 (85)	N (40)
Wetness (w)			
Drainage	S1 (100)	S1 (100)	S1 (100)
Fertility Status (f)			
pH	S2(85)	S2(85)	S2(85)
OC%	N (40)	N (40)	N (40)
Total nitrogen	N (40)	N (40)	N (40)
CEC	S3 (60)	S3 (60)	S3 (60)
Available P	S3 (60)	S3 (60)	S3 (60)
Exchangeable K	N (40)	N (40)	N (40)
Exchangeable Ca	S3 (60)	S3 (60)	S3 (60)
Exchangeable Mg	S3 (60)	S3 (60)	S3 (60)
Base saturation	S2 (85)	S2 (85)	S1 (100)
Aggregate suitability			
Current suitability	N (23)	N (13)	N (6)
Potential suitability	S3 (34)	N (14)	N (9)

Aggregate suitability class scores: 100-75= S1, 74-50=S2, 49- 25=S3, 24-0=N
S1= highly suitable, S2 = moderately suitable, S3 = marginally Suitable, N = Currently not suitable

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V. Conclusion

The suitability evaluation results showed that land characteristics such as annual mean rainfall, annual mean temperature, drainage were highly suitable (S1) while soil texture was moderately suitable (S2) in AFAFP and EDIFP soil units whereas that of IMAFP soil unit was not suitable (N) for the production of rice. Fertility characteristics such as total nitrogen, organic carbon and exchangeable K were not suitable (N) while available phosphorus, exchangeable Ca, Mg, and CEC were marginally suitable (S3) in all the soil units whereas pH was moderately suitable (S2) and only base saturation was moderately suitable in AFAFP and EDIFP whereas it was highly suitable(S1) in IMAFP soil unit. Fertility status was the factor limiting the suitability of the soil for rice production in the study area. Therefore to obtain maximum production of rice, improvement of the soils by increasing the organic matter level through the incorporation of organic residues such as farmyard manure, plant residues, and household refuse should be done. Also the application of fertilizer and liming rice plots to raise the level of CEC should also be practiced.

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