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Rice Production in the Flood Plains of River Benue, Nigeria: Prospects and Challenges

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ABSTRACT

There exist opportunities to increase rice production in Nigeria as currently rice production is low and consumption level is high. The floodplains of river Benue offer great potential for sustainable large scale rice production. Twenty-five thousand hectares of land bordering river Benue were selected to assess the fertility, texture and drainage status of the soil for rice production, and to suggest possible soil management practices for optimising rice production. Standard field sampling methodologies and soil laboratory procedures were employed. The soils of the area were found suitable for rice production but with certain identified constraints. Apart from the low soil nutrient status of the floodplain, which could be easily mediated with fertiliser application, the most critical limitation related to poor drainage and flooding. To avert this problem, it is recommended that a proper drainage network be designed and executed along with the construction of strategic embankments to prevent flooding of the river Benue.

Keywords: Food security, land evaluation, Nigeria, rice.

INTRODUCTION

Globally, rice falls within the top three most important cereal crops (Haefele *et al.* 2014). Many households in Nigeria depend on rice to meet their daily food demands. The annual quantity of rice produced locally (3.6 million tonnes) is not sufficient to meet local consumption (5.5 million tonnes) (Liverpool-Tasie *et al*. 2015). Consequently, the government of Nigeria has relied largely on rice importation to meet the national consumption rate (Terwase and Madu 2014). Recently, there was a ban on rice importation with emphasis on increasing local production of rice. This led to an increase in the market price of rice because production is still very low. Hence, the purchase of rice has gradually become beyond the reach of an average Nigerian. While rice farmers try to expand their areas of cultivation, the short fall between production and local consumption of rice in Nigeria could be partly responsible for the current economic recession in the country.

The need to boost local production requires extensive cultivation under a mechanised system (Ray *et al*., 2013). In precision agriculture, both terrain and fertility data are required. It is estimated that 75% of rice land are wetlands where

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rice grows in flooded fields during part or throughout the growing season. The traditional wetland rice cultivation could be considered sustainable because of its moderate but stable yield which has been maintained for many years without adverse effects on soil (Haefele *et al*. 2014; Lawal *et al*. 2014). Flooding plains are usually regarded as good agricultural land due to seasonal deposits of rich alluvium that replenish the soil nutrient status (Kyuma 1985; Patrick 1990; Biller and Bruland 2013; Brierley and Fryirs 2013). Wetland rice fields favour the growth and activities of nitrogen-fixing bacteria (Vignesh *et al*. 2015).

Furthermore, the River Niger is reputed to be the longest river in Nigeria and West Africa, the third longest river in Africa behind Rivers Nile and Congo. At 1400 kilometers, River Benue is the major tributary of River Niger and the second longest river in Nigeria (Andersen and Golitzen 2005). It originates from Adamawa Plateau in Cameroon and is of economic importance to Nigeria in several ways. Generally, it is assumed that river banks are fertile due to seasonal deposits from the overflowing river. Due to differences in volume, size, topography and inherent soil fertility, there might be heterogeneity in the distribution of fertility around the floodplain (Brierley and Fryirs, 2013). Sustainable production of rice in this floodplain therefore, requires an understanding of the geospatial pattern of the soil characteristics (both physical and fertility status). To this extent, 25,000 hectares of land adjoining river Benue were selected for this study. The objectives of this study were to evaluate and map the fertility and textural status of the soil for rice production and to suggest possible soil management practices for optimising sustainable rice production on the land. This study is expected to provide basic soil management infomation for large scale rice production in the flood plain of river Benue in an effort to reduce the shortfall between demand and supply of rice especially as a result of the economic recession in Nigeria.

MATERIALS AND METHODS

Description of study site

The area is located on the southern bank of river Benue in Basa Local Government Area of Kogi State, Nigeria (Fig. 1). The study area covers about 25,000 hectares in the alluvial plain and lies in the immediate vicinity of the southern bank of the river Benue and ranges in altitude from 35 m to 77 m above sea level (MASL). This area is liable to seasonal flooding from river Benue and has several inland basins and back-swamps. About 70% of the land area that falls within this plain is poorly drained.

The land use land cover analysis of the study site indicates that the area is presently covered by alluvial flood plains in the immediate vicinity of river Benue where the rice farmers are mostly found and fresh water back swamps which retain the bulk of the flood waters from river Benue and the riparian forests. Immediately after the back swamps are moderately well drained, arable farm lands used for crop production. The common crops grown in the area include lowland rice, benni seed, bambara nut, groundnut, guinea corn, maize, cassava and cashew.

Lying to the South-eastern boundary of the site is a combination of grassland, densely vegetated wood land comprising a variety of hardwoods, shrubs and in some instances big trees. It was also observed that most of the wooded savannah in the area has been subjected to serious logging activities. Nomadism is a major problem to farmers around the area. There are reported cases of damage to field crops by the grazing nomadic cattle.

