Assessment of the Effects of Seasonal Flooding on the Properties of Floodplain Soils of Wukari, Taraba State, Nigeria

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Authors’ contributions

This work was carried out in collaboration among all authors. Author ATG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors TB and AC managed the analyses of the study. Authors TB and ATG managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The aim of this study was to examine the effects of seasonal flooding on the properties of floodplain soils of Wukari Area of Taraba state. The treatments consisted of five different locations of Gidan-Idi, Gindin-Dorowa, Tsokundi, Rafin-Kada and Nwuko and three different soil sample depths of 0-20 cm, 20-40 cm, and 40-60 cm laid out in a completely randomized design (CRD) and replicated three times. Soil samples were collected from each plot in 2016 and 2017. All soil samples were analyzed for physical and chemical properties. The results obtained were subjected to analysis of variance and means separated using F-LSD test at p≤0.05. The results of the soil properties analysis showed that some of the determined parameters were significantly different at the different sample locations at p≤0.05. The soils of Wukari Floodplains are mostly clay loam in texture having very slightly acid to

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neutral soil reaction, moderate organic matter, low total N, moderate available P, low exchangeable bases and CEC. The flood plain soils were moderate in soil fertility, a confirmation of the general characteristic of Savanna soils. The soils were not deficient in micronutrients. Seasonal flooding had significant (positive) influence on some physical and chemical properties of the flood plains most particularly at Rafin-Kada.

Keywords: Soil; floodplain; effects; assessment; properties.

1. INTRODUCTION

Flooding is the most common of all environmental hazards and it regularly claims over 20,000 lives per year and adversely affects around 75million people worldwide, causing about one third of all deaths, one third of all injuries and one third of all damages, from natural disasters [1]. In Nigeria, floods are common features during the rainy season (May-October) occurring naturally on the flood plains when water in the rivers and their tributaries overflow their banks. These floods are usually restricted to the river flood plains which are low lying coastal areas of the country. Annual floods occur in different environments in Wukari Local Government Area (LGA). The existence of a distinct wet and dry season in Wukari allows for these fluctuations of the water level in these areas. Floodplains of rivers, the margins of lakes and (seasonal) wetlands, are the environments where the water level changes within the year and are therefore suitable for the practice of flood recession agriculture. In Wukari LGA, the wet season starts from April and ends in October and sometimes November, with mean annual rainfall of 1300 mm and mean air temperature of 28°C. Wukari LGA falls under the tropical sub-humid climate with distinct dry and wet season with high temperature throughout the year. The climate is classified as the Aw according to Koppen’s classification Scheme [2]. These environments exist in the high and lowlands in Wukari LGA and are distributed all over the local government area. Flood recession areas are often classified as wetland areas, and there may be competition with other wetland uses. The spread of the wetland areas gives a first indication where flood recession farming occurs [3,2]. Productive soils are developed in situ as land tends to be immovable; the resultant benefits however are diffusing in that air, water and climate are not limited spatially [2,4].

During flooding, lands and buildings are submerged rendering many people homeless, properties destroyed and lives lost [2]. After floods, the assessment of damages typically centers on homes, business, roads, utility services, lives lost and others, forgetting that flood water also can have pronounced influence on soil physical and chemical properties as well as creating potentially serious environmental issues. During the flood some of the things destroyed transported and finally deposited on the soil, especially those from contaminated sites may contain toxic elements, and these may affect both the physical and chemical properties of the soil [2]. The effects of flooding on the fertility status of floodplain soils are subject of unusual scientific interest and great practical importance. Its scientific interest derives from the many unusual features of flooded soils, its practical importance need no emphasis. Floodplain soils are commonly rich agriculturally but these areas are liable to the danger of water-borne pollution and inundation. Floodplains are at one end, and the same time profitable, hazardous and rapidly change geo-morphologically in the environments. To some degree, nutrient rich materials that are lost by upland soils are deposited on the river floodplains and delta. Physicochemical properties of soil are complex, often non-linearly related and spatially and temporarily dynamics [2]. Although there have been many studies on soil physicochemical properties of soil, only little systematic attempts in northeastern Nigeria have been made to understand the fertility behaviour of floodplain soils. There has also been limited information on the physical and chemical properties of soils affected by the recent Nigerian flood disaster particularly as it affects soil properties. The study is limited to the floodplain soils of Nwuko, Tsokundi, Rafin-Kada, Gidan-Idi and Gindin-Drowa all in Wukari LGA of Taraba state, Nigeria. Therefore objective of this study include, to determine the physicochemical properties of the floodplain soils of Wukari LGA of Taraba State, Nigeria, in order to assess the effects of seasonal flooding on the properties of the floodplain soils of the study area.
2. MATERIALS AND METHODS

2.1 Description of the Study Area

The floodplain soils of Gidan-Idi, Gindin-Dorowa, Tsukundi, Rafin-Kada and Nwuko are located in Wukari LGA of Taraba State, Nigeria. The soils are mostly alluvial savanna soils Wukari Local Government Area lies on latitude 7°51’N, longitude 9°47’E and 152 m above sea level. Total land area is 4,308 km² and total population is 241,546 by the 2006 census. Wukari LGA is located in the Northern Guinea Savannah agro-ecological zone of Nigeria and has 2 distinct seasons; wet and dry. The wet season starts from April and ends in October, with mean annual rainfall range of 1200-1300 mm and mean air temperature of 28°C and can reach 40°C in March. Wukari Local Government Area has common boundaries with Ibi LGA to the North-West; Gassol LGA to the North-East; Donga LGA to the South-East; and Benue State to the South-West. The common tillage practices in the floodplain soils include animal tractions by use of ox-drawn plough and tractor mounted harrows. The common crop grown is rice (*Oryza sativa*). Secondary crops include sugar cane (*Saccharum officinarum*), vegetables (*Onions* (*Allium cepa*), *pepper* (*Capsicum anuum*), *greens*) and maize (*Zea mays*). Fishing activities such as cat fish (*Siluriformes*), lung fish (*Dipnoi*) and brick making are common.

2.2 Soil Sample Collection

Soil samples were collected from five different flood affected towns in Wukari LGA of Taraba State, Nigeria, using soil auger in 2016 and 2017. In each location, samples were collected at depths 0-20 cm, 20-40 cm and 40-60 cm respectively. The composite samples from each were bulked and homogenized and representative samples were finally taken after series of coning and quartering.

2.3 Soil Sample Preparation

The soil samples were air-dried for a period of one week in a clean well ventilated laboratory, homogenized by grinding, passed through a 2 mm (10mesh) stainless sieve and stored in labeled polythene bags ready for analysis.

