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Impact Of Toposequence On Soil Chemical Properties In Floodplain Irrigated Soils Of Gadabiyu Area Of Kwali Area Council, Abuja Federal Capital Territory, Nigeria

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Abstract —This study assessed the effect of topo sequence position on soil chemical properties in flood plain irrigated soils of GADA BIYU area of KWALI Area Council, Abuja, FCT. Two catanas (A and B) and three slope segments were identified. Soil samples were collected from each profile pit in accordance with horizons starting from lower horizons to avoid contaminating samples. Transect placement and sampling intervals along transects were determined subjectively to capture the full range of soil variability within landforms. The depth of the auger borings was 0-15 and 15- 30 cm (surface and sub-surface respectively). The soils were analyzed forSoil pH, Organic Carbon, Total Nitrogen, Available Phosphorus, CEC, Exchangeable Cations and Percentage base saturation, Exchangeable acidity in the soil. Descriptive statistics and a One-way Analysis of Variance were used to analyze the data. .Findings revealed that values gotten for soil pH shows that the soil in the study area is moderately acidic, in the same vein ANOVA result showed that there was no significant difference ($p>0.05$) in the pH values of the soil determined in H_2O and in KCl, The study further revealed that the EC values were rated low to moderate, also Organic carbon and soil organic matter showed the same trend in the soils, the values gotten indicated a moderate to very high distribution within the profiles and along the toposequence with much higher values in the middle and lower slope sections. Furthermore, The total nitrogen values within the profiles decreased with increasing soil depth, however, the distribution of nitrogen within the profile. Also findings show that the value of P recorded in the soil was rated as being high with a mean value of 15.83 $mgkg^{-1}$in the upper slope, 16.02$mgkg^{-1}$ in the middle slope and 20.92$mgkg^{-1}$ respectively in the same vein findings revealed that the distribution of the basic cations in the soil showed that Ca and Mg were the most abundant in the soil. Also the the cation exchange capacity of the soils along the topo sequence recorded was very low. Based on the findings the study recommended that organic matter should be continuously applied to the soil as a means of improving soil structure, and the nutrient capital reserve of the soil.

Keywords-Toposequence, Catena, Irrigation, Physical Properties.

Introduction

Soils vary in their physical, chemical, morphological and mineralogical characteristics where topography happens to be a major factor which controls most surface processes taking place [11]. Adjacent soils that show differing profile characteristics reflecting the influence of local topography are calledtoposequence. Topography has an influence on soil chemicaland physical properties and also on the pattern of soil distributionover landscape [12]. As the landscape is undulating, soilcharacteristics at different topographic positions differ. Toposequencerefers to a succession of sites from crest to the valleybottom which contains a range of soil profiles that arerepresentative of the landscape and soils [15]. Soil propertiesvary in vertical and lateral directions and such variationsfollow systematic changes as a function of the land scapeposition (slope), soil forming factors and/or soil managementpractices (land use).

Generally, topography influences soil morphological, chemical and physical properties and also affects the pattern of soil distribution over landscape even when the soils are derived from the same parent material [11]. This gives rise to a succession of soil types, known as a catena from the hilltop to the valley bottom. The catenary differentiation of soils is of pivotal importance to the management of soils in different topographic positions in the landscape. Consequently, understanding the roles of topography in a landscape will help in assessing productive values of soils and most importantly, in developing strategies for its conservation and reducing uniform soil management which could result in some parts of an agricultural field receiving insufficient inputs, while other parts receive an excess [18’.

The objective of this study was to determine the impact of toposequenceon the chemicalproperties of the soil, using appropriate statisticalmethods, in order to contribute to the validationof indicators of soil fertility in the irrigated soils of gadabiyu area of kwali area council.

MATERIALS AND METHODS

Study area

Kwali Area Council of the Federal Capital Territory was created on the 1st October 1996. It lies between 8^0 28' - 8^0 54' North of the Equator and Longitude 6^0 50' -7^0 13' East of the Green Witch Meridian. The council has a total land mass of about 1700km square. The settlements pattern is dispersed with the indigenous clustered type within Kwali, Leda, Dangara, Gada-biyu, Sheda, Kilankawa, Dabi and Pai. The main ethnic groupings include the Gbari, Ganagana, Bassa, Fulani, and others [5].