There are several villages connected together by motorable roads. Also, within the confines of the site are several seasonal rivulets and rivers that drain into river Benue.

Study Approach

The selected area for this study was mapped out from the political map of Kogi State, Nigeria to cover a greater part of Basa – a local government area known for rice production (Fig. 1). The geo-referenced map was uploaded on the most recent Google Earth Imagery and this was interpreted to provide the base map as well as the land-use land cover map (LULC) of the farm site (Fig. 2).

The base-map was then divided into regular polygons using ArcGIS 12. The polygon centre points within the grid map were designated as the composite sampling point (Fig. 3). The composite sampling points were then uploaded into a hand held geographic positioning system.

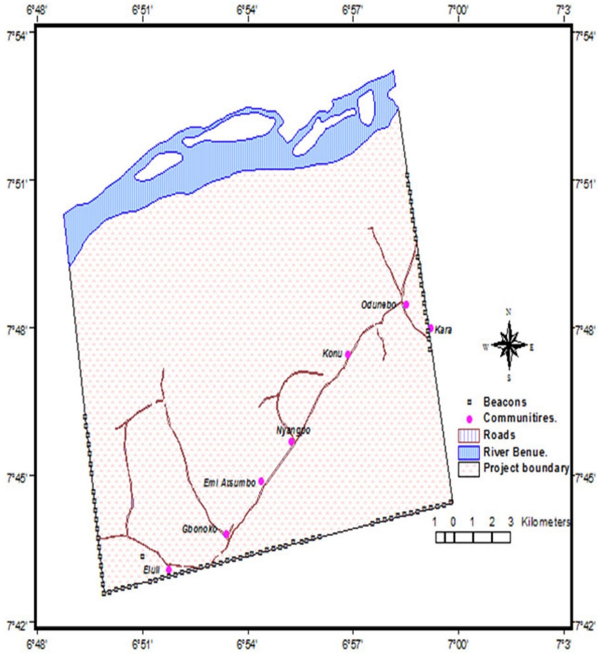

Fig. 1: Location of the project site

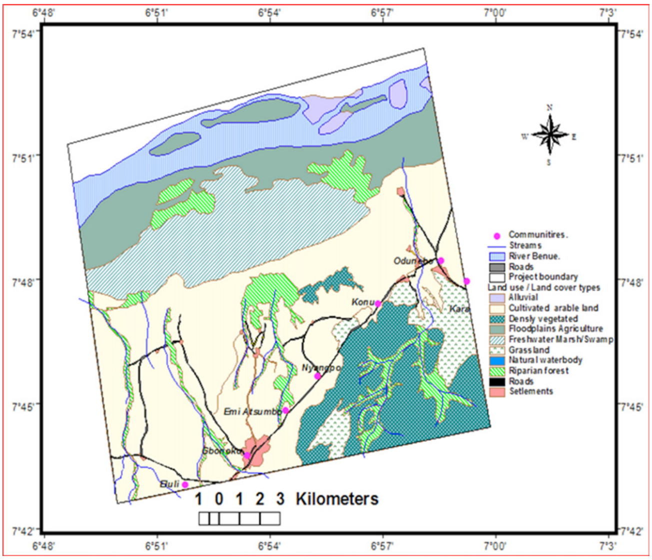

Fig. 2: Land use land cover (LULC) map of project site

(GPS) for mapping. Composite samples were taken from the surface (0-35 cm depth) at the designated point using an auger. Subsurface samples were also taken at 15-cm intervals from 40-120 cm and characterised morphologically by standard field methods (Schoeneberger *et al.* 2012) to ascertain the subsurface texture and drainage conditions. The composite samples taken were well labelled in the field and transported to the laboratory where they were air dried and sieved with a 2 mm sieve prior to analyses.

Soil Analyses

Particle size distribution was determined mechanically using the hydrometer method. Soil pH in water (1: 2) was determined using glass electrode pH meter (Hanna Instruments UK). Total nitrogen was determined using macro-Kjeldahl method (Bremner 1996). Phosphorus was determined by Bray 1 method (Bray and Kurtz 1945), organic carbon determined using Walkley and Black method (Walkley 1947). Exchangeable cations (potassium, calcium, sodium and magnesium) were extracted using 1N ammonium acetate, K and Na in the extract were read on a flame photometer while Ca and Mg were read on atomic absorption spectrophotometer (AAS). The available micronutrients were extracted with 0.04 M EDTA and read on an atomic absorption spectrophotometer (Fisherscientific, Kansas, USA).

