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Full Length Research Paper

Evaluation of fertility status and irrigation potentials of selected *Fadama* soils in Adamawa State, North-eastern Nigeria

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The study was conducted to determine the fertility status and irrigation potentials of selected Fadama soils in Adamawa State, North-eastern Nigeria. An area of about 54 ha of Fadama land was randomly selected within each site based on their usage for intensive irrigation agriculture. Three transects that are 300 m apart were cut in each of the Fadama areas. Four sampling points that are 150 m apart were located along each transect. The latitude and longitude of the areas sampled were determined with the aid of Global Positioning System (GARMIN, 12 Channel Receiver Model). The samplings were made at (0 to 20 cm) depth with hand trowel at each point. All soil samples were analyzed for physical and chemical properties. The soils were Silt loam, loam and silty clay loam. Soil reaction varied from slightly acidic to neutral. The selected Fadama soils of Adamawa State, North-eastern Nigeria in their present status has low to moderate nutrient with moderate buffering capacity. These areas have potential for irrigation of rice, vegetables and maize crops, using underground and surface water. The incorporation of crop residues and application of inorganic fertilizers to the soils will play an important role in nutrient availability of these soils. Regular soil evaluation is imperative for sustainable crop production and increase yield.

Key words: Fadama soils, potential, nutrients, fertility, irrigation, properties.

INTRODUCTION

In Nigeria, wetland soils are called by various names, Fadama, a Hausa word for wetland soils, has assumed a permanent occupancy in the Nigerian soil science literature (meaning low-lying swamp area consisting of fluvial deposits and containing extensive exploitable aquifers) (Gandi and Radashekara, 1989). The word also refers to a seasonally flooded area used for farming during the dry season. Ojanuga et al. (1996) maintains that these soil types are located in coastal swamps, river/stream, floodplains and inland valleys/depressions. They occupy about 7.2% (783 km^2) of Nigeria's land mass and are spread from the coast in the south to the Sahel regions in the north traversing climatic vegetation, geological and political boundaries. Batjes (1992) noted that many paddy fields and natural floodplains occur in depressed topographic positions and hydrological settings that favour the supply of basic as well as organic matter from surrounding sites. These soils may be mineral or organic. The Fadamas are regarded as rich agricultural areas and contain land and water resources that could easily be developed for irrigation agriculture (Anon, 1993).

The Fadama soils of the northern states of Nigeria have become very prominent in view of their support for intensive agricultural production. The Bauchi State Agricultural Development Project (BSADP, 1994) has estimated that about 4.9 million ha of Fadama land can be obtained and harnessed within the country for accelerated food production. The Fadama potential is

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highest in Adamawa State (625,000 ha.), based on available area for irrigation that is free of forest cover and requires no drainage (Ramalan et al., 1998). These Fadama lands are of considerable value to irrigation agriculture and are mostly used for the irrigation of lowland rice, maize and vegetable crops. Muhammad (2000), in a previous study, revealed that yield of 7.8 tons of paddy rice and 11.5 tons of amaranths were obtained under irrigation in these Fadama areas. He pointed out that, Gerio Fadama creates employment for about 1,400 families on an area of 350 ha, and also create economic activities to 800 men and women who purchase and retail vegetables, rice, fresh maize and sweet potatoes.

The increasing need of crop production for the rising population is causing the rapid expansion of irrigation throughout the world (Farnji and Mahajan, 1996). Therefore, irrigation in Nigeria has become an issue of vital importance considering present population growth rate. According to Mogne (1991), irrigation allows countries to bring otherwise useless land into production, help increase yields by facilitating the introduction of more productive and high-valued crops, and promotes crop intensification by reducing the fallow period and allowing farmers to grow several crops throughout the season.

Soil fertility index such as texture, pH, organic matter content, cation exchange capacity, exchangeable sodium percentage, available phosphorus, percentage nitrogen (%N) and percentage base saturation, are important soil chemical properties influencing nutrient availability and retention in soil. Ponnamperuma (1976) reported that organic matter content ranging from low to high cannot be used to make yield prediction in an irrigation project because land development will likely disturb the topsoil organic matter content. On the other hand, Ankerma and Large (2007) maintained that phosphorus test reading 12 to 15 ppm may be considered adequate for most crops with high yield goals. FAO (1986) found out that the value of cation exchange capacity (CEC) exceeding 8 Cmol (+) kg^{-1} soil reflects soils that are capable of satisfactory production under irrigation. Lombin and Knabe (1981) pointed out that low CEC could be attributed to low organic matter content, low clay content and the kaolinitic mineralogy of the soils.