2.4 Soil Sample Analysis

The particle-size distribution (soil texture), was determined using Bouyoucos hydrometer method for mechanical analysis [5]. Soil particle density determined using pycnometer method. Bulk density was determined by the Core Sampler Method of known soil volume [6]. Soil porosity was calculated from the soil densities; bulk and particle densities using formula.

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\text{Porosity,} \% = 1 - \frac{\text{Bulk density}}{\text{Particle density}}
\]

Available water capacity was determined with pressure plate apparatus as described by [7]. Water holding capacity was determined as gravimetric water content of a quantity of soil fully saturated with water. It was determined using porous cup method.

Soil pH was measured electrometrically using glass electrode pH meter in a solid-liquid ratio of 1:2.5 [8]. The Electrical conductivity (EC) was determined alongside pH (soil water suspension) using EC meter device. Total organic carbon was analysed by wet digestion and the organic carbon content was multiplied by a factor (1.724) to get the percentage organic matter [9]. Total nitrogen was determined by micro-Kjeldahl digestion method [10]. Available phosphorous was determined by Bray I method according to the procedure of [9]. Exchangeable bases were determined by the neutral ammonium acetate procedure buffered at pH 7.0 [11]. Exchangeable acidity was determined by titration method. Cation exchange capacity was determined using neutral ammonium acetate leachate method [12]. Base saturation was computed as total exchangeable bases divided by cation exchange capacity. Exchangeable sodium percentage (ESP), sodium absorption ratio (SAR), and carbon-nitrogen (C/N) ratio were all determined by mathematical expressions. Extractable iron and aluminium were determined by the sodium citrate, sodium bicarbonate and sodium dithionite (CBD) method described by [13]. All reagents used in this study were of pure analytical grade and all the analyses were done in duplicate.

2.5 Statistical Analyses

The statistical analysis follows a five (5) treatment (location) effects with three (3) replications each in a randomized linear model.
procedure of statistic 8.0 version 2004 for ANOVA to test significant effect at 95% confidence limit using the procedure by [14]. If significant differences are observed, treatment means was separated using F-LSD.

3. RESULTS AND DISCUSSION

3.1 Effects of Seasonal Flooding on Soil Physical Properties of the Floodplains

The effects of seasonal flooding on soil physical properties of the study sites in 2016 and 2017 are presented in Tables 1 and 2 respectively. The parameters assessed include particle size distribution, particle density, bulk density, porosity, available water capacity and water holding capacity.

3.2 Particle Size Distribution

The lowest value of mean sand fraction of the soil recorded in the flood plains is 34.7% while the highest mean value is 37.8%, the lowest value of mean silt fraction of the soil recorded in the flood plains is 26.0% while the highest mean value is 28.5% and the lowest value of mean clay fraction of the soil recorded in the flood plains is 35.8% while the highest mean value is 37.7%. Generally, the mean values indicate that the clay fraction dominated the fine earth separate. This was closely followed by the sand fraction, while the silt fraction was the lowest. The soil textures in these areas are mainly clay loam, which is medium texture. The statistical analysis performed showed that the sand fraction was significantly in the year 2016 at the soil depth of 0-20 cm but not significantly different at the soil depth of 20-40 cm and 40-60 cm and in 2017, the sand fraction was not significantly different at the soil depth of 0-20 cm but was significantly different at the depths of 20-40 cm and 40-60 cm at P≤0.05 level of significance. The values of sand within the range of 28.0-40.0% was reported by [15] for soils of Geriyo irrigation project (GIP), Yola, Adamawa state and 26.91-37.15% mean values of 2 years research earlier reported by [16] for soils of River Galma in Zaria, Kaduna state, Nigeria.

The silt fraction was not significantly different at P≤0.05 in the year 2016 at all the soil depths and in 2017 the silt fraction was not significantly different at the soil depth of 0-20 cm but was significantly different at the depths of 20-40 cm and 40-60 cm at P≤0.05 level of significance. However, increase in silt content with seasonal flooding may add to soil fertility [2]. The clay fraction of the floodplain soils were significantly different at all the soil sample depths in 2016 and in 2017 the clay fraction significantly different at the soil depth of 0-20 cm but was not significantly different at the depths of 20-40 cm and 40-60 cm at P≤0.05 level of significance. The means separation using F-LSD at 0.05 probability levels showed the differences among some of the flood plain locations are statistically significant for the sand, silt and clay soil fractions.

3.3 Soil Densities and Porosity

The lowest value of mean soil particle density recorded in the flood plains is 2.50 g/cm³ while the highest mean value is 2.53 g/cm³. This agrees with [17], who reported that the average arable minerals soils of high organic matter may be considered to have a particle density of 2.4 to 2.5 g/cm³. The Analysis of Variance (ANOVA) test confirm the observed variations, in that, the differences amongst the different flood plain locations are statistically significant at 0.05 probability level for the soil depth of 40-60 cm but not significantly different at the soil depths of 0-20 cm and 20-40 cm in 2016 and in 2017 the difference amongst the different locations are statistically significant at 0.05 probability level for soil depth of 20-40 cm but not significantly different at the soil depths of 0-20 cm and 40-60 cm. The analysis of means using F-LSD at P≤0.05 shows that only few of the location means are statistically different.

Bulk density of the flood plains had lowest mean value of 1.30 g/cm³ and highest mean value of 1.33 g/cm³. These values also agree with [17] that density of clay loam surface normally ranged from 1.00 to 1.60 g/cm³. Plant performs best in bulk densities below 1.4 g/cm³ and 1.6 g/cm³ for clayey and sandy soils respectively [18]. Root growth could also be inhibited due to high bulk density because of soil resistance to root perpetration, poor aeration, slow movement of nutrients and water and the accumulation of toxic gases and root exudates [19,20]. The bulk density values of the flood plains were lower than 1.6 g/cm³, thus rated medium, a range considered not to impede root penetration [18]. Therefore bulk density will not be a retarding factor for crop cultivation in the study area. The ANOVA test confirm the observed variations, in that, the differences amongst the different flood plain locations are statistically significant at 0.05 probability level for
the soil depths of 0-20 cm and 20-40 cm but not statistically significant at the soil depth of 40-60 cm in 2016 and the in 2017 the difference amongst the different locations are statistically insignificant at 0.05 probability level for all the soil depths. The analysis of means using F-LSD at ps.05 shows that only few of the location means are statistically different.

Porosity is a measure of the volume of voids in the soil, that is those parts of the soil volume not occupied by solids but either by air or/and water. On the average, the lowest soil porosity obtained from the flood plains was 47.15% while the highest porosity obtained was 49.01%. The soils of the flood plains were porous as [21] recommended that soils having porosity of 45-50% by volume are good agricultural soils. Therefore, porosity is not a limiting factor in this present study since all the soils are within a range of 45-50%. The ANOVA showed that porosity of the floodplain soils were significantly different at the soil depths of 0-20 cm and 20-40 cm but not significantly different at the soil depth of 40-60 cm in 2016 and in 2017 the porosity of the soil locations statistically insignificant for all the sample depths at ps.05 level of significance. The means separation using F-LSD at 0.05 probability levels showed the differences among some of the mean water holding capacity of the flood plain locations are statistically significant.