Geospatial and Statistical Analyses

Preparing Excel Data for Importation

The results of analyzed soil samples were recorded against the respective coordinates indicating the geographical locations on the field. The spread sheet of parameters (field) against specific sample points (records) was then saved in a specified directory on the computer in preparation for importation into the Geographic Information Systems environment. Specifically for Excel 2007, the table was saved as a Text (tab delimited) file format in Universal Transverse Mercator (UTM) (WGS 1984) Minna datum and Zone 32 meters North of the equator. The worksheet containing the analysed soil data was selected and imported into the Arcview 3.2 spatial analyst environment.

It was important to ensure that the data follow a normal distribution curve that is not skewed to the right or left. The data were therefore graphically displayed using histogram in Arcview 3.2. The data followed a normal distribution pattern. Data cleaning was conducted to ensure that any outliers were removed before subjecting the data to spatial analysis.

Spatial Interpolation

The inverse distance weighted (IDW) interpolator was utilised to create a continuous surface of a soil nutrient map for all parameters analysed. This is because it is one of the most applied and deterministic interpolation techniques in the field of soil science (Zandi *et al.* 2011; Bhunia et al. 2016). Soil samples collected at very close range are likely to be statistically invariant and as such it is good to make estimates based on nearby known locations as does IDW interpolation by assigning weights to the interpolating points in the inverse of its distance from the interpolation point. Accordingly, closer points are assigned more weights (so, more impact) than distant points and vice versa. This according to Robinson and Metternicht (2006) makes the known sample points implicit to be self-governing from each other as expressed below.

$$Z(x_0) = \frac{\sum_{i=1}^{n} \frac{x^{\mathrm{j}}}{h_{ij}^{ji}}}{\sum_{i=1}^{n} \frac{1}{h_{ij}^{ji}}}$$

where $z(x_0)$ is the interpolated value, n represents the total number of sample data values, xi is the ith data value, hij is the separation distance between interpolated value and the sample data value, and ß denotes the weighting power.

The table of geographic coordinates of soil samples and their corresponding results of analysed parameters were added to the GIS. The points were then added to the work space as events theme and then used to produce a continuous map of each parameter by selecting Interpolate Grid from the Surface menu choosing IDW as the Method, and specific parameters in the Z Value Field. A grid map of the farm boundary was created and utilised as the analysis mask??? or mark in the Analysis Extent in the Analysis Properties dialog of Analysis menu. For this task, Nearest Neighbour and the default number of 12 neighbours were chosen.

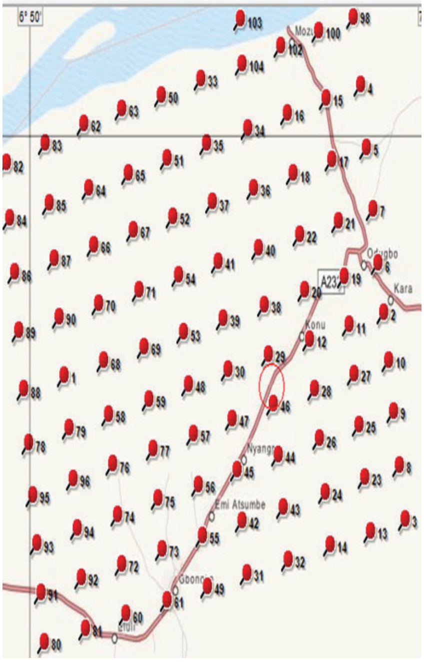

Fig. 3: Composite sampling points

RESULTS AND DISCUSSION

Soil Characteristics

Based on the soil depth and drainage characteristics, there were three major soil types viz: deep poorly drained, deep well drained without stones and shallow well drained with gravels. The soils in the deep poorly drained unit were developed from recent alluvium and were poorly drained loamy sand or sandy clay loam surface over sandy clay, sandy clay loam or clay and not gravelly. This soil type was susceptible to seasonal flooding from river Benue but considered suitable for rice production with the provision of artificial drainage.

The deep well drained soils had brown loamy sand to sandy loam surface soil overlying red sandy clay loam subsurface soils. This soil type had no stones within 100 cm soil depth. This soil occurred in the immediate surroundings of the poorly drained soils and occupied the eastern part of the land from the junction of Emi Estumbe through Emi Jacob to Odugbe.

The last soil type resembled the second in colour and textural characteristics but was shallow and gravelly. Gravels occurred in this soil type at depths < 30 cm in most cases. This soil type was found at the base of the hills which formed the southern boundary of the land and ranacross the entire length of the land from Kara through Gboloko to the south-western boundary after Eluli. The two other soil types were only suitable for arable cropping.

Soil Physical Characteristics

About 76% of the surface soils were predominantly loamy sand (LS) in texture, while about 17% of the surface soils were sandy loam (SL) in texture and the remaining 7% were sandy clay loam (SCL) in texture (Fig. 4). The soils were generally high in sand (sandy skeletal), moderate in clay and very low in silt. The sand particle size fraction ranged from 70.2% to 89.4%, while the clay content of the soils ranged from 9.6% to 20.4% and the silt content ranged from 0.4% to 9.8%.