Check basin irrigation is the most common method of irrigation in these Fadama areas. This is the simplest in principle of all methods of irrigation. There are many variations in its use, but all involve dividing the field into smaller unit areas, between 3 × 3 m area for vegetables and maize and 10 to 15 × 15 to 20 m for rice irrigation, so that each has a nearly level surface. Bunds or ridges are constructed around the areas forming basins within which the irrigation water can be controlled. The basins are filled to the desired depth and the water is retained until it infiltrates into the soil. When irrigating rice, or ponding water, the depth of water may be maintained for considerable periods by allowing water to continue to flow into the basins.

Jamala and Shehu (2011) noted that despite the fact that irrigation is capital intensive, farmers seem to persist on irrigated rice cultivation even though the average land holding of a farmer is half a hectare. The potentials of the Fadama lands in Nigeria for intensive rice cultivation have not been fully exploited and to increase rice production in Nigeria, intensified use of Fadama lands is inevitable. The Fadama areas have potentials for irrigation. Using underground and surface water, they still remain under-developed; limiting significant commercial activities. As a result of their potentials for intensive irrigation agriculture, there is need for adequate and efficient soil fertility evaluation that will provide reliable soil information for sustainable crop production and increase yield per hectare. The World Bank (1992) has estimated that it would take about 30 years before the full potential of the Fadama is fully realized in Nigeria.

Knowledge of the soil fertility status within a potential irrigation area is essential for economic and technical reasons. The design of the irrigation scheme itself is dependent on detailed knowledge of soils lying within the irrigable Fadama areas. Studies and information on soil fertility status of these Fadama soils is scanty; therefore, this study was conducted to determine the fertility status and irrigation potentials of selected Fadama soils in Adamawa State, North-eastern Nigeria. The results of this study will provide soil fertility information within the *Fadama* lands.

MATERIALS AND METHODS

The study area

Adamawa lies between latitudes 8°11′ N and longitude 11.5°E and 13.5°E. The study areas were located at Ngurore, latitude 9° 17′ N and longitude 12° 14′ E; Lake Gerio, latitude 9°16′ N and longitude 12° 44′ E; Mubi, latitude 10° 18′ N and longitude 13° 16′ E and Uba, latitude 10°33′ N and longitude 13° 20′ E. Agriculture is the most important economic activity in the area, employing more than 90% of the labour force. Most of the farmers are subsistence oriented.

The area receives an annual rainfall of 700 to 1600 mm. Rainfall distribution is unimodal, with much of the rain falling between May and October. The wettest months are August and September (Adebayo, 1997). The rainy season is followed by a long dry season. During this period, the area comes under the strong influence of the hammattan (winds that originate in the Sahara and blow across the Sahel region). The hammattan is very dry and as a result, humidity may be as low as 10 to 20% during the dry season.

The temperature characteristics are typical of the West African savannah climate. Temperature in this climate region is high throughout the year because of high radiation income, which is relatively evenly distributed throughout the year (Adebayo and Tukur, 1999). Maximum temperature can reach 40°C particularly in April while minimum temperature can be as low as 18°C between December and January. The mean monthly temperature ranges from 26.7°C in the south to 27.8°C in the north-eastern part (Kowal and Knabe, 1972).

Humidity follows the simple relationship with the change of the seasons. It is generally lowest in the dry season and it is about 20%, and it is very high in the wet season; about 80% in August. An increase in the humidity always precedes the onset of the rains in May.

With the southerly movement of the inter-tropical convergence zone from October to April, the wind blows consistently from the north or more often the north-east. During this period, the area is exposed to very dry winds (the hammattan) blowing from the Sahara, and often carrying a thick haze of wind borne, diatomaceous dust (Carroll and Hope, 1970). From May throughout the summer, it rains until September. The direction is reversed and the wind blows mainly across the area from the southeast.

This area is richly supplied with a network of river and streams. Rivers Benue and Yedsarem form the major rivers. They are joined by numerous tributaries. The topography is generally flat, becoming undulating and hilly toward the northeast.

The soils are generally young and do not show horizon differentiation. The soils are fairly good, and belong to capability classes II and III, and are somewhat uniform across the study area. One distinct soil class can be identified as Typic Topaqualf (United States Department of Agriculture [USDA] classification), or Gleyic Cambisol (FAO).