3.4 Available Water Capacity and Water Holding Capacity

The lowest value of mean available water capacity recorded in the flood plains is 0.25 m/m while the highest mean value is 0.27 m/m. Generally, the available water capacity of these soils is low. With this low available water capacity, irrigation application of the basin method will be appropriate since no run-off of soil or water takes place and wetting depth can be more uniform. It is best suited for soils of moderate to low infiltration rates. The ANOVA showed that available water capacity of the floodplain soils was statistically insignificant for all the soil sample depth in both 2016 and 2017 at ps.05 level of significance.

Water holding capacity of the flood plains had lowest mean value of 79.7% and highest mean value of 85.4%. This shows that the soils have fairly high water holding capacities. The high water content of the flood plains is expected due to high organic matter and clay content. The ANOVA showed that water holding capacity of the floodplain soils were significantly different at the depths of 20-40 cm and 40-60 cm but not significantly different at the soil depth of 0-20 cm in 2016 and in 2017, the water holding capacity of the floodplain soils were significantly different at the depth of 0-20 cm but not significantly different at the depths of 20-40 cm and 40-60 cm at ps.05 level of significance. The means separation using F-LSD at 0.05 probability levels showed the differences among some of the mean water holding capacity of the flood plain locations are statistically significant. Similar values of 0.24-0.27 m/m were recorded for fadama soils in south eastern Nigeria [22,23].

3.5 Effects of Seasonal Flooding on Soil Chemical Properties of the Floodplains

Table 3 shows the effects of seasonal flooding on soil chemical properties of the study sites in 2016 and Table 4 is the effects of seasonal flooding on soil chemical properties of the study sites in 2017. The parameters considered under chemical properties include pH, electrical conductivity (EC), organic carbon (OC), organic matter (OM), total nitrogen (TN), available phosphorus (AP), exchangeable bases (Ca, Mg, Na and K), exchangeable acidity (H+Al), cation exchange capacity (CEC), base saturation (BS), exchangeable sodium percentage (ESP), sodium absorption ratio (SAR), carbon-nitrogen ratio (C-N ratio), iron oxide (FeO) and aluminium oxide (Al₂O₃).

3.6 Soil pH and Electrical Conductivity

The soils of the flood plains had mean pH values range from 6.44 to 7.37. Soil reaction was slightly acidic to neutral [24]. According to [24], a pH range of 5.5 to 7.0 is the preferred range for most crops. These values are within the pH requirement for most arable crops for nutrient up take [25]. The Analysis of Variance (ANOVA) test confirms the observed variations, in that, the differences amongst the different flood plain locations are statistically significant for all the soil sample depths in 2016 but are statistically insignificant for all the soil sample depths in 2017 at 0.05 probability level. The analysis of means using F-LSD at Ps≤0.05 shows that only few of the location means are statistically different.
Table 1. Effects of seasonal flooding on soil physical properties of the study sites in 2016

| Soil Depth (cm) | Location     | Particle size distribution | Textural Class | Particle density (g/cm³) | Bulk density (g/cm³) | Porosity (%) | AWC (m/m) | WHC (%) |
|----------------|--------------|-----------------------------|----------------|--------------------------|----------------------|--------------|-----------|----------|
| 0-20           | NWRS         | 35.0 27.6 37.4              | CL             | 2.52 1.32                | 47.42 0.27           | 84.7         | 83.3      |          |
|                | TSRS         | 37.0 25.7 36.9              | CL             | 2.51 1.31                | 47.88 0.26           |             |           |          |
|                | RKRS         | 39.1 24.9 36.7              | CL             | 2.52 1.33                | 47.09 0.26           | 84.1         |           |          |
|                | GIRS         | 39.0 25.0 36.0              | CL             | 2.51 1.32                | 47.61 0.25           | 84.6         |           |          |
|                | GDRS         | 35.1 27.5 37.4              | CL             | 2.54 1.32                | 48.03 0.26           | 83.9         |           |          |
| 20-40          | NWRS         | 36.0 27.0 37.0              | CL             | 2.52 1.31                | 48.88 0.27           | 86.1         |           |          |
|                | TSRS         | 36.7 26.3 37.0              | CL             | 2.53 1.30                | 48.75 0.26           | 83.3         |           |          |
|                | RKRS         | 37.7 26.3 36.0              | CL             | 2.52 1.33                | 47.15 0.26           | 83.7         |           |          |
|                | GIRS         | 38.0 25.0 37.0              | CL             | 2.50 1.32                | 47.14 0.26           | 84.6         |           |          |
|                | GDRS         | 35.5 27.1 37.4              | CL             | 2.52 1.31                | 47.82 0.26           | 83.1         |           |          |
| 40-80          | NWRS         | 35.4 27.2 37.3              | CL             | 2.51 1.31                | 48.08 0.26           | 84.9         |           |          |
|                | TSRS         | 37.0 26.0 37.0              | CL             | 2.53 1.31                | 48.28 0.26           | 83.0         |           |          |
|                | RKRS         | 37.0 27.0 36.0              | CL             | 2.53 1.33                | 47.36 0.25           | 83.5         |           |          |
|                | GIRS         | 37.7 25.3 37.0              | CL             | 2.53 1.31                | 48.16 0.27           | 87.6         |           |          |
|                | GDRS         | 35.5 27.1 37.4              | CL             | 2.51 1.31                | 47.81 0.26           | 83.0         |           |          |

F-LSD = 0.05

| Soil Depth (cm) | Location     | Particle size distribution | Textural Class | Particle density (g/cm³) | Bulk density (g/cm³) | Porosity (%) | AWC (m/m) | WHC (%) |
|----------------|--------------|-----------------------------|----------------|--------------------------|----------------------|--------------|-----------|----------|
| 0-20           | NWRS         | 34.9 28.8 38.6              | CL             | 2.51 1.32                | 48.54 0.26           | 80.1         |           |          |
|                | TSRS         | 37.8 26.2 36.0              | CL             | 2.50 1.32                | 47.27 0.26           | 85.7         |           |          |
| 20-40          | NWRS         | 36.0 27.0 37.0              | CL             | 2.53 1.32                | 46.57 0.26           | 86.0         |           |          |
|                | TSRS         | 36.7 27.7 35.8              | CL             | 2.51 1.31                | 47.75 0.25           | 82.7         |           |          |
|                | RKRS         | 35.7 27.5 36.8              | CL             | 2.51 1.30                | 48.11 0.26           | 79.7         |           |          |
|                | GIRS         | 36.0 27.3 36.7              | CL             | 2.54 1.32                | 47.83 0.27           | 83.3         |           |          |
|                | GDRS         | 36.1 26.9 37.0              | CL             | 2.52 1.32                | 47.41 0.27           | 81.7         |           |          |