Most of the areas lying close to river Benue were either sandy loam or sandy clay loam in texture. These areas were poorly drained and had extensive back swamps or inland basins. The subsurface layers (>50 cm depth) of these areas were either sandy clay loam or sandy clay in texture and highly susceptible to flooding because they were within the flood plain of river Benue. All the areas that had loamy sand texture were well drained.

Rice grows on a variety of land; however there is a marked difference between the drainage requirements of upland and lowland rice. At the early stage of growth, both upland and lowland rice require soils that are well-drained for direct seeding. For transplanted lowland rice, a somewhat poorly drained well puddle soil can support the rice seedling. Apart from drainage conditionss, rice requires deep, loamy soils with moderate bulk density (1.2-1.6 g/cm^3), total porosity (higher than 50%) and a ground water table below 0.75 t0 1.20 m depth. The soil requirements for upland rice production are similar to those of lowland rice but the soil must be moderately well drained with high available water holding

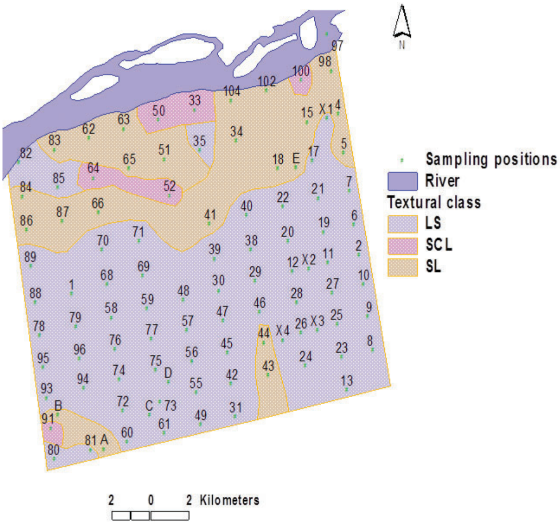

Fig. 4. Spatial distribution of soil texture

Note: LS = loamy sand, SCL = sandy clay loam, SL = sandy loam capacity. In upland rice, available water holding capacity of 15% or more (15 cm per meter depth of soil is required. However, in terms of soil texture, upland rice has been produced on soils ranging from loam to loamy sand while lowland rice requires soils ranging from clay loam to sandy loam.

Maintenance of proper physical, chemical and biological conditions of the soil is necessary for realising higher growth, yield and quality of rice. Although, the observed soil texture in this evaluation could be adequately managed with appropriate manure to produce good rice yield, it will be necessary to have a proper drainage network for the northern part of the land before it can become suitable for lowland rice production.

Chemical Properties of the Soils

Soil pH ranged from moderately acid to moderately alkaline (6.0 -7.9). The pattern of the pH distribution correlates with the distribution of LULC (Fig. 5). The area of land consisting of the flood plain and back swamp and which abuts river Benue had the lowest pH, ranging from 6.0 to 6.3. The moderately well drained arable land found immediately after the back swamps had a slightly higher pH that ranged from 6.3 to 6.5. The highly elevated densely vegetated south-eastern boundary of the soil had pH ranging between 6.5 and 6.9. Most of the soils had pH that ranged from slightly acid (6.1-6.5) to neutral (6.6-7.3). Less than 10% of the total land area had pH above 6.8.

The optimum soil pH for rice production range from 5.5 to 6.5 but rice can tolerate a considerable degree of soil acidity and alkalinity. Hence, it is found growing in soils with pH in the range of 5 to 8.5. Liming is required if pH is less than 5.0.

Soil acidity adversely affects rice growth, yield and quality. Under acidic conditions, the adverse effects are due to aluminium, iron and manganese toxicity.

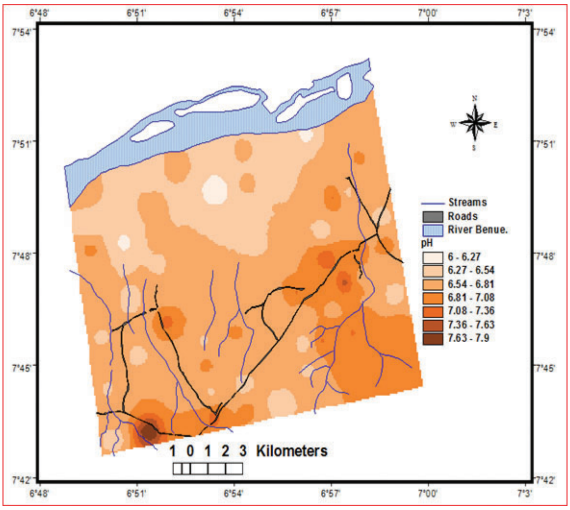

Fig. 5: Spatial distribution of pH

Aluminium toxicity can cause P deficiency symptoms due to precipitation of alumino-phosphate complexes within the plant and in the soil. The observed pH range of the soil seems to be adequate for rice production. Liming and the addition of gypsum will definitely not be necessary in the present situation.