Soil sampling

An area of about 54 ha of Fadama land was randomly selected within each site. The sampling points were selected in such a way that about 50 m to the edges of the irrigable land were avoided and the bias points like depressions, higher elevations and burnt spots were avoided. Three transects that are 300 m apart were cut in each of the Fadama areas. Four sampling points that are 150 m apart were located along each transect. The samplings were made at 0 to 20 cm depth with hand trowel at each point respectively, giving a total of twelve samples from each site. The latitude and longitude of the areas sampled were determined with the aid of GPS (GARMIN, 12 Channel Receiver Model). Next, the altitude of the Fadama areas (that is, height above sea level) was used to determine the sampling points. At the Mubi Fadama, sampling points are altitude 843, 842.8, 843.1 and 842.9 m (height) above sea level (the upper slope), altitude 841.1, 841, 840.9 and 841.2 m (height) above sea level (the middle slope) and altitude 839.8, 840, 840.2 and 838.9 m (height) above sea level (the down slope); in the Gerio Fadama, points were at altitude 154, 153.7m, 154.1 and 153.9 m (height) above sea level (the upper slope), altitude 153.1, 153, 152.9 and 153 m (height) above sea level (the middle slope) and altitude 152, 152.4, 152.2 and 151.8 m (height) above sea level (the down slope); at the Uba Fadama, sampling points were made up of altitude 828, 827.6, 827.9 and 828.2 m (height) above sea level (the upper slope), altitude 826, 825.8, 826.1 and 826.3 m (height) above sea level (the middle slope) and altitude 824.2, 823.7, 824 and 823.9 m (height) above sea level (the down slope) and at the Ngurore Fadama land, sampling points include altitude 178, 177.5, 178.2 and 176.8 m (height) above sea level (the upper slope), altitude 177, 177.3, 177.1 and 176.8 m (height) above sea level (the middle slope) and altitude 176, 175.5, 176.2 and 175.8 m (height) above sea level (the down slope). Samples were bagged and labelled. They were taken to the laboratory for physical and chemical analysis.

Laboratory analysis

The soil samples of each site was pooled and homogenized, air dried for one week at 28°C, crushed in wooden mortar and sieved with a mesh of 2 mm diameter. All soil samples were analyzed for pH (1:2.5), soil to water ratio with the use of glass electrode pH meter as described by Bates (1954), particle size, using hydrometer method as described by Bouyoucos (1951), electrical conductivity, and soil organic carbon, using chromic acid oxidation procedure of Walkley and Black (1934). Available phosphorus was extracted with 1 N NH_4F and 0.5 N HCl (Bray and Kurtz, 1945) at the wavelength of 660 nm, the titrimetric method for the determination of calcium and magnesium in the soil was as described by Black (1965). The regular Macro-Kjeldahl method as described by Black (1965) was used for the determination of soil total nitrogen; potassium and sodium was determined in 1 M neutral NH_4Ac soil extract using flame photometry and exchangeable acidity (the titration method) as described by Mclean (1965). The effective cation exchange capacity and cation exchange capacity were determined by summation method. The exchangeable sodium percentage was obtained by expressing the exchangeable sodium as percentage. The percentage base saturation was obtained by expressing the cation exchange capacity as a weight percentage of effective cation exchange capacity. The sodium adsorption ratio was obtained by dividing the ion concentration of the sodium with the square root of the sum of half the ion concentration of calcium and magnesium.

RESULTS AND DISCUSSION

The soil texture of the study areas ranges from loam in Mubi Fadama, silt clay in Ngurore Fadama and silt loam in both the Gerio and Uba Fadama soils (Table 1). The soil pH measured in water of Gerio, Ngurore and Uba Fadama soils varied from slightly acidic to neutral (FAO, 2005), while in the Mubi Fadama, the soil reaction was observed to be neutral. It is indicative that the pH range was optimum for the irrigation of most crops, but proper management should be maintained in order to reduce the chances of alkalinity hazards. The organic carbon content (Figure 2) was high in the Gerio, Ngurore and Mubi Fadama soils and moderate in the Uba silt loam soils. Soil organic carbon plays an important role in nutrient availability and soil aggregate formation (Yan et al., 2007).