The Kwali climate is the hot, humid tropical type. It is such that its elements have ranges that are transitional from those of the southern and northern parts of the country. The area has distinct wet (March - October) and dry (November - February) seasons with average annual rainfall of 1358.7mm and mean temperature range of between 20.70C - 30.80C [5] Rainfall play a vital role with respect to agricultural activities within the study area and most farming activities highly depend on rainfall [5].

The alluvial soil of Iku plains, gleysols and fluvisols are noteworthy in the study area. The soils are complex in their degree of taxonomic variations. The drainage conditions of the soil depend on the depth of water table. The colour of the soils is modified by mottling due to poor drainage. The area has clayish and sandy loam soil texture with occasional swampy areas used for fadama (irrigated) farming. There is the upland soils of the ferruginous red tropical type, often derived from crystalline acid or sandy rocks and contained high proportion of silt. They are most suited for cereal and tuber crops production [5].

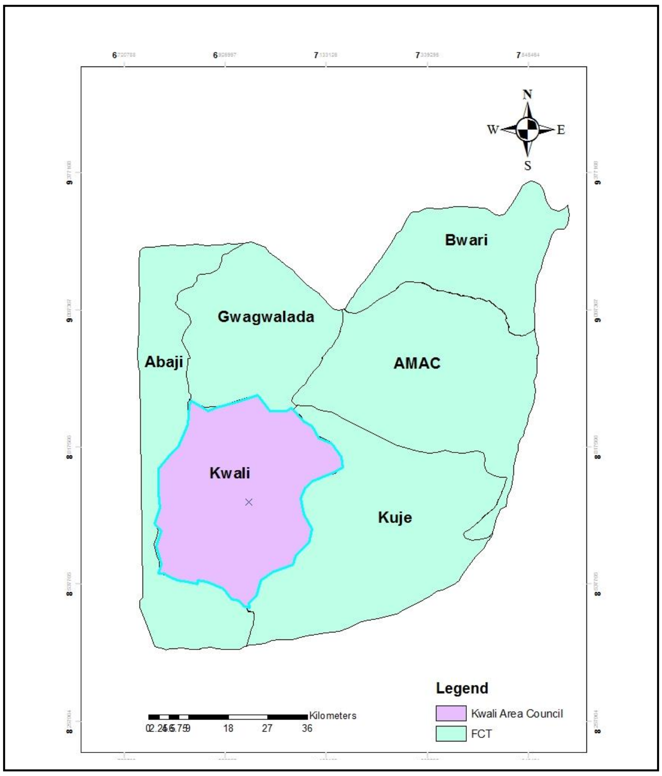

Fig.1: Abuja, FCT Showing Kwali Area Council, Source: UniAbujaGis Lab

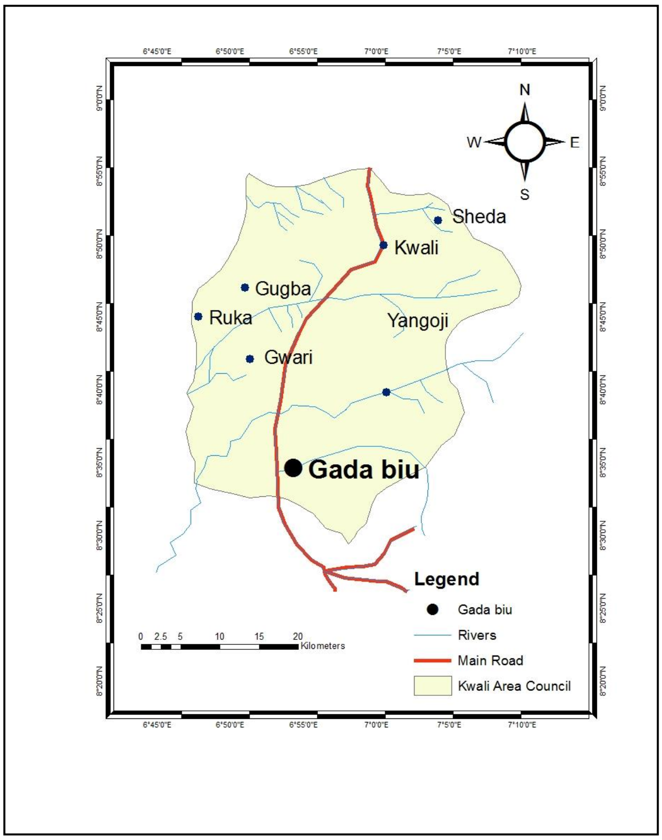

Fig. 2: Kwali Area Council showing the Study Area, Source: UniabujaGis Lab

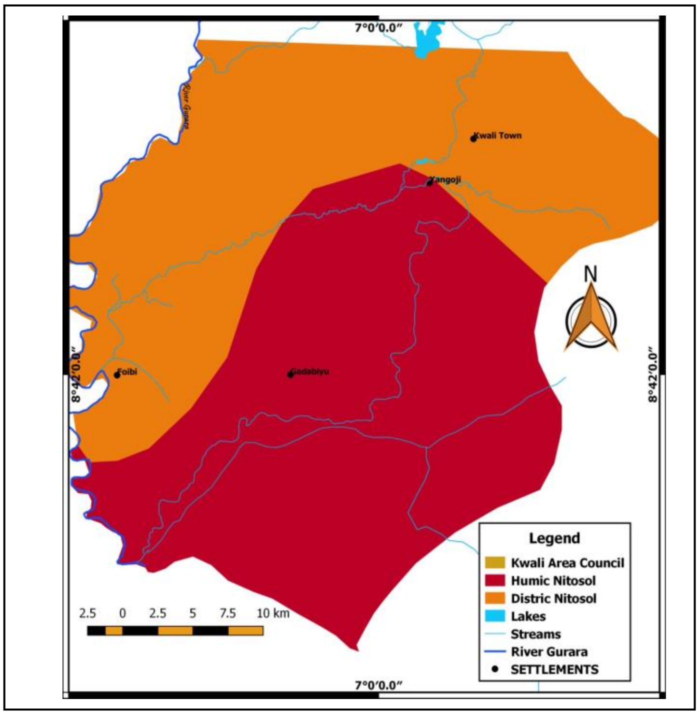

Figure 1.3: Soil Map of the Study area**,**

Source: FAO, 2017

Kwali area council has a vast land conducive for agricultural activities. The rich and fertile land makes it suitable for cultivation of varieties of crops with large spread of fadama land suitable for rice farming. The Fadama land in Kwali area council is estimated to be over 40,000 hectares [5].