The organic carbon content of the soils ranged from very low (0.32%) to very high (3.58%). The distribution of soil organic carbon (OC) content did not follow a specific pattern as noted for the soil pH (Fig. 6a). However, the area around the flood plains, back swamps, riparian forests and highly vegetated area had the highest OC contents. Generally, it was observed that 1, 35, 26, 15 and 23% of the land had very low (<0.4%), low (0.4 – 1.0%), moderate (1.0 – 1.5%),

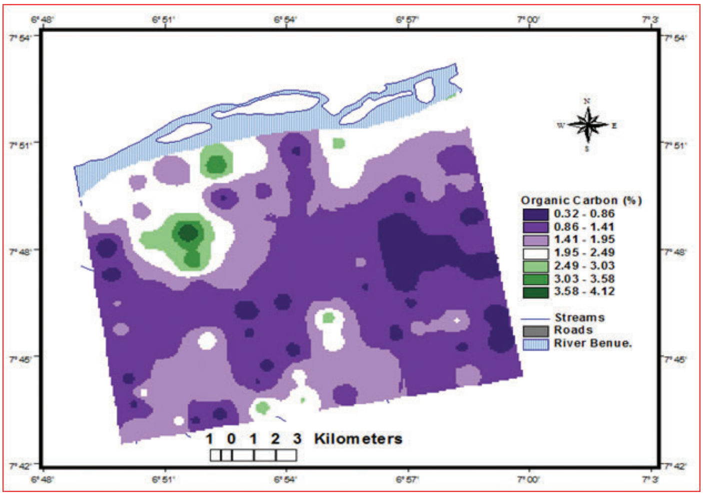

Fig. 6a: Spatial distribution of organic carbon

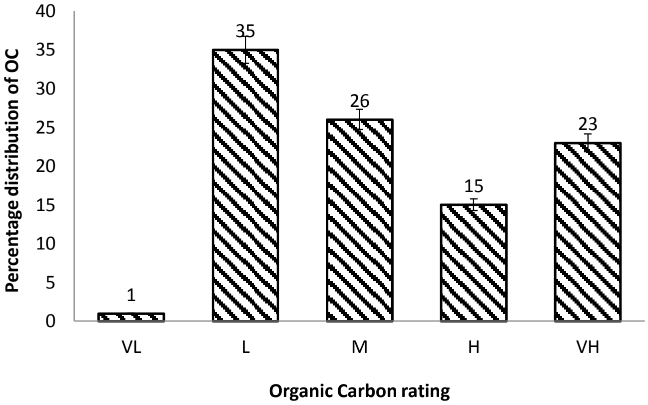

Fig. 6b: Percentage rating of organic carbon
Note: VL= Very low; L = Low; M = Moderate; H = High; VH = Very high

high (1.5 – 2.0%) and very high (>2.0%) OC content respectively (Fig. 6b).

The total nitrogen content of the soils was also generally very low and ranged from very low (0.02%) to moderate (0.22%). The spatial distribution of the soil nitrogen contents (Fig. 7a) indicates that the nitrogen content of 61% of the total area of land is very low (<0.10%), 36% of the total area had low (0.10- 0.20%) total nitrogen content while only 3% of the total land area had moderate (0.20 – 0.50%) nitrogen content(Fig. 7b).

In terms of nutrient requirement, rice requires a highly fertile soil for optimum performance. Soils with moderate to high nitrogen content (0.2%–1.0%) will be