F-LSD = 0.05

Key: NWRS-Nwuko floodplains; TSRS-Tsokundi floodplains; RKRS-Rafin Kada floodplains; GIRS-Gizandó floodplains; GDRS-Gindin Dorowa floodplains; CL- Clay Loam; F-LSD-Fischer’s Least Significant Difference

Table 2. Effects of seasonal flooding on soil physical properties of the study sites in 2017

| Soil Depth (cm) | Location     | Particle size distribution | Textural Class | Particle density (g/cm³) | Bulk density (g/cm³) | Porosity (%) | AWC (m/m) | WHC (%) |
|----------------|--------------|-----------------------------|----------------|--------------------------|----------------------|--------------|-----------|----------|
| 0-20           | NWRS         | 34.9 26.2 38.6              | CL             | 2.51 1.32                | 48.54 0.26           | 80.1         |           |          |
|                | TSRS         | 37.8 26.2 36.0              | CL             | 2.50 1.32                | 47.27 0.26           | 85.7         |           |          |
| 20-40          | NWRS         | 36.0 27.0 37.0              | CL             | 2.53 1.32                | 46.57 0.26           | 86.0         |           |          |
|                | TSRS         | 36.7 27.7 35.8              | CL             | 2.51 1.31                | 47.75 0.25           | 82.7         |           |          |
|                | RKRS         | 36.0 27.3 36.7              | CL             | 2.54 1.32                | 47.83 0.27           | 83.3         |           |          |
|                | GIRS         | 36.7 26.7 36.7              | CL             | 2.51 1.31                | 47.61 0.26           | 82.7         |           |          |
|                | GDRS         | 36.1 26.9 37.0              | CL             | 2.52 1.32                | 47.41 0.27           | 81.7         |           |          |

F-LSD = 0.05

| Soil Depth (cm) | Location     | Particle size distribution | Textural Class | Particle density (g/cm³) | Bulk density (g/cm³) | Porosity (%) | AWC (m/m) | WHC (%) |
|----------------|--------------|-----------------------------|----------------|--------------------------|----------------------|--------------|-----------|----------|
| 0-20           | NWRS         | 34.8 28.5 36.5              | CL             | 2.52 1.32                | 47.62 0.26           | 81.7         |           |          |
|                | TSRS         | 36.7 27.7 35.8              | CL             | 2.51 1.31                | 47.88 0.26           | 83.6         |           |          |
| 20-40          | NWRS         | 36.0 27.3 36.7              | CL             | 2.54 1.32                | 47.83 0.27           | 83.3         |           |          |
|                | TSRS         | 36.7 27.7 35.8              | CL             | 2.51 1.31                | 47.88 0.26           | 83.6         |           |          |

F-LSD = 0.05

Key: NWRS-Nwuko floodplains; TSRS-Tsokundi floodplains; RKRS-Rafin Kada floodplains; GIRS-Gizandó floodplains; GDRS-Gindin Dorowa floodplains; CL- Clay Loam; F-LSD-Fischer’s Least Significant Difference
| Soil Depth (cm) | Location | Particle size distribution | Textural class | Particle density (g/cm³) | Bulk density (g/cm³) | Porosity (%) | AWC (m/m) | WHC (%) |
|----------------|----------|----------------------------|----------------|--------------------------|---------------------|--------------|-----------|---------|
| F-LSD 0.05     | NWRS     | 1.08                       | Sand (%)       | 0.85                     | -                   | 0.02         | -         | 0.25    | 84.1    |
|                | TSRS     | 35.0                       | Silt (%)       | 28.6                     | 36.5                | 2.51         | 1.33      | 47.15   | 0.27    | 84.1    |
|                |          | 36.3                       | Clay (%)       | 28.0                     | 36.3                | 2.52         | 1.31      | 47.95   | -       | -       |
| 40-60          | RRKS     | 36.3                       |                |                          |                     |              |           |         |         |
|                | GIRS     | 36.3                       |                |                          |                     |              |           |         |         |
|                | GDRS     | 36.1                       |                |                          |                     |              |           |         |         |
| F-LSD 0.05     |          | 0.82                       |                |                          |                     |              |           |         |         |

Key: NWRS-Nwuku floodplains; TSRS-Tsokundi floodplains; RRKS-Kafin Kada floodplains; GIRS-Gidan Dorowa floodplains; GDRS-Gidan Dorowa floodplains; CL-Clay Loam; F-LSD-Fisher's Least Significant Difference

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Table 3. Effects of seasonal flooding on soil chemical properties of the study sites in 2016