The percentage nitrogen of the various Fadama soils (Figure 3) range from very low to low, below 0.15% critical level was recommended (Sobulo and Osiname, 1981; Agboola et al., 1982). Available phosphorus (Figure 4) was found to be low in Gerio, Ngurore and Mubi Fadama soils and very low in the Uba Fadama silt loam soils, as also observed by Enwezor and Sobulo (1981), indicating serious deficiency problem of phosphorus. Agboola et al. (1982) recommended a critical level of 8.1 mgkg^{-1} soil. A range of 3 to 30 mgkg^{-1} soil has also been reported (Mamza, 1997). The exchangeable potassium (Figure 5) generally ranged from moderate to high in all the soils under consideration (Sobulo and Osiname, 1981). Boul et al. (1975) suggested a critical minimum of 0.2 Cmol (+) kg^{-1} soil. The value of exchangeable calcium (Table 1) indicate moderate to high calcium status of the various Fadama soils.

Exchangeable magnesium values were high to very high. Thus, magnesium is likely to constitute constraints to agricultural productivity in these Fadama soils. The exchangeable sodium percentage (ESP) of the various soils falls within the limit of 1 to 15%. This indicates that salinity problem is not anticipated in these areas. The effective cation exchange capacity (Figure 1) was moderate in the Gerio Fadama (20.83 Cmol (+) kg^{-1}) soil, Uba Fadama (15.21 Cmol (+) kg^{-1}) soil and Ngurore

Table 1. Characteristics of Fadama soils in Adamawa State.

Property	Gerio Fadama	Uba Fadama	Ngurore Fadama	Mubi Fadama
Textural class	SCL	SL	SCL	L
pH (1:2.5) In H_2O	6.8	6.6	6.4	7.3
O/C	1.97	1.37	1.67	1.87
% N	0.05	0.04	0.03	0.03
P mg/kg	5.2	2.1	3.1	6.6
K Cmol (+)kg^{-1}	0.81	0.75	0.60	1.46
Na Cmol (+)kg^{-1}	0.12	0.11	0.13	0.12
Ca Cmol (+)kg^{-1}	13.2	7.2	11.2	7.6
Mg Cmol (+)kg^{-1}	6.6	7.0	8.3	3.6
EC (ms/cm)	0.1	0.15	0.12	0.08
ECEC Cmol (+)kg^{-1}	20.83	15.21	20.35	12.86
ESP	12	11	13	12
PBS	99.5	98.9	99.4	99.3
SAR	0.038	0.041	0.042	0.051

SL: silt loam; L: loam; SCL: silty clay loam.

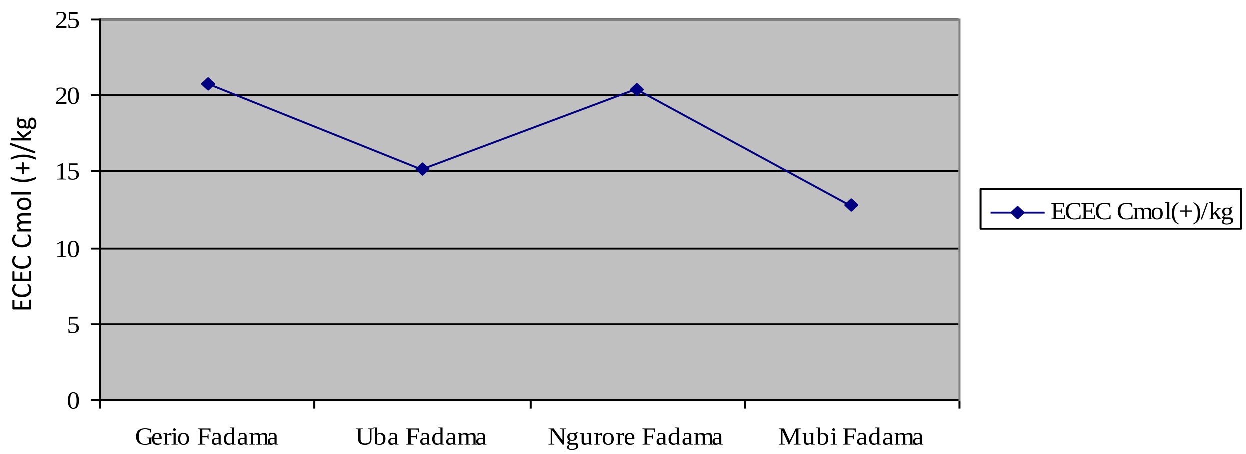

Figure 1. Distribution of ECEC of Fadama soils of Adamawa State.