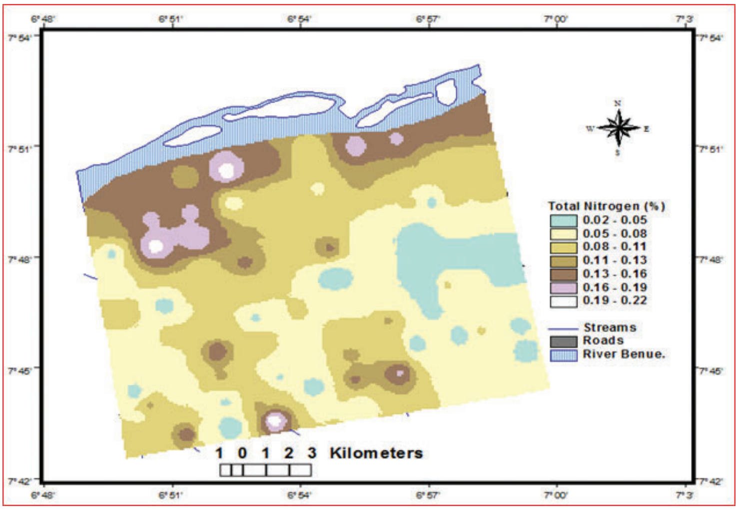

Fig. 7a: Spatial distribution of total nitrogen

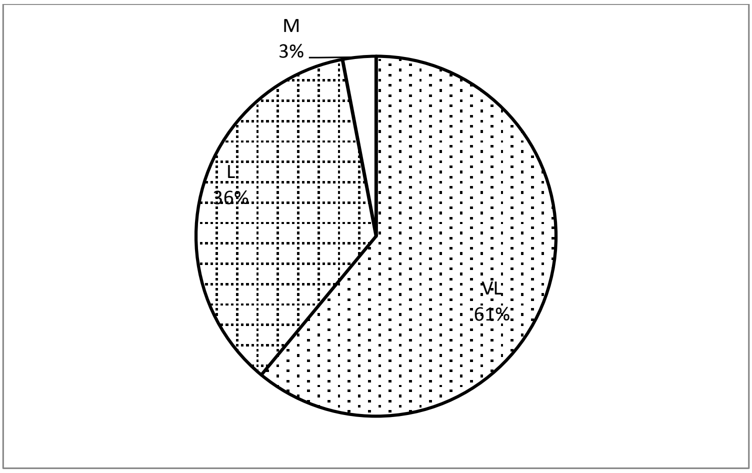

Fig. 7b: Percentage rating of total nitrogen

Note: VL= Very low; L = Low; M = Moderate more appropriate for rice production. Only about 3% of the total land area met this requirement. Thus, application of nitrogen either from organic or inorganic sources will be required for optimum performance of rice on these soils. Since more than 90% of the soil is currently deficient in nitrogen, a renewable source of N, like manure will probably be more viable in the long run.

The exchangeable bases (calcium, magnesium, potassium and sodium) contents of the soils were very low. The exchangeable potassium (K) status of the soil ranged from 0.01 cmolc kg^{-1} (low) to 0.09 cmolc kg^{-1} (very low).

The spatial distribution of K in the soils (Fig. 8) showed that the northern

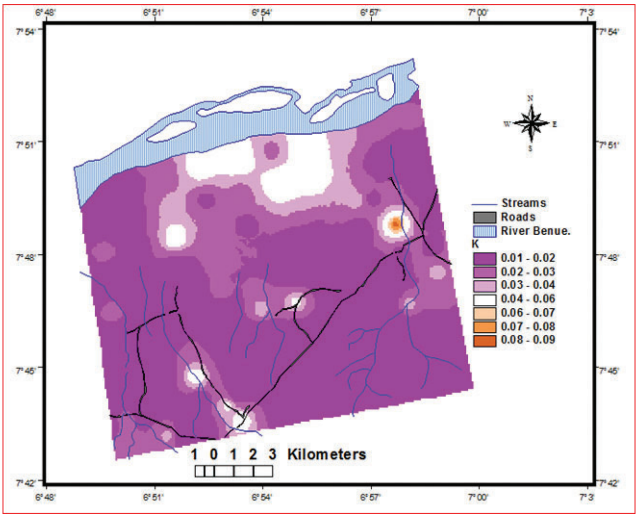

Fig. 8: Spatial distribution of exchangeable potassium

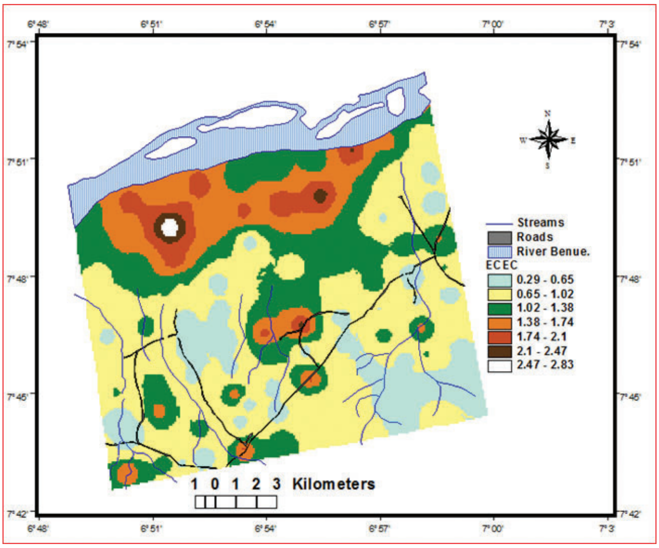

Fig. 9: Spatial distribution of effective cation exchange capacity

part of the area lying close to river Benue contained slightly higher amounts of K than the southern part of the area. The southern part with lower K is presently more intensely cultivated than the northern part that is subjected to seasonal flooding. This may have been the reason for the higher K content of the northern part of the area. For optimum performance, the critical soil K requirement for rice cultivation is 0.30 $cmol_c$ kg^{-1} (Isitekhale *et al.* 2014). As the exchangeable potassium (K) status of the soil of the site is lower than the critical requirement for rice production, potassium fertiliser application will be required to upgrade the productive status of the soil from the current very low level (<0.2 $cmol_c$ kg^{-1}) to moderate or high level (0.6-1.2 $cmol_c$ kg^{-1}). To achieve this, the Federal Fertilizer Department, Federal Ministry of Agriculture and Rural Development (FFD) recommends that 30-40 kg K_2O per hectare be applied (FFD 2011).