The Climate favours the production of a wide variety of crops, which include legumes (groundnuts, soyabean, lima bean, bambara nut and pigeon pea); cereals (maize, millet, sorghum and rice), solanecious crops (peppers, tomato, garden eggs and ginger); tree crops (guava, cashew, mango, orange and paw-paw); and root and tuber crops (yam, sweet potatoes, cocoyam and cassava). For livestock production, the animals that are mostly kept are swine, goats, sheep and poultry. Hunting and bee-keeping are also practiced [5].The area is mainly occupied by small holder rainfed and irrigation farmers who grow crop such as yam, rice, melon seed, cocoyam, cassava, peppe, tomato, okro, rice, onion, garden eggs, spinage, beniseed and millet among others [5].

Field procedures

The toposequence survey was carried out using a Germin GPS to detect both the various segments of the geodetic heights and the coordinates of the segments (Mapping Units). Transects were taken with the use of tape. Two catanas (A and B) and three slope segments were detected and the slopes are classified on Table 1.

Table 1: Topo sequence slope segments Elevation, Interval Distance and Coordinates.

SLOPE	COORDINATES OF PROFILE PITS						
	ELEVATION/HIGHT	INTERVAL HORIZONTAL DISTANCE	COORDINATES Of SLOPE SEGMENTS	*CATANA A*		*CATANA B*	
Upper slope (MU1)	96m	0-200	N08˚36'753"	E 006^{0} 55'165"	E6.919432	N 8.61257	E6.920833
Middle slope (MU2)	Mid-slope	85m	200-700	N08^{0}36'649"	E 006^{0} 55'134"	E6.918897	N8.610845
Lower slope (MU3)	Lower slope	78m	700-1000	N08^{0} 36" 385"	E 006^{0} 54'835"	E6.9139	N8.606472