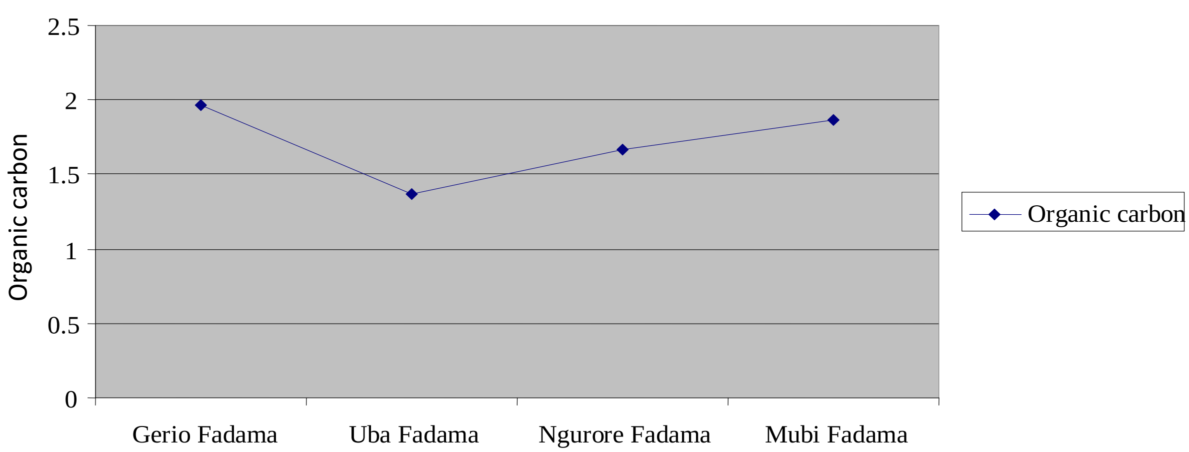

Figure 2. Distribution of organic carbon of Fadama soils of Adamawa State.

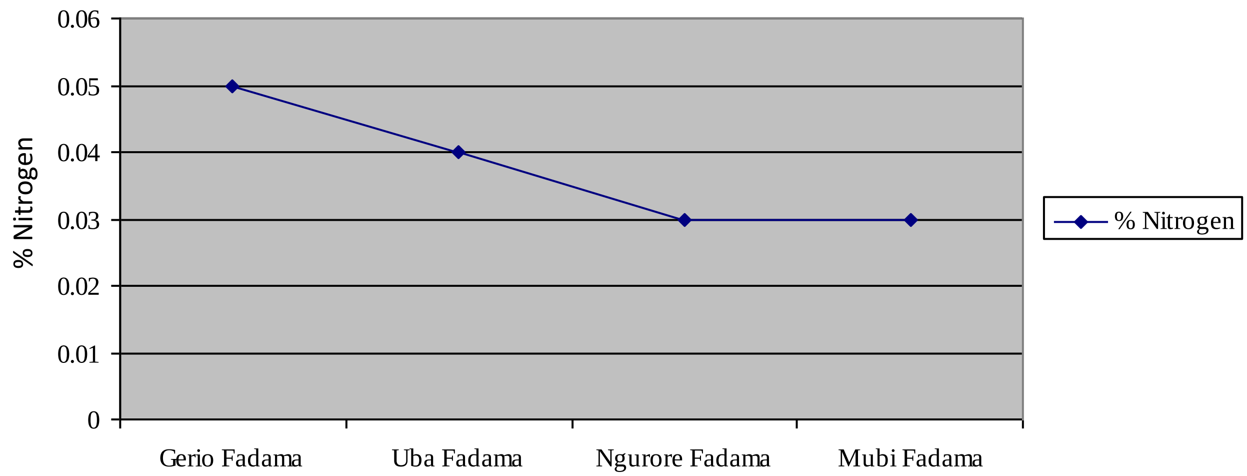

Figure 3. Distribution of % N of Fadama soils of Adamawa State.