The exchangeable sodium (Na), calcium (Ca) and magnesium (Mg) contents of the soils were also very low. While the values of Ca ranged from 0.03 cmolc kg^{-1} to 1.97 $cmol_c$ kg^{-1}, those of Mg ranged from 0.04 to 0.47 $cmol_c$ kg^{-1}. The Na values ranged from 0.03 to 0.17 $cmol_c$ kg^{-1}. The range of values observed for both Ca and Mg content of the soils are grossly inadequate for the production of rice as these values fall below the critical requirement for rice production. The exchangeable sodium percentage (ESP) of the soils are lower than 15% indicating that the soils are not saline. Although the levels of these nutritional elements are low in the soil, care must be taken in their management because of the high pH of the soils (neutral pH).

The effective cation exchange capacity (ECEC), which is a measure of the ability of the soil to store plant nutrients either naturally or with applied fertilisers, is very low. The ECEC of the soils ranged from 0.29 to 2.83 $cmol_c$ kg^{-1} (Fig. 9). This range of values is suboptimal for rice production. Rice production requires soils with CEC greater than 16 $cmol_c$ kg^{-1}. Soils with CEC less than 5 $cmol_c$ kg^{-1} are regarded as highly unsuitable for rice production (Table 1). The spatial distribution of the ECEC shows that the alluvial plain and the adjourning land area have the highest ECEC, ranging from1.02 to 2.47$cmol_c$ kg^{-1}. The highly cultivated areas have lower ECEC values.

The micronutrient status of the soil ranged from low to moderate in copper (Cu) and zinc (Zn) but ranged from high to very high in iron (Fe) and manganese (Mn). The values of Cu in the soils ranged from 0.02 mg kg^{-1} (low) to 0.58 mg kg^{-1} (high) while the values of Zn ranged also from 0.10 mg kg^{-1} (low) to 5.42 mg kg^{-1} (very high). Both Fe and Mn had excessively high values that ranged from 6.21 mg kg^{-1} to 305.0 mg kg^{-1} and from 0.51 mg kg^{-1} to 92.14 mg kg^{-1} respectively.

Rice is highly sensitive to Mn deficiency, and Zn is the most important micronutrient limiting rice growth and yield (Neue *et al.* 1998). According to De Datta (1989), rice performs best when the zinc content of the soils is in the range of 2.0 to 2.5 mg kg^{-1}. Generally, Zn, Fe and Mn deficiency is common on neutral and calcareous soil, intensively cropped soils, paddy soils and poorly drained soils. Fertiliser recommendations for rice production in many parts of Africa often neglect the importance of micro-nutrients in achieving good yield. Thus, the

Africa Rice Center, Cotonou, Benin (Sikirou et al. 2015) accepts the possibility of iron and zinc deficiencies occurring between 1-2 and 3-4 weeks after seedling emergence respectively. This research institute recommended the application of foliar spray of ferrous sulphate or zinc sulphate, only as a corrective measure.

Although the effect of micronutrient toxicity on rice production has not been extensively documented in literature, it is well established that high concentrations of iron and manganese under a fluctuating water table can lead to the formation of plinthites, which is not desirable in agricultural land (Biller and Bruland 2013). Also, Bouwman *et al.* (2013) reported that a high concentration of iron under reducing soil condition or low soil pH can lead to phosphorus fixation, especially when the clay content of the soil is also high.

It is important however, to note that the availability of iron for plant uptake is also controlled by soil pH. In soils with pH values above 5.0, the activity of iron is highly reduced, but when the pH is less than 3.5, iron becomes insoluble.

Practical Implication of Soil Fertility Status

A baseline fertility study such as this is desirable as it helps in determining the optimum quantity of macro and micronutrient application.

Chemical constraints in the soils, such as acidity and low fertility, are relatively easy to correct or control. However, poor physical conditions like soil compaction due to intense mechanisation, impeded drainage or flooding, when limiting, are much more difficult to ameliorate. For this reason, the physical properties of soil are considered as critical factor in rice growth. The soil requirements for the cultivation of rice suggested by Sys *et al*. (1991; 1993) and De Datta (1989) are found in Table 1.