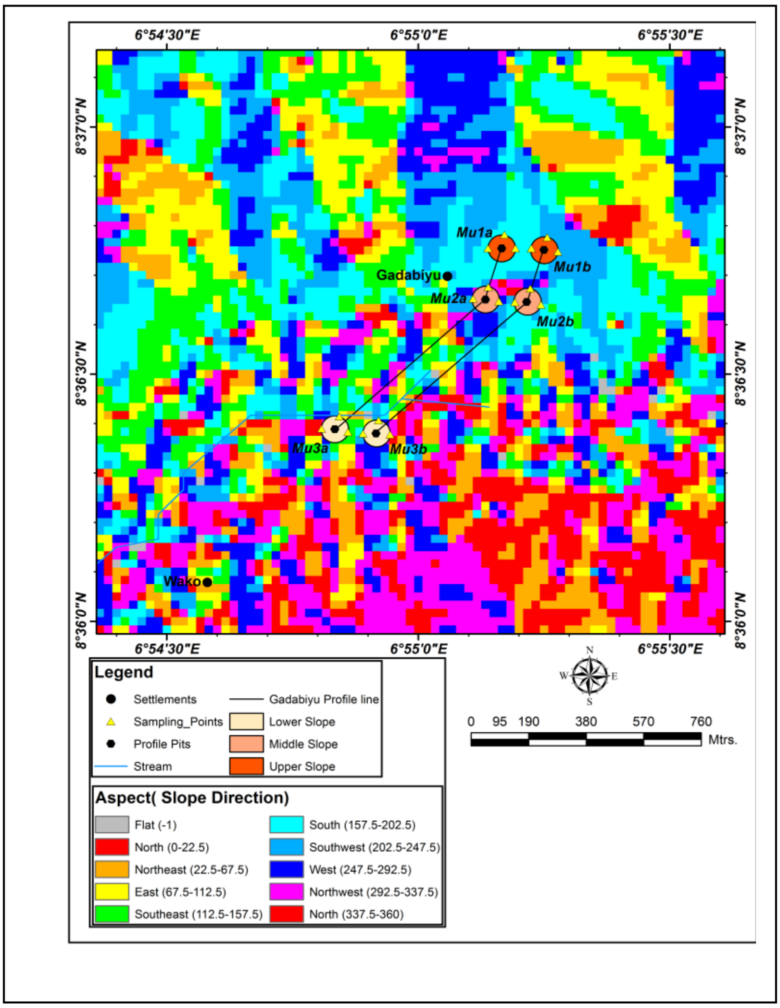

Figure 4: **Aspect Map of the Profile Pits**

Source: Field work

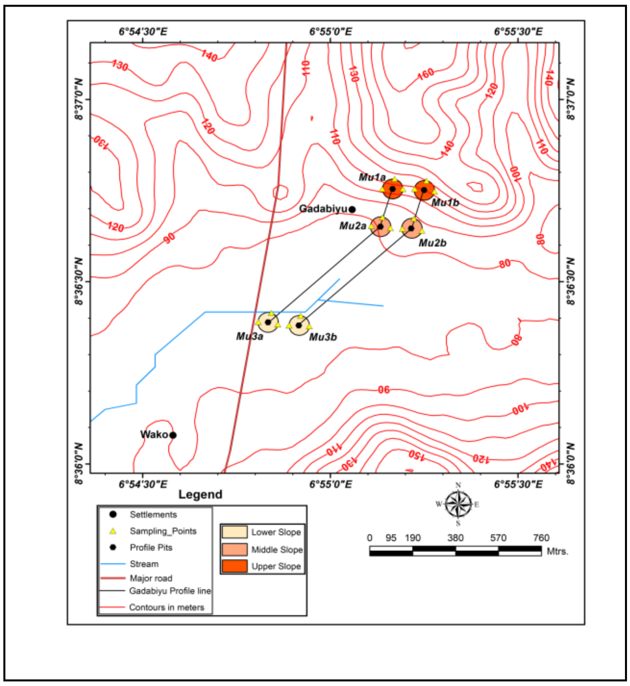

Figure 5: Topography of the Study area also showing the Sampling Pits

Source: Field work

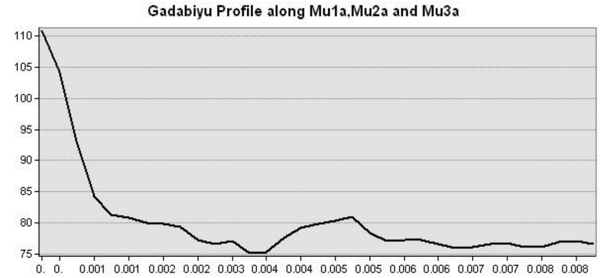

Figure 6: Gada-biyu Profile along Catana ‘A’