| Depth (cm) | Location | pH (H₂O) | EC dS/m | OC (%) | OM (%) | Total N (%) | Avail P (%) | K | Ca | Mg | Na | TEB Cmol (+/kg) | EA | CEC | BS (%) | ESP (%) | SAR | C/N Ratio | FeO g/kg | Al oxides g/kg |
|------------|----------|----------|---------|--------|--------|-------------|-------------|---|----|----|----|----------------|----|-----|--------|---------|-----|-----------|----------|----------------|
| NWRS       | 6.73     | 1.23     | 1.46    | 2.52   | 0.165  | 0.32        | 4.3         | 0.81| 0.21| 5.63| 5.15| 10.79         | 52.1| 1.97| 0.13   | 8.86    | 3.9 | 0.7       |
| TSRS       | 7.03     | 1.27     | 1.48    | 2.56   | 0.123  | 0.26        | 4.1         | 0.73| 0.23| 5.35| 4.78| 10.13         | 52.8| 2.33| 0.15   | 12.06   | 3.8 | 0.4       |
| 0-20       | RRKS     | 6.47     | 0.81    | 1.52   | 2.62   | 0.194       | 4.5          | 0.86| 0.21| 5.89| 4.50| 10.38         | 56.67| 2.95| 0.13   | 9.33    | 4.0 | 0.5       |
| GIRS       | 6.80     | 1.41     | 1.53    | 2.64   | 0.124  | 0.28        | 4.7          | 0.83| 0.24| 5.77| 5.11| 10.88         | 52.69| 2.21| 0.15   | 12.52   | 4.8 | 0.4       |
| GDRS       | 6.67     | 1.26     | 1.47    | 2.54   | 0.163  | 0.29        | 4.7          | 0.82| 0.23| 6.06| 4.51| 10.55         | 57.33| 2.11| 0.13   | 9.00    | 4.3 | 0.8       |
| F-LSD 0.05 | NWRS     | 0.10     | 0.02    | 0.03   | 0.05   | 0.02        | 0.2          | 0.72| 0.02| 0.35| 0.08| 0.36         | 1.60| 0.12| 0.02   | -       | 0.19|           |
| TSRS       | 7.03     | 1.27     | 1.48    | 2.56   | 0.125  | 0.27        | 4.2          | 0.73| 0.24| 5.44| 4.85| 10.28         | 52.9| 2.33| 0.15   | 11.98   | 3.6 | 0.7       |
| 20-40      | RRKS     | 6.64     | 0.82    | 1.53   | 2.64   | 0.164       | 4.6          | 0.86| 0.22| 5.92| 4.52| 10.46         | 56.59| 2.07| 0.13   | 9.33    | 3.9 | 0.6       |
| GIRS       | 6.81     | 1.42     | 1.51    | 2.56   | 0.126  | 0.29        | 4.6          | 0.82| 0.24| 5.94| 5.17| 11.12         | 55.57| 2.22| 0.15   | 12.23   | 4.6 | 0.4       |
| GDRS       | 6.78     | 1.26     | 1.47    | 2.53   | 0.163  | 0.28        | 4.6          | 0.82| 0.25| 6.02| 4.52| 10.53         | 57.13| 2.23| 0.15   | 8.98    | 4.2 | 1.2       |
| F-LSD 0.05 | NWRS     | -        | 0.04    | 0.07   | 0.02   | 0.02        | 0.4          | 0.20| 0.05| 0.29| 0.21| 0.36         | 1.51| 0.17| 0.02   | 0.29    | 0.26| 0.35      |
| TSRS       | 6.82     | 1.31     | 1.43    | 2.47   | 0.173  | 0.32        | 4.5          | 0.83| 0.25| 5.94| 5.16| 11.09         | 53.4| 2.30| 0.15   | 8.30    | 3.7 | 0.9       |
| 40-60      | RRKS     | 6.88     | 0.79    | 1.53   | 2.65   | 0.166       | 4.6          | 0.86| 0.22| 5.96| 4.49| 10.45         | 57.04| 2.12| 0.13   | 9.24    | 4.3 | 1.0       |
| GIRS       | 6.81     | 1.42     | 1.53    | 2.64   | 0.125  | 0.30        | 4.7          | 0.83| 0.24| 6.08| 5.14| 11.22         | 54.23| 2.17| 0.15   | 12.32   | 4.4 | 0.3       |
| GDRS       | 6.81     | 1.26     | 1.47    | 2.53   | 0.131  | 0.29        | 4.7          | 0.80| 0.23| 5.94| 4.51| 10.44         | 56.84| 2.27| 0.14   | 11.47   | 3.9 | 1.2       |
| F-LSD 0.05 | NWRS     | 0.09     | 0.03    | 0.05   | 0.02   | 0.02        | 0.3          | 0.32| 0.47| 2.28| -   | 0.02         | 1.78| 0.45| 0.15   | -       | -   |           |

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Table 4. Effect of seasonal flooding on soil chemical properties of the study sites in 2017

| Depth (cm) | Locn | pH (H₂O) | EC (dS/m) | OC (%) | OM (%) | Total N(%) | Avail P (%) | K (%) | Ca (%) | Mg (%) | Na (%) | TEB (cmol (+)/kg) | EA (%) | CEC (%) | BS (%) | ESP (%) | SAR | C/N Ratio | FeO (g/kg) | Al oxides (g/kg) |
|------------|------|----------|-----------|--------|--------|------------|-------------|-------|--------|--------|--------|-----------------|--------|--------|--------|--------|-----|-----------|-----------|------------------|
| 0-20       | NWRS | 7.37     | 1.27      | 1.42   | 2.45   | 0.180      | 0.28        | 4.7   | 0.82   | 0.23   | 5.99   | 4.51          | 10.51  | 57.09  | 2.23   | 0.14   | 7.90 | 3.6       | 1.0       |                  |
|            | TSRS | 7.03     | 1.25      | 1.54   | 2.66   | 0.231      | 0.28        | 4.7   | 0.83   | 0.22   | 5.93   | 5.27          | 11.20  | 53.09  | 1.93   | 0.13   | 6.71 | 5.8       | 0.4       |                  |
|            | RKRS | 6.77     | 1.29      | 1.51   | 2.60   | 0.120      | 0.31        | 4.2   | 0.84   | 0.24   | 5.59   | 4.78          | 10.37  | 53.94  | 2.35   | 0.15   | 12.58 | 3.8       | 0.7       |                  |
|            | GIRS | 6.68     | 1.84      | 1.47   | 2.53   | 0.187      | 0.31        | 4.7   | 0.81   | 0.25   | 6.05   | 4.50          | 10.55  | 57.22  | 2.40   | 0.16   | 7.88 | 5.1       | 0.7       |                  |
|            | GDRS | 6.76     | 1.29      | 1.43   | 2.46   | 0.147      | 0.32        | 4.9   | 0.82   | 0.23   | 6.27   | 4.74          | 11.01  | 56.96  | 2.09   | 0.14   | 9.98 | 5.6       | 0.5       |                  |
| 20-40      | NWRS | 6.88     | 1.26      | 1.43   | 2.48   | 0.179      | 0.29        | 4.8   | 0.82   | 0.24   | 6.18   | 4.79          | 11.03  | 56.06  | 2.21   | 0.14   | 6.60 | 5.3       | 0.6       |                  |
|            | TSRS | 7.00     | 1.26      | 1.54   | 2.65   | 0.235      | 0.32        | 4.5   | 0.83   | 0.23   | 5.88   | 4.82          | 10.70  | 54.95  | 2.21   | 0.14   | 6.60 | 5.3       | 0.6       |                  |
|            | RKRS | 6.87     | 1.30      | 1.53   | 2.64   | 0.172      | 0.30        | 4.2   | 0.84   | 0.25   | 5.63   | 5.00          | 10.96  | 51.86  | 2.28   | 0.16   | 9.49 | 4.0       | 0.7       |                  |
|            | GIRS | 6.62     | 1.85      | 1.47   | 2.53   | 0.207      | 0.33        | 4.8   | 0.85   | 0.24   | 6.22   | 4.52          | 10.74  | 57.90  | 2.24   | 0.14   | 7.01 | 5.1       | 1.1       |                  |
|            | GDRS | 7.06     | 1.29      | 1.42   | 2.45   | 0.140      | 0.32        | 4.8   | 0.84   | 0.23   | 6.21   | 4.72          | 10.93  | 56.83  | 2.07   | 0.14   | 10.98 | 5.4       | 0.4       |                  |
| 40-60      | NWRS | 7.34     | 1.27      | 1.48   | 2.53   | 0.176      | 0.29        | 4.6   | 0.81   | 0.23   | 6.05   | 4.71          | 10.76  | 56.10  | 2.14   | 0.15   | 8.43 | 3.6       | 0.7       |                  |
|            | TSRS | 6.88     | 1.27      | 1.54   | 2.66   | 0.234      | 0.32        | 4.5   | 0.82   | 0.26   | 5.93   | 4.88          | 10.81  | 53.23  | 2.10   | 0.14   | 6.61 | 5.5       | 0.5       |                  |
|            | RKRS | 6.87     | 1.32      | 1.52   | 2.63   | 0.143      | 0.30        | 4.4   | 0.83   | 0.25   | 5.73   | 5.35          | 11.08  | 51.78  | 2.26   | 0.16   | 10.68 | 3.6       | 0.5       |                  |
|            | GIRS | 6.81     | 1.86      | 1.44   | 2.49   | 0.146      | 0.28        | 4.9   | 0.83   | 0.25   | 6.47   | 4.54          | 11.64  | 55.62  | 2.20   | 0.14   | 10.28 | 5.4       | 0.8       |                  |
|            | GDRS | 6.67     | 1.30      | 1.43   | 2.45   | 0.160      | 0.31        | 4.7   | 0.83   | 0.20   | 6.00   | 4.70          | 10.69  | 56.06  | 1.84   | 0.12   | 8.92 | 5.4       | 0.6       |                  |
| F-LSD 0.05 |     |          | -         | 0.07   | 0.05   | 0.08       | 0.03       | 0.11  | 0.02   | 0.2    | 0.02   | 0.22          | 0.48   | 1.515  | 0.22   | 0.01   | 1.56 | 0.56      | 0.30      |                  |
| F-LSD 0.05 |     |          | -         | 0.03   | 0.04   | 0.05       | 0.00       | 0.50  | 0.02   | 0.2    | -     | 0.19          | -      | -      | 3.47   | -      | -    | 0.45       | 0.37      |                  |
| F-LSD 0.05 |     |          | -         | 0.03   | 0.03   | 0.04       | 0.05       | 0.50  | 0.02   | 0.2    | -     | 0.19          | -      | -      | 3.47   | -      | -    | 0.45       | 0.37      |                  |
3.7 Organic Carbon and Organic Matter