For the production of rice in soils with low fertility status such as these soils, FFD(2011) recommended that nitrogen fertiliser should be applied at a rate of 100kg N per hectare (ha) for low land rice either as NPK 20:10:10 (5 bags basal) with urea (2 bags top-dress) and 80 kg N per hectare for upland rice applied as NPK 20:10:10 (4 bags basal) with urea (1½ bags top-dress).

Similarly, it is recommended that phosphorus be applied at a rate of 30–40 kg P_2O_5 per hectare as SSP (167-225 kg or 3½ - 4½ bags) in soils with low native phosphorus. The recommended rate of application of potassium is 30-40 kg K_2O per hectare. Furthermore, in addition to the recommendation for N, P and K, it is also recommended that to enhance the growth of both upland and lowland rice, foliar spray of Boost Xtra at the rate of 1 litre ha^{-1} be applied four times starting from 4 weeks of planting/transplanting using a spray volume of 200l ha^{-1} of water.

Because of the low effective cation exchange capacity of the soils, a large quantity of fertiliser cannot be added to the soils at once. Therefore split application of fertiliser is suggested for soils with low ECEC (Liverpool-Tasie *et al.* 2015). Furthermore, because of its slower rate of release of nutrients and its effects on the improvement of soil physical and hydrological properties, application of organic manures (FYM at 25 tonnes/ha), growing of green manure crops and turning them into soil is recommended for the cultivation of rice.

TABLE 1

Soil quality characteristic requirement for the production of rice

Land Qualities	$S1_1$	$S1_2$	S2	S3	N1	N2
Topography (t): Slope (%)	<2	3-4	5 – 6	7 - 8	9 – 10	>10
Drainage (s):						
Wetness	WD (ID)†	MWD (ID) †	MD	ID (WD) †	PD (WD) †	PD (WD) †
Flooding	Fo	Fo	F1	F1	F2	F3
Soil physical properties (s)						
Texture	L (LC)†	Lfs (SLC) †	LS (SL) †	S	S	S
Structure	Cr (SAB) †	C (SAB) †	SAB (Cr) †	SAB (Cr) †	Col (Cr) †	Col (Cr) †
Coarse fragments (%) (0-45cm)	<3	3 – 5	5 – 10	10 – 15	>15	
Soil depth (cm)	>75	65 -70	50 – 65	35 – 50	30 – 35	<30
Fertility (f)						
pH	5.5 – 6.5	5.0 - 5.5	4.5 – 5.0	4.0 -4.5	<4.0	
Cation Exchange Capacity (cmol kg^{-1})	>16.0	12.0 -16.0	8.0 -12.0	5.0 – 8.0	<5.0	
Base saturation (%)	>80	70 – 80	50 -70	40 – 50	25 -35	<25
Organic carbon (%) (0-30 cm)	>2.0	2.0 – 1.5	1.2 – 1.5	1.0 – 1.2	1.0	<1.0
Macro- nutrients						
Nitrogen (%)	>2.0	1.5 – 2.0	1.0 – 1.5	0.5 – 1.0	<0.5	
Phosphorus (mg kg^{-1})	>20	15 – 20	8 – 15	5 – 8	3 – 5	<3
Potassium (cmol/kg)	>0.5	0.3 -0.5	0.2 – 0.3	0.1- 0.2	<0.1	
Micro-nutrient (0.5 N Hcl)						
Iron (mg kg^{-1})	>4.5	3.5 – 4.5	2.5 – 3.5	1.5 – 2.5	1.0 – 1.5	<1.0
Zinc (mg kg^{-1})	2.0-2.5	1.5 – 2.0	1.0 – 1.5	0.8 – 1.0	0.6 -0.8	<0.6
Manganese (mg kg^{-1})	1.5 – 1.7	1.0 – 1.5	0.8 – 1.0	0.6 – 0.8	0.5 – 0.6	<0.5

Source: Sys *et al*. (1991, 1993); De Datta (1989)

† = ratings for lowland rice production; SAB =Sub Angular Blocky; Col = Columnar; Cr = crumb; WD = Well Drained; MWD = Moderately Well Drained; ID= Imperfectly Drained; PD = Poorly Drained; L= Loamy; SL= Sandy Loam; LS= Loamy Sand; Lfs = Loamy fine sand; SCL= Sandy Clay Loam; Fo =Rarely flooded; F1= Flooding expected; F2= Irregularly flooded; F3 = regularly flooded.

CONCLUSION

The study concluded that the area under consideration has great potential for sustainable rice production though not without some physico-chemical constraints. The limitations observed in the studied soil for rice production are (i) low soil fertility (macro and micro nutrients), (ii) poor drainage of the alluvial plain, (iii) susceptibility to flooding (alluvial plains) and (iv) steep slopes (hilly) in the southern part. The most critical limitation relates to poor drainage and flooding. To resolve this problem, we recommend designing a proper drainage network along with the construction of strategic dykes to prevent flood waters from river Benue.

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