VOL. 7, NO. 11, NOVEMBER 2012 ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science

www.arpnjournals.com

RAINFED RICE PRODUCTIVITY POTENTIALS OF RIVER KATSINA ALA FLOODPLAIN SOILS OF AGASHA, BENUE STATE, NIGERIA

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ABSTRACT

Rice is severely in short supply in Nigeria despite the vast occurrence of natural conditions for its successful cultivation. Attempts at large scale rice production even on river floodplain soils are largely unsuccessful due to poor soil management as a consequence of lack of soil information. The objectives of this study were to characterize, classify and assess the productivity potentials of some soils along River Katsina - Ala Floodplain for rainfed rice production. The area was soil surveyed at detailed level using the grid method. Four soil units were identified based on morphological characteristics. The soils were generally deep (120-190cm) and somewhat poorly to very poorly drained. They were fine textured with clay content ranging from 19% to 53%. Soil pH varied between 5.00 and 5.97; the percentage organic carbon content was low to moderate (1.20-2.99%) with corresponding low to moderate N and P; effective cation exchange capacity was also rated as low to moderate (3.60-8.29 cmol/kg) the percentage base saturation was high ranging from 56 to 79% while extractable Fe content was less than 5mg/kg. Soil units I and II were classified as Aeric Chromic Vertic Epiaqualfs/vertic Luvic Stagnosols; unit III soils were classified as Aeric Haplustepts/Gleyic Fluvisols and unit IV soils classified as Aeric Kandiaqualfs/ Gleyic Luvisols. In terms of suitability for Rainfed rice production soil units I, ll and lv were rated as moderately suitable (s_2) while unit lll soils were rated as non suitable.

Keywords: rainfed rice, productivity potentials, floodplain soils.

INTRODUCTION

Rice is one food crop that has experienced the fastest growth in consumption over and above other food crops in Nigeria in recent times. Some observers attributed this phenomenon to urbanization, change in taste, ease of cooking and the numerous ways rice is prepared and consumed (Idoga and Azagaku 2005; Nigeria village square 2008). Unfortunately while rice production is on the increase, its local production seems to decline bringing about a negative balance. This balance is made up by importation which has continued unabated since the eighties despite intermittent ban (Ashraf *et al*., 1988). Since then, the huge sums of money spent on rice importation have attracted public comments. In 2008 for instance, Nigerians rejected Federal Government plan to import rice to the tune of ₦80b (Nigeria village square 2008).

However, it was reported recently that Nigeria spends over ₦360b yearly on rice importation (Nigeria village square, 20011). The question is "for how long can Nigeria continue to depend on developed world for food supply?" Any nation that cannot feed her citizens cannot be said to be truly independent. This question has become more relevant with the increasing global energy crises. The diversion of grain to ethanol production rather than the food needs of poor nations has worsened the precarious food situation of the developing world. Population explosion and rapid urbanization are other factors that may aggravate food security problems in Nigeria.

The low level of rice production despite the vast occurrence of seemingly good natural conditions for its successful cultivation in Nigeria remains a puzzle till date. According to Ashraf *et al*., (1988) and Daramola (2005), a large concentration of fertile inland valleys is found in the Middle Belt states of Niger, Kwara, Plateau (including Nasarawa), Gongola (present day Adamawa and Taraba) and Benue where population pressure is relatively low and therefore can be properly harnessed for rice culture. In some of these states, attempts have been made in the past at large scale rice production, but failed. A case in point was the Angourough inland valley in Agasha ward of Guma Local Government Area of Benue state. This area which is an extensive wetland along the southern bank of river Katsina-Ala had been commercially cultivated to rice and abandoned in quick successions by individual large scale farmers and private organizations probably because of crop failures and/ or declining yield. This study was carried out to investigate the soils of the area and assess their suitability for rainfed rice production.