The soils organic carbon (OC) contents of the flood plains had highest mean value of 1.54% and lowest mean value of 1.40%. The organic carbon of the area is rated moderate. This may be due to seasonal flooding of the area, which results in anaerobic conditions hindering the complete decomposition of organic matter [27]. The Analysis of Variance (ANOVA) test confirm the observed variations, in that, the differences amongst the different flood plain locations are statistically significant at 0.05 probability level for all the soil depths in both the years investigated. The analysis of means using F-LSD at P≤0.05 shows that only few of the location means are statistically different.

The soils organic matter (OM) contents of the flood plains had highest mean value of 2.66% and lowest mean value of 2.41%. Organic matter was generally low in the soils according to [28] ratings ( >20% very high, 10-20% high, 4-10% medium, 2-4% low and < 2% very low). The low organic matter content of the soils in Wukari flood plains has been attributed to factors such as continuous cultivation, frequent burning of farm residues commonly carried out by farmers in the area which tends to destroy much of the organic materials that could have been added to the soil [29]. Furthermore, [30] stated that low organic matter content in soils could be due to rapid decomposition and mineralization of organic materials contributed by sparse vegetation in the hot semi-arid climate as promoted by radiation. The comparatively higher mean values over some flood plains reflect greater vegetal cover, and or less oxidative decomposition. The comparatively lower value over other areas on the other hand is a reflection of the scanty vegetal cover, and rapid oxidative decomposition due to high temperature [31].

The Analysis of Variance (ANOVA) of the soil organic matter content test confirm the observed variations, in that, the differences amongst the different flood plain locations are statistically significant at 0.05 probability level for all the soil depths in both the years investigated. The analysis of means using F-LSD at P≤0.05 shows that only few of the location means are statistically different.

3.8 Total Nitrogen and Available Phosphorus

The total nitrogen of the flood plains had highest mean value of 0.235% and lowest mean value of 0.120%. The values were rated low with higher values concentrating at the surface soils. Total nitrogen is mobile in soils, as a result its losses through various mechanism like NH₃ volatilization, succeeding denitrification, chemical and microbial fixation, leaching and runoff results in residual/available nitrogen becomes poor in soils [32]. Total nitrogen values of the soils changed irregularly with depth which could be attributed to influence of continuous cultivation, a common practice that is accompanied by crop residue removal. The Analysis of Variance (ANOVA) of the soil total nitrogen content shows that the differences among the different flood plain locations are statistically significant at 0.05 probability level at the soil depths of 20-40 cm and 40-60 cm but not statistically significant at the soil depth of 0-20 cm in 2017. The analysis of means using F-LSD at P≤0.05 shows that only few of the location means are statistically different.

The available phosphorus content of these soils is high with highest mean value of 17.06% and lowest mean value of 14.38%. These high values may be due to the fact that phosphorus is characteristically immobile, and tend to remain fixed at the surface. Leaching has little or no effect on phosphorus available and so is clay. [32] observed that available phosphorus of representative ‘Fadama’ soils ranged from moderate to high. The irregular pattern in accumulation of phosphorus at the surface; a pronounced occurrence in the savanna was attributed to decrease in the return of phosphorus to soil surface as the vegetation...
becomes sparser [33]. The Analysis of Variance (ANOVA) of the soil available phosphorus shows that the differences among the different flood plain locations are statistically significant at 0.05 probability level at the soil depth of 0-20 cm but not statistically significant at the soil depths of 20-40 cm and 40-60 cm in 2016 and in 2017 the differences among the different flood plain locations are statistically significant at the soil depths of 0-20 cm and 20-40 cm but not statistically significant at the soil depth of 40-60 cm. The analysis of means using F-LSD at \( P \leq 0.05 \) shows that only few of the location means are statistically different.

### 3.9 Exchangeable Bases

#### 3.9.1 Exchangeable calcium (Ca)

Exchangeable Ca ranked highest on the exchange site. The ranges in value for mean exchangeable calcium of the soils were 4.20 to 4.90 cmol (+) /kg. The exchangeable Ca in the flood plains was rated medium range. Calcium was the dominant exchangeable base in all the soils. Similar result was reported by several researchers [7]. The predominance of Ca was partly due to exchange sites having high affinity for calcium [34] and also due to calcium bearing parent material [35]. The Analysis of Variance (ANOVA) of the soil exchangeable calcium shows that the differences among the different flood plain locations are statistically significant at 0.05 probability level for the soil depths of 0-20 cm and 40-60 cm but not statistically significant for the soil depth of 20-40 cm in the year 2016 and in the year 2017, the difference among the different locations are statistically significant at 0.05 probability level for the soil depths of 0-20 cm and 20-40 cm but not statistically significant at the soil depth of 40-60 cm. The analysis of means using F-LSD at \( P \leq 0.05 \) shows that only few of the location means are statistically different.