Source: Field Work 2017/2018

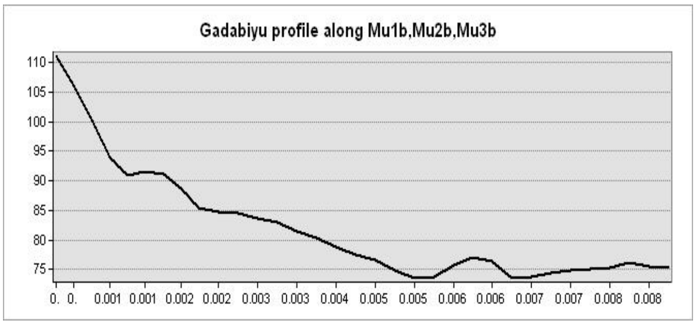

Figure 7: Gada-biyu Profile along Catana ‘B’

Source: Field Work 2017/2018

Soil samples collection

Profile Pits Preparation and Soil samples collection

Prior to the preparation of profile pits, two parallel toposequences (50m apart) were selected and delineated into three slope positions based on elevations assessed using a GPS device. For proper studies, three (3) slope units were realized; MU1, MU2, and MU3 (upper slope, middle slope and lower slope respectively). Two (2) profile pits (a and b) were dug in each of the soil units established along the three slope segments, maintaining the standard dimension of 2m x 1.5m x 2m (Length x width x depth respectively).

Soil samples were collected from each profile pit in accordance with horizons starting from lower horizons to avoid contaminating samples. Transect placement and sampling intervals along transects were determined subjectively to capture the full range of soil variability within landforms as described by Young et al, [26]. Random auger borings were also made around each profile pit and bulked together to form composite samples for each soil unit studied. The depth of the auger borings was 0-15 and 15- 30 cm (surface and sub-surface respectively).These layers are considered the most productive soil layers that exert the greatest effect on crop yield and geomorphologic processes are enacted within such layers [4]. .Deep auger borings were made in each of the profile pits beyond 200cm to determine the nature of the underlying substrata (Plate 1 to2).

Plate 1: Researcher and her field assistants taken Measurements of Transects at Gada-biyu Irrigation Area.

Source: Fieldwork

Plate 2: Researcher and her field assistants taken Soil samples in Upper slope Profile Pits at Gada-biyu Irrigation Area.

Source: Fieldwork

- **LABORATORY METHODS**

The prepared samples were analyzed for some physical properties at IITA Analytical Laboratory Ibadan, Nigeria based on standard procedures as follows:

i. Soil pH

The soil pH in water (1:1) and in KCl (1:1) was determined by electrometric method. Twenty grams of sieved soil was weighed into a 50ml beaker and 20ml of distilled water or KCl was added as required, and was allowed to stand for 30minutes, while the suspension was stirred occasionally with glass rod. The electrode of the pH meter was then inserted into the suspension and the reading of the pH was noted and recorded as described by Mclean, [15].

ii. Organic Carbon

Organic carbon was determined by the modified Walkley – Black method as described by Nelson and Summers [16], which involves the oxidation of soil sample with dichromate and tetraoxosulphate (VI) acid. Two grams of sieved soil was mixed with 10ml of potassium dichromate solution ($K_2Cr_20_7$) alongside with 20ml of concentrated sulphuric acid (H_2SO_4) and allowed to digest for 30 minutes before 10mls of distilled water was added. Three drops of phenolphthalein indicator was added and titrated against ferrous sulphate (Fe_2SO_4). A blank solution was prepared without soil samples and their readings were taken. The organic carbon was then calculated using the relationship:

$$OC = N\frac{(V1-V2)}{W}\,0.3F \qquad (5)$$

Where:

N = normality of ferrous sulphate solution

V1= ml ferrous ammonium sulphate for the blank

V2 = ml ferrous ammonium sulphate for the sample

F = correction factor = 1.33

% organic matter in soil = % organic carbon x 1.729 and convert to gkg^{-1}.

iii. Total Nitrogen

Total nitrogen was determined by the macro-Kjeldahl digestion and distillation procedures as described by Bremmer[8]. Mercury catalyst tablets were used to aid the digestion. The soil samples were digested with concentrated tetraoxosulphate (VI) acid after addition of excess caustic soda. Ten grams of soil samples was weighed into a dry 500ml conical flask, 20mls of distilled water was added. The flask was then swirled for a few minutes and then allowed to stand for about 30 minutes. Half a tablet of mercury catalyst was added to 10g of potassium sulphate (K_2SO_4). Then 30mls of concentrated sulphuric acid (H_2SO_4) was added through a measuring cylinder. The flask was then heated for 3 hours to ensure complete digestion of the contents. The flask was then allowed to cool, and then 100mls of distilled water was added slowly. The digest was transferred to a clean 250 volumetric flask with caution. The sand particles were then washed with distilled water and the flask made to mark with distilled water. The digest was then distilled into boric acid (H_3BO_3) using 10N NaOH.

iv. Available Phosphorus

Sodium bicarbonate {Na (HCO_3)$_2$} extracting solution was used in this analysis (Olsen and Dean, 1965). Five grams` of soil was measured into a 125ml conical flask and 15ml extracting solution was added and the content was shaken for 30 minutes in a mechanical shaker. The suspension was then filtered through the whatman filter paper No. 1 into a glass tube and then stirred. The solution was then used for phosphorus determination using colourimeter.

v. Cation Exchange Capacity (CEC)

This was determined by neutral 1N ammonium acetate method. Twenty-five grams of the sieved soil sample was weighed into a 50ml Erlenmeyer flask and 50ml of neutral 1N NH4OAC was added and left-over night. The suspension was then filtered using a moist whatman filter paper No. 4. The soil sample was leached with more NH_4OAC solution to remove all exchangeable bases and to saturate the exchange sites of the colloids with NH_4^+. Thirty ml of 99% isopropyl alcohol was added to the sample and the suspension was then shaken mechanically to remove excess NH_4OAC. The NH_4^- saturated soil was then transferred to a 500ml Kjeldahl flask and 200ml of deionized water was added and also 3g magnesium oxide added into the flask. The content of the flask was then distilled into 50ml of 4% H_3BO_3 solution after methylene blue indicator was added. The ammonium absorbed in the distillate in the 4% boric acid solution was titrated with standard 0.1N hydrochloric acid. The total cation exchange capacity was calculated and expressed as cmol kg^{-1} of soil. Blank determination was carried out following the same procedure but without soil.

vi. Exchangeable Cations and Percentage base saturation

This was determined by ammonium acetate extraction method as described by IITA [13]. The soil samples were shaken for two hours then centrifuged at 2000 rpm for 5 – 10 minutes after decanting into a volumetric flask, thirty ml of ammonium acetate was added again and shaken for 30 minutes, centrifuged and the supernatant transferred into same volumetric flask. Ca and Mg was then determined using the Atomic Absorption Spectrophotometer (AAS) while the Na and K were determined using flame photometer.

The percentage base saturation of the soil was calculated using the relationship below:

$$\text{PBS} = \frac{\text{exchangeable bases}}{\text{cation exchange capacity}} \times 100 \quad - \quad - \quad - \quad - \quad - \quad (6)$$

vii. Exchangeable acidity

The exchange acidity was determined using barium chloride triethanolamine method as described by Peech [22]. Ten grams of soil sample was weighed into a 125ml Erlenmeyer flask and 100ml of the extracting solution (0.5N $BaCl_2$-0.055N triethanolamine) was added. The suspension was then thoroughly mixed, covered with stopper and allowed to stand overnight. The suspension was transferred into a Pyrex Buchner funnel size No. 40, fitted with 4.25cm Whatman No. 32 filter paper. The flask was then rinsed into the funnel using extracting solution. The soil suspension was leached to obtain the leachate. The leachate therefore was transferred quantitatively into a 250ml volumetric flask and made to a volume with the extracting solution. The leachate was again transferred into a 500mls Erlenmeyer flask