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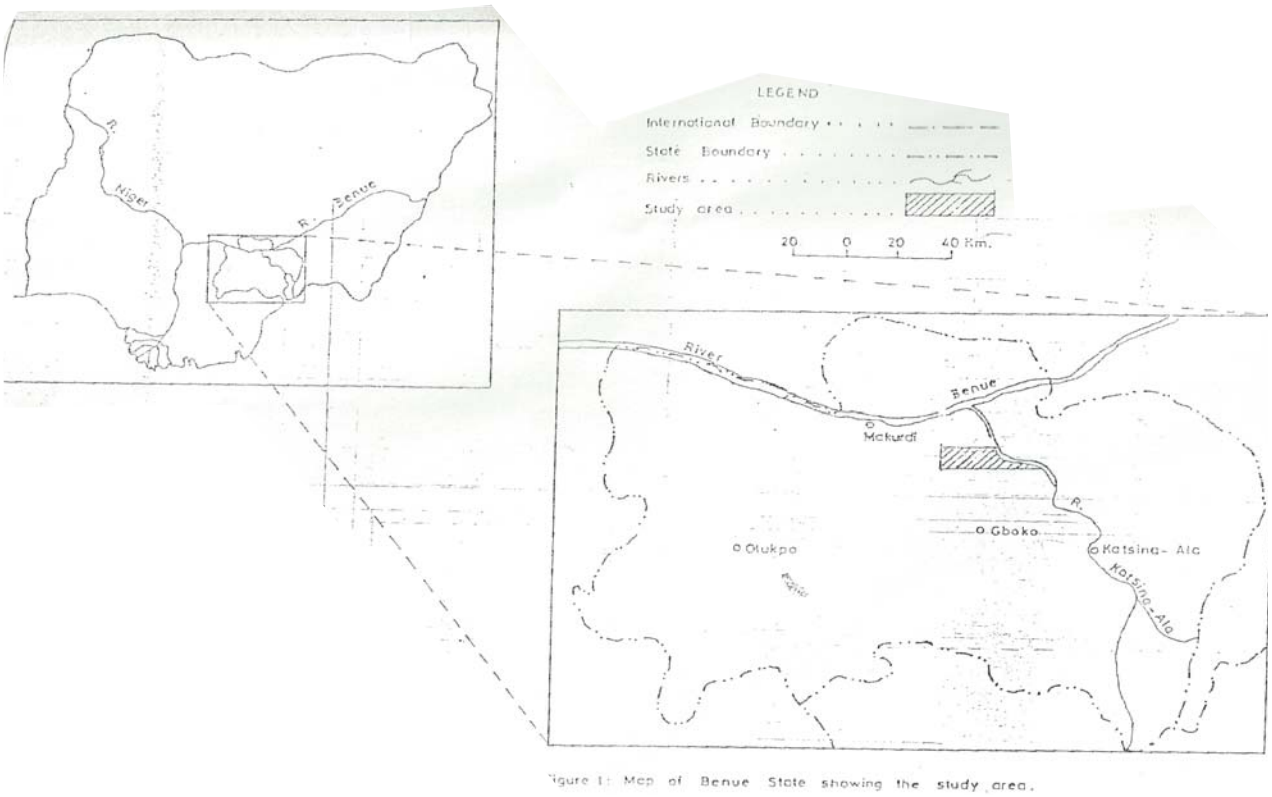

Figure 1: Map of Benue State showing the study area.

Figure-1. Map of Benue showing the study area.

MATERIALS AND METHODS

Study area

The study area is Agasha, located about 3km east of the River Benue confluence with River katsina-Ala at Gbajimba (Figure-l). The area lies between latitudes07^0 10' 45" N and 07^{0}13' 45" N and longitudes 08^{0}33' 00" and 08^0 36' 15" E. The area experiences distinct wet and dry seasons with the mean annual rainfall of about 1100mm falling between April and October of most years. The mean monthly maximum air temperature is about 32^{0}c while the mean minimum air temperature is 25^{0}C. The area is an extensive floodplain along river katsina-Ala bank with a mean width of about 1.2km.