#### 3.9.2 Exchangeable magnesium (Mg)

Exchangeable Mg ranked next to Ca on the exchange site. Mg values were generally in the medium range. The mean values of exchangeable Mg of the flood plain soils ranged from 0.77 to 0.85 cmol (+) /kg. The range in value of magnesium were moderate and will not affect plant growth as [36] reported that high accumulation of Mg in the soil may cause deterioration of soil structure, lower water intake rates and affect chemical and biological properties of the soil. The Analysis of Variance (ANOVA) of the soil exchangeable Mg shows that the differences among the different flood plain locations are statistically significant at 0.05 probability level at the soil depths of 20-40 cm and 40-60 cm but were not statistically significant at the soil depth of 0-20 cm in 2016 and in the year 2017, the difference among the different soil sample locations are statistically insignificant at 0.05 probability level at all the soil depths investigated. The analysis of means using F-LSD at \( P \leq 0.05 \) shows that only few of the location means are statistically different.

#### 3.9.3 Exchangeable potassium (K)

Exchangeable K ranked next to Mg on the exchange site and the mean values of the flood plain soils ranged from 0.24 to 0.33 cmol (+) /kg. K values were generally in the medium range. The Analysis of Variance (ANOVA) of the soil exchangeable K content test confirm the observed variations, in that, the differences amongst the different flood plain locations are statistically significant at 0.05 probability level at all the soil depths in both the study periods. The analysis of means using F-LSD at \( P \leq 0.05 \) shows that only few of the location means are statistically different.

#### 3.9.4 Exchangeable sodium (Na)

Exchangeable Na ranked next to potassium on the exchange site, the ranges in mean values for exchangeable Na of the flood plain soils were 0.21 to 0.27 cmol (+) /kg. Na values were generally in the medium range. The Analysis of Variance (ANOVA) of the soil exchangeable sodium content test confirm the observed variations, in that, the differences amongst the different flood plain locations are statistically significant at 0.05 probability level at the soil depth of 20-40 cm but statistically insignificant at the soil depths of 0-20 cm and 40-60 cm in the year 2016 and in the year 2017, the difference amongst the different soil sample locations are statistically significant at 0.05 probability level at the soil depths of 20-40 cm but statistically insignificant at the soil depths of 0-20 cm and 40-60 cm in the year 2016 and in the year 2017, the difference amongst the different flood plain locations are statistically different. Generally, the exchangeable bases occurred in the order Ca>Mg>K>Na in all the flood plains, this corroborates earlier reports on soils of the Nigerian savannah [19]. The exchangeable bases were generally in the medium range indicating moderate basic nutrient status of the soils. The relatively higher values of
exchangeable bases at the surface soil were attributed to application of crop residues as manure, considering the coarse texture of the soils which makes them prone to leaching. For the soil as a whole, exchangeable bases were medium, losses of nutrients by leaching was moderate in the study area. Lower range of exchangeable bases is a reflection, presumably, of high level of leaching that has taken place in soils. The feature, however, may be partly due to the granitic nature of the soil parent materials.

3.9.5 Total exchangeable bases (TEB)

The range in mean values for TEB of the soils were 5.57 to 6.44 cmol (+)/kg. The Analysis of Variance (ANOVA) of the soil TEB confirm the observed variations, in that, the differences amongst the different flood plain locations are statistically significant at 0.05 probability level for the soil depths of 0-20 cm and 40-60 cm but statistically insignificant at the soil depth of 20-40 cm in 2016 while in the year 2017, the different flood plain locations are statistically significant at 0.05 probability level for the soil depths of 0-20 cm and 20-40 cm but statistically insignificant at the soil depth of 40-60 cm. The analysis of means using F-LSD at p≤0.05 shows that only few of the location means are statistically different.

3.10 Exchangeable Acidity (EA)

The EA comprises exchangeable hydrogen and exchangeable aluminium. The highest mean EA value obtained from Wukari flood plains was 5.54 cmol (+)/kg and the lowest mean value was 4.50 cmol (+)/kg. The values were classified as generally in the medium range which suggests that the soils have little or no acidity problems, except for incipient acidity in some horizons. However, the low pH values would suggest that liming and/or use of farm yard manure incorporated into the soils would restore pH values to the range of pH 5.0 to 6.0 at which most nutrients are readily available to crop roots [20]. The Analysis of Variance (ANOVA) of the soil exchangeable acidity test confirm the observed variations, in that, the differences amongst the different flood plain locations are statistically significant at 0.05 probability level at the soil depths of 0-20 cm and 20-40 cm but were statistically insignificant at the soil depth of 40-60 cm in 2016 while in 2017, the differences amongst the different flood plain locations are statistically significant at 0.05 probability level at the soil depths of 0-20 cm and 40-60 cm but were statistically insignificant at the soil depth of 20-40 cm. The analysis of means using F-LSD at p≤0.05 shows that only few of the location means are statistically different.

3.11 Cation Exchange Capacity (CEC)

The mean value of CEC of Wukari flood plains ranged from 10.32 to 11.64 cmol (+)/kg (Table 4). The CEC of Wukari flood plains were rated medium based on the findings of [37] who reported CEC values of < 6, 6 - 12 and > 12 cmol (+)/kg as low, medium and high respectively. The cation exchange capacity values of the flood plain soils were rated medium which could be attributed to high clay content. The moderate values of CEC also suggest that the soils are formed from highly weathered materials of granitic origin, which are low in basic cations. Low to moderate cation exchange capacity values were reported to be an indication of dominance of sesquioxide and kaolinitic clays in the fine earth fractions [38]. The exchange sites were dominated by Ca followed by Mg, probably because of soils affinity for these cations, Ca is well supplied naturally in soils [17]. The Analysis of Variance (ANOVA) of the soil cation exchange capacity test confirm the observed variations, in that, the differences amongst the different flood plain locations are statistically significant at 0.05 probability level at the soil depths of 0-20 cm and 20-40 cm but were statistically insignificant at the soil depth of 40-60 cm in 2016 while in 2017, the differences amongst the different flood plain locations are statistically significant at 0.05 probability level at the soil depth of 0-20 cm but were statistically insignificant at the soil depths of 20-40 cm and 40-60 cm. The analysis of means using F-LSD at p≤0.05 shows that only few of the location means are statistically different.