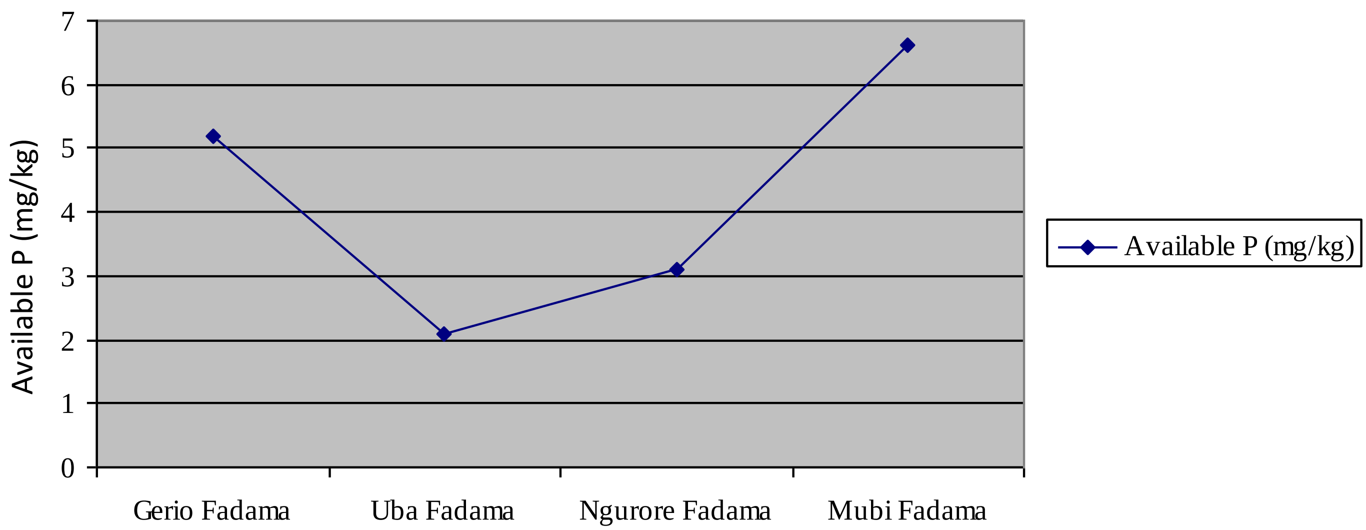

Figure 4. Distribution of available P of Fadama soils of Adamawa State.

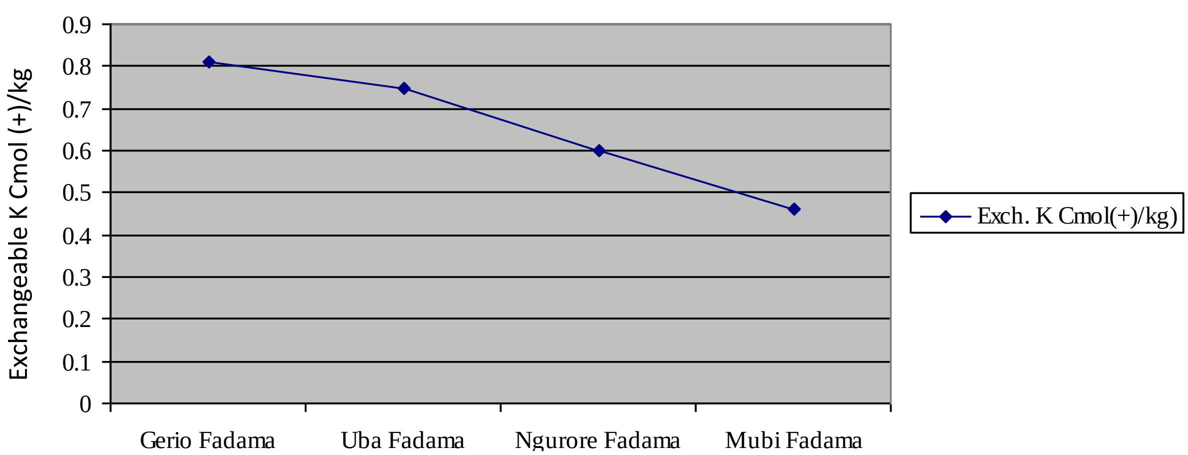

Figure 5. Distribution of exchangeable K of Fadama soils of Adamawa State.

Fadama (20.35 Cmol (+) kg^{-1}) soil. In the Mubi Fadama, it was found to be low (12.86 Cmol (+) kg^{-1} soil). This could be attributed to the low clay content of the soils, and this agreed with earlier findings (Lombin and Knabe, 1981).

Conclusion

The selected Fadama soils of Adamawa State, North-eastern Nigeria in their present status have low to moderate nutrient content with moderate buffering capacity. These areas have potential for irrigation of rice, vegetables, and maize crops, using underground and surface water. The incorporation of crop residues to the soils will play an important role in nutrient availability and soil aggregate formation of these soils. Inorganic fertilizers are also required in order to enhance crop growth and performance. Regular soil evaluation is imperative for sustainable crop production and increase yield.

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