The geomorphology of the area reveals a raised levee just by the river bank which slopes gently southwards into the depression with gilgai formation in some places. This depression forms the lowest portion of the flood plain and seems to run parallel to the river course. The depression rises gently into the undulating plains of the upland.

The Ezeaku shale group forms the dominant geology of the study area, accounting for the undulating topography with little or no rock outcrops (FagbamI, and Akamigbo, 1986). The major occupations are farming and fishing. Rice, maize, cassava, yam; and vegetables (particularly dry season okra) are the major crops of the area.

Field and laboratory studies

About 400 ha of the extensive floodplain was soil surveyed using the grid method with traverses at 100m along the baseline. Auger point investigations were conducted at 100m along the traverses using soil colour, texture, consistence, surface characteristics and topography as differentiating features for delineating soil boundaries. Based on the aforementioned characteristics, four soil units were identified. Two profile pits were sunk in each of the four units. The pits were described using the guidelines of soil profile descriptions (soil survey staff, 1998). Soil samples were collected from identified horizons and carefully labeled for laboratory analysis.

The soil samples were air dried, gently crushed and sieved to obtain the l fine earth fraction (<2mm). The samples were analyzed for particle size distribution using hydrometer method as described by Day (1965). Soil pH was determined by electrometric method as described by Hesse (1971). Soil organic carbon was determined by the Walkey Black method based on the oxidation of organic matter by potassium dichromate (Hesse, 1971). Total N was determined using the macro Kjeldahl procedures. The Bray 1 method was employed for available P (IITA 1979). Exchangeable bases were extracted using neural NH_40AC as the displacing solution. Calcium and magnesium were read on atomic absorption spectrophotometer, while potassium and sodium were read on flame photometer. Exchange acidity was determined using INKCl (IITA, 1979). Effective cation exchange capacity was calculated

as the sum of exchange acidity and exchangeable bases. The percentage base saturation was calculated as total exchangeable bases divided by ECEC multiplied by 100.