3.12 Base Saturation (BS)

BS of the flood plains had highest mean value of 57.90% and lowest mean value of 51.39%. The values were rated moderate being generally between 50 and 80%. The medium values indicate that the soils have moderate potentials for supplying plant nutrients; hence, the necessity for adequate soil management, most especially the upland. Similar result was reported by [39] and [40] on basement complex soils in Zaria. [16] stated that the base saturation of fadama soils ranged from less than 20% to higher than 80%. This agreed to a large extent with what is obtained here. The ANOVA showed that the base saturation of the floodplain soils were significantly different for the different
locations investigated at p≤.05 level of significance at the soil depth of 20-40 cm but were not significantly different at the soil depths of 0-20 cm and 40-60 cm in 2016 while in 2017, the base saturation of the floodplain soils were significantly different for the different locations investigated at p≤.05 level of significance at the soil depths of 0-20 cm and 20-40 cm but were not significantly different at the soil depth of 40-60 cm. The means separation using F-LSD at 0.05 probability levels showed the differences among some of the mean base saturation of the flood plain locations are statistically significant.

3.13 Exchangeable Sodium Percentage (ESP), Sodium Absorption Ratio (SAR) and Carbon-Nitrogen Ratio (C/N Ratio)

The mean values of ESP ranged from 1.84 to 2.40%. The ESP of the flood plains are rated low based on the findings of [25] that rated ESP below 15% as low and above 15% as high, the critical limit for sodicity. The results suggest no sodicity risk to these soils since none of the values is up to 15%. Sodic soils are usually more dispersed, less permeable to 98 water and are of poor soil tilth, usually plastic and sticky when wet and are more prone to form clods and crust on drying [41]. The Analysis of Variance (ANOVA) test confirm the observed variations, in that, the differences amongst the different flood plain locations are statistically significant at 0.05 probability level at the soil depth of 0-20 cm but were not statistically significant at the soil sample depths of 20-40 cm and 40-60 cm in both the years studied. The analysis of means using F-LSD at p≤.05 shows that only few of the location means are statistically different.

The mean values of SAR ranged from 0.12 to 0.16 (Table 4). The values are rated low, below the threshold value of 13 for sodic soils. The results suggest no sodicity risk to these soils since none of the values is up to 13. Too much sodium can lead to excessive swelling of the soil, which may result in structural collapse referred to as dispersion. Dispersive soil is very prone to water logging, which can greatly reduce the profitability of farmers. When dry, dispersive soil tends to be too hard for roots and seedlings to penetrate. [42], recommend the application of gypsum to improve soil structural stability by providing a mildly saline soil solution that is not strong enough to adversely affect water uptake by most crops, but restricts movement of water molecules into the space between clay particles. Gypsum also contains calcium, which displaces sodium and magnesium from the exchange sites between clay particles. The ANOVA showed that the sodium absorption ratio of the floodplain soils were significantly different for the different locations investigated at p≤.05 level of significance at the soil depth of 20-40 cm but were not significantly different at the soil depths of 0-20 cm and 40-60 cm in 2016 while in 2017, the sodium absorption ratio of the floodplain soils were significantly different for the different locations investigated at p≤.05 level of significance at the soil depths of 0-20 cm and 40-60 cm but were not significantly different at the soil depth of 20-40 cm. The means separation using F-LSD at 0.05 probability levels showed the differences among some of the mean sodium absorption ratio of the flood plain locations are statistically significant.

The C/N ratio is an indication of the extent of decomposition of organic matter and release of nutrient such as nitrogen. The highest mean value of the carbon-nitrogen ratio of the flood plains was 12.58 and the lowest mean value was 6.60. The general low values of C-N ratio were due to low surface organic matter content and leaching. The ANOVA showed that the carbon-nitrogen ratios of the floodplain soils were significantly different for the different locations investigated at p≤.05 level of significance for the soil depths of 20-40 cm and 40-60 cm but were not significantly different at the soil depth of 0-20 cm in 2016 while in 2017, the C/N ratios of the floodplain soils were significantly different for the different locations investigated at p≤.05 level of significance for the soil depths of 0-20 cm and 40-60 cm but were not significantly different at the soil depth of 20-40 cm. The means separation using F-LSD at 0.05 probability levels showed the differences among some of the mean C/N ratio of the flood plain locations are statistically significant.

3.14 Extractable Iron Oxide (FeO) and Aluminium Oxide (Al₂O₃)

The highest mean value of the extractable iron oxide content of the flood plains was 5.77 g/kg and the lowest mean value of the extractable FeO content of the flood plains was 3.60 g/kg. The generally low extractable FeO percentage obtained in these soils appear to indicate that low amounts of extractable iron is contained in the fluvialite soil parent material from which the soils are presumed to be derived. The Analysis of Variance (ANOVA) of the soil extractable iron
oxides shows that the differences among the different flood plain locations are statistically insignificant at 0.05 probability level at all the soil depths investigated. The differences among the different flood plain locations are statistically significant at 0.05 probability level at all the soil depths investigated. The analysis of means using F-LSD at p≤0.05 shows that only few of the location means are statistically different.

The mean value of the Al₂O₃ content of the flood plains was 0.017% and the lowest mean value of the Al₂O₃ content of the flood plains was 0.037% (Table 2). Values of extractable Al₂O₃ obtained in the floodplains are low. It is possible that Al₂O₃ in these soils have been depleted and used for clay formation by neo formation such that only trace amounts of extractable Al₂O₃ is left in the soil. Such clays that may have formed in these soils include kaolinite, illite and smectite [7]. The ANOVA of the aluminium oxide contents of the floodplain soils showed that the differences among the different flood plain locations are statistically insignificant at 0.05 probability level at all the soil depths investigated in 2016 while in 2017, the differences among the different flood plain locations are statistically significant at 0.05 probability level at soil depths of 0-20 cm and 20-40 cm but were statistically insignificant at the soil depth of 40-60 cm. The means separation using F-LSD at 0.05 probability levels showed the differences among some of the mean aluminium oxide contents of the flood plain locations are statistically significant.

4. CONCLUSION

From the study conducted it can be concluded that:

i. The soils of Wukari Floodplains are mostly clay loam in texture having very slightly acid to neutral soil reaction, moderate organic matter, low total N, available P, exchangeable bases and CEC.

ii. The floodplain soils are moderate in soil fertility, a confirmation of the general characteristic of Savanna soils.

iii. The soils were not deficient in micronutrients.

iv. Seasonal flooding had significant influence (P ≤ 0.05) on soil bulk density, porosity, water holding capacity and some chemical properties. The properties were positively influenced most by the flooding at Rafin-Kada location.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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