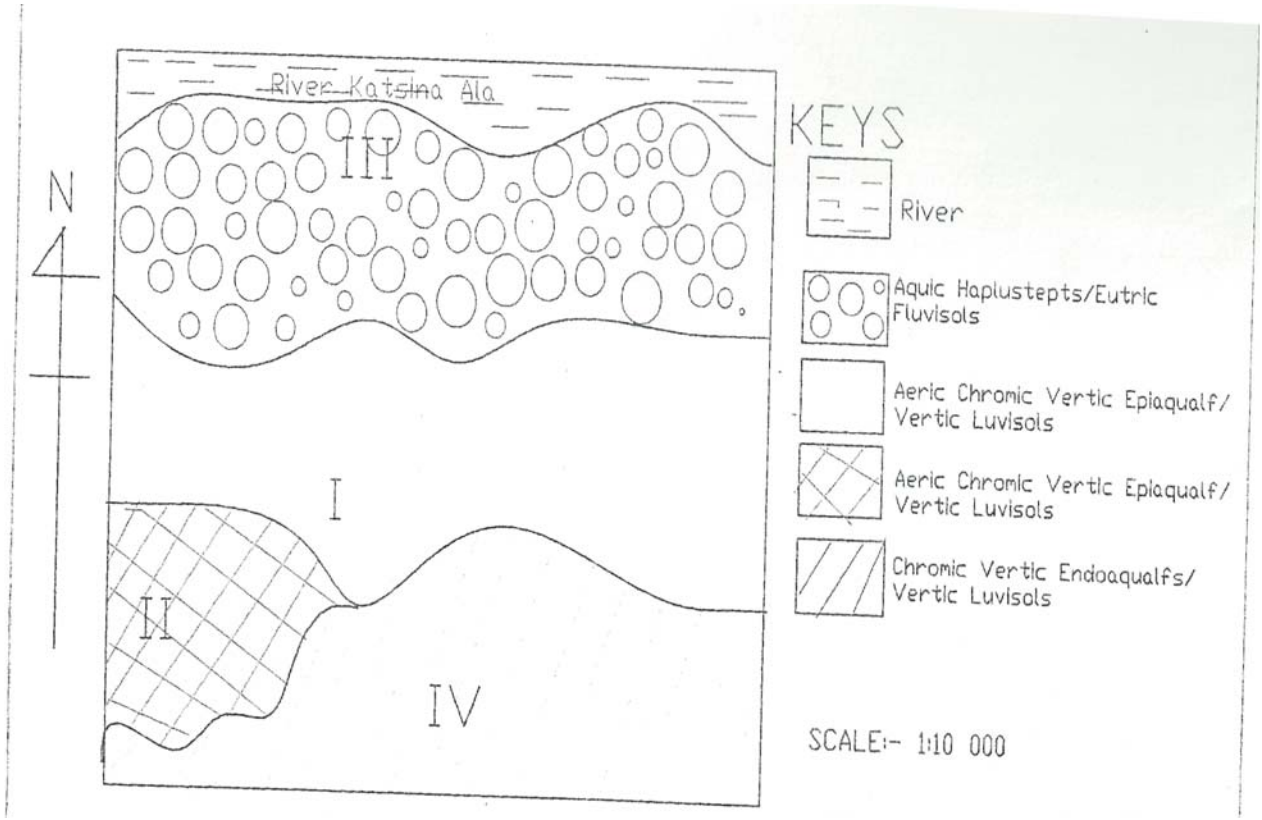

Figure-2. Soil Map of Angourough.

RESULTS AND DISCUSSIONS

Soil morphological characteristics

Figure-2 shows the spatial distribution of the four soil mapping units. The soils were somewhat poorly (unit lll soils on raised levee) to very poorly drained (units l, ll and lv soil on depression). The soils were generally fine textured with clay content ranging from 19% to 53%, probably as a result of the Ezeaku shale formation in the area (Fagbami and Akamigbo 1986). The clay content of all the units except unit lll increased with depth while sand content decreased with depth. This could be as a result of eluviation and illuviation processes. The irregular distribution of clay and sand fractions in unit lll could be due to different types of sediments with different textures deposited yearly according to their sources. The surface horizons of all the soil units had predominantly moderate to strong, medium to coarse sub angular blocky structures probably as a result of the relatively high organic matter and clay contents.

VOL. 7, NO. 11, NOVEMBER 2012 ISSN 1990-6145
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Table-1. Physical and chemical properties of soils of angourough.

Horizon	Depth (cm)	Particle size analysis			Textural Class	pH H_20 1:2	Organic Carbon (%)	Available P (mg/kgp)	Total N (%)	Exchangeable cations				Exchangeable acidity	ECEC	Extractable Fe	Base saturation %
		Sand	Silt %	Clay						Ca	Mg	K	Na				
										Cmol/kg^{-1}							
Soil unit I																	
Pedon 1 Aeric Chromic Vertic Epiaqualf /Vertic, Luvisols																	
A	0-20	44.5	22.0	33.5	CL	5.90	2.79	12.0	0.24	3.52	2.46	0.27	0.13	1.90	8.28	1.65	77
B	20-40	44.8	16.0	39.2	CL	5.14	1.75	9.5	0.16	2.38	1.28	0.25	0.12	1.90	5.93	1.75	68
Bt_1	40-60	36.6	20.2	43.2	C	5.35	1.00	9.5	0.09	1.28	1.10	0.24	0.10	2.00	4.72	2.08	58
Bt_2	60-80	32.8	18.0	49.2	C	5.83	0.80	9.5	0.07	1.48	1.04	0.22	0.10	2.20	5.04	2.40	56
Bt_3	80-130	28.8	18.0	5 3.2	C	5.66	0.50	9.0	0.04	2.48	0.98	0.21	0.09	2.00	5.76	2.45	65
Pedon 2 Aeric Chromic Vertic Epiaqualfs/Vertic Luvisols																	
A	0-22	47.0	23.5	29.5	CL	5.85	2.58	13.6	0.26	3.48	2.68	0.28	0.15	1.70	8.29	1.55	79
B	22-38	45.6	20.4	34.0	CL	5.45	1.56	11.4	0.11	2.24	1.86	0.21	0.14	1.75	6.20	1.80	72
Bt_1	38-68	40.8	19.0	40.2	C	5.35	0.90	9.8	0.10	2.36	1.20	0.24	0.16	1.80	5.76	2.00	68
Bt_2	68-92	38.0	18.0	44.0	C	5.56	0.80	10.9	0.08	1.84	1.42	0.20	0.15	2.00	5.61	2.35	64
Bt_3	92-128	26.5	17.0	46.5	C	5.65	0.50	11.0	0.04	1.94	1.52	0.21	0.17	2.00	5.40	2.45	66
Soil unit II																	
Pedon 3 Aeric Chromic Vertic Epiaqualfs/Vertic Luvisols																	
A	0-25	58.8	20.0	21.2	SL	5.97	2.02	14.3	0.22	2.62	1.30	0.29	0.14	1.55	5.90	1.78	74
B	25-50	44.8	27.0	28.2	L	5.05	0.92	12.0	0.11	1.84	0.98	0.27	0.14	1.60	4.83	1.65	67
Bt_1	50-65	40.8	26.0	33.2	CL	5.64	0.77	10.0	0.06	2.28	1.42	0.25	0.13	1.80	5.88	2.00	69
Bt_2	65-85	31.2	22.0	46.8	C	5.46	0.84	9.0	0.07	1.62	1.48	0.25	0.13	1.80	5.28	2.20	66
Pedon 4 Aeric Chromic Vertic Epiaqualfs/Vertic Luvisols																	
A	0-27	60.0	20.5	19.5	SL	5.75	1.95	12.6	0.20	2.14	1.20	0.22	0.15	1.65	5.36	1.58	69
B	27-54	52.5	21.0	26.5	L	5.15	1.15	10.5	0.10	1.81	1.24	0.24	0.16	1.70	5.15	1.88	67
Bt_1	54-70	48.4	19.6	32.0	CL	5.50	0.75	10.6	0.06	2.03	1.20	0.22	0.14	1.70	5.29	1.95	68
Bt_2	70-101	44.0	18.0	38.0	CL	5.55	0.55	11.4	0.05	1.90	1.64	0.24	0.14	1.80	5.72	2.15	69
Bt_3																	
Soil unit III																	
Pedon 5 Aquic Haplustept/ Eutric Fluvisols																	
A	0-30	46.8	13.2	40.0	CL	5.00	1.54	11.5	0.18	2.06	1.46	0.27	0.15	1.30	5.24	1.60	75
AB	30-50	45.2	19.2	35.6	CL	4.94	1.06	10.5	0.14	1.84	1.44	0.26	0.13	1.30	4.97	1.65	74
BC	50-80	44.6	23.2	33.2	CL	5.08	0.92	8.0	0.10	1.54	0.84	0.26	0.11	1.25	4.00	1.75	69
C_1	80-100	46.8	20.0	33.2	CL	5.46	0.56	10.0	0.05	1.76	0.66	0.23	0.10	1.20	3.95	1.85	70
C_2	100-120	48.8	20.0	31.2	CL	5.30	0.62	8.0	0.05	1.32	0.76	0.22	0.10	1.20	3.60	1.90	67
Pedon 6 Aquic Haplustept/Mollic Fluvisols																	
A	0-26	48.5	15.5	36.0	CL	5.25	1.05	9.8	0.10	2.26	2.40	0.26	0.16	1.50	5.28	1.85	73
AB	26-51	44.6	21.0	34.4	CL	5.05	0.70	10.0	0.06	1.90	1.26	0.27	0.13	1.50	5.06	1.90	70
BC	51-79	48.2	20.8	31.0	CL	5.00	0.50	8.5	0.05	1.60	1.00	0.21	0.15	1.35	4.31	2.10	69
C	79-110	50.0	20.0	30.0	CL	5.05	0.50	8.0	0.05	1.34	0.98	0.22	0.14	1.20	3.88	1.90	69
Soil unit IV																	
Pedon 7 Aeric Chromic Vertic Epiaqualfs/Vertic Luvisols																	
A	0-25	68.8	12.0	19.2	SL	5.89	1.25	14.0	0.12	2.42	1.16	0.28	0.14	4.00	1.50	5.50	1.25	73
B	25-35	59.8	18.0	22.8	SCL	5.68	0.69	14.5	0.07	2.16	0.98	0.27	0.14	3.55	1.70	5.25	1.10	68
Bt_1	35-85	54.8	18.0	27.2	SCL	5.41	0.50	8.0	0.06	1.62	1.06	0.25	0.11	3.04	1.75	4.79	1.46	63
Bt_2	85-120	52.8	18.0	29.2	CL	5.27	0.50	12.0	0.05	2.90	1.46	0.23	0.10	4.69	1.85	6.54	1.45	72
Bt_3	120-150	46.8	22.0	31.2	CL	5.42	0.30	7.5	0.03	2.72	1.40	0.20	0.10	4.42	1.85	6.27	1.50	70
Pedon 8 Aeric Chromic Vertic Epiaqualfs/Vertic Luvisols																	
A	0-20	65.4	15.6	19.0	SL	5.94	1.10	13.5	0.14	2.35	1.22	0.24	0.16	3.95	1.50	5.47	1.43	76
B	20-40	60.2	18.4	21.4	SCL	5.80	0.65	13.2	0.10	2.32	1.20	0.22	0.16	3.90	1.65	5.55	1.39	70
Bt_1	40-75	55.0	15.0	30.0	SCL	5.65	0.50	12.0	0.07	1.08	1.00	0.29	0.14	3.51	1.60	5.11	1.28	69
Bt_2	75-115	50.0	18.0	32.0	CL	5.45	0.50	9.5	0.05	1.51	1.10	0.24	0.11	3.96	1.80	4.76	1.56	62
Bt_3	115-140	44.0	20.0	36.0	CL	5.50	0.50	10.0	0.03	2.01	1.32	0.27	0.16	3.76	1.80	5.56	1.60	68

Soil chemical properties

The pH values in Table-1 indicated that the soils of the area were slightly to moderately acid in reaction. Soil pH of surface horizon ranged between 5.0 and 5.97. These Figures generally decreased with depth probably because of the effect of nutrient biocycling (Ogunwale *et al.*, 2002). The percentage organic carbon was highest (2.97) in pedon I probably because of incorporation of the crop/vegetation residues to the soil and the droppings from cattle that reared in the field during the dry season. The percentage nitrogen was generally low (0.24%) and this could be attributed to release from plant tissues, gaseous loss, leaching and volatilization (Belvins *et al.*, 1996).

Available phosphorus values were moderate to high (8.00PPm - 14.5PPm). The values were high in the surface horizon but decreased with profile depth probably because of the relationship of organic carbon with phosphorus. Exchangeable ca and mg dominated over K

and Na in the exchange complex. This is in agreement with earlier findings of Fagbami and Akamigbo, (1986). Effective cation exchange capacity values were low to moderate ranging from 3.6cmol/kg^{-1} to 8.29cmol/kg^{-1}. The moderate ECEC values of the surface horizons could be due to the influence of soil organic matter which decreased with depth, while those of lower horizons may be indicative of the contribution of clay colloids which increased with depth.

The percentage base saturation was high, ranging from 56% to 79%. The distribution was irregular in all the units. This could be attributed to the active plant litter decomposition process which incorporates cations from the litter into the soil surface (Malgwi, 1979).

Soil classification

The USDA soil taxonomy (soil survey staff, 1998) and the WRB, (2006) were used in classifying the soils of the area.

All the pedons showed increasing trend in the amount of clay with depth (except soil unit lll) and also a high degree of soil aggregation. This trend is indicative of the presence of argillic horizon. The base saturation values of the argillic horizons were quite high (> 35% by sum of cations). These characteristics qualify the soil as Alfisols. The presence of mottles and gilgai micro- relief further qualify the soils as Aqualfs. Soil unit's l and ll showed evidence of Episaturation by the presence of mottles right from soil surface and the dorminant matrix colour of 10YR and 2.5Y therefore qualify as Epiaqualfs. They further qualify as Aeric chromic vertic Epiaqualfs because of the presence of cracks narrower than 2cm and shallower than 50cm, as well as the dominance of colour hue of 10YR and even yellower (2.5Y). Unit lv soils qualify as Chromic Vertic Endoaqaulfs because of endosaturation. Unit lll soils were somewhat poorly drained having drainage mottles within 50cm-100cm of soil surface which implies that the upper 50cm of the soil remain dry for 90 or more consecutive days as dictated by the climate of the area. The soils showed a decreasing clay soil content with depth. They therefore qualify as inceptisols. The inferred ustic soil moisture regime of the area places these soils into the suborder ustepts. The clay distribution pattern of these soils places them in the great group Haplustepts. They are further classified as Aquic Haplustepts because of the aquic soil conditions within 75cm of soil surface.

In the (WRB, 2006) the soi[s have higher clay content in the subsoil than in the topsoil as a result of pedogenic processes (especially clay migration) leading to an argic subsoil horizon. Soil unit's l, II and IV had evidence of redoximorphic features caused by surface water which periodically wet both topsoil and subsoil leading to the formation of mottles. For these reasons, the classify as Stagnosols (WRB, 2006). They further qualify as Vertic Luvic Stagnosols (Eutric) because of the Vertic properties and the higher clay content of the subsoil as well as the high base status of the soils.

Soils of unit lll were somewhat poorly drained. They had higher clay content in the top soil than in the subsoil. They had high base saturation and low activity clay at certain depth. The soils therefore qualify as Fluvisols. The soils further classify as Gleyic Fluvisols (Greyic) (Eutric) because of the redoximorphic features within 75cm of the mineral soil surface

Evaluation of soil properties for rice production

The establishment of land unit that best matches an intended land use is the principle behind land evaluation. One of its basic features is the comparison of these characteristics of the land with the requirements of the intended land use, in this case swamp rice production. One of the most important requirements of rice crop is the availability of water throughout the growing period to enhance growth and yield. Water is therefore the most important limiting factor in rainfed rice production. Apart from rainfall, flooding and underground seepage constitute additional sources of water to the soil of river Katsina-Ala floodplain, making the soil saturated for most parts of the year (aquic soil conditions). The high clay content of the soils and the low-lying or depressional landscape do not permit the soils to lose water as fast as they receive units (I, ll and lv). Consequently, water remains at or near soil surface for one to two months in most years. Based on this feature these soils can be described as fadama soils. Ojanuga, *et al*., (1996) had recommended the utilization of this type of soils for rice production based on their aquic conditions.

In terms of water supply therefore, the soils can be considered to have little or no limitations to rice production (soil unit I, ll and lV) except for years of poor rainfall. In years of excess rainfall rice crop can be lost through submergence. This explains the S2 rating under moisture in Figure-2. Soil fertility may constitute a problem as percentage organic carbon and total N were low to moderate. This can be addressed by the incorporation of rice straw as well as inorganic fertilizer application. Soil unit lll were somewhat poorly drained and may not have sufficient soil moisture content to guaranty good rice yield under rainfed condition. They are therefore rated as non-suitable (NS). This study shows clearly that not every seemingly good river flood plain soil that is suitable for rice production. This may explain the failure of past rice project, as crop failure from soil unit lll could contribute significantly to crop yield reduction, such that the project might not be able to break even. Such soils should be avoided or put to other crops such as maize or cassava or even upland rice. For this reason efforts should be made to investigate soil conditions before new rice fields are opened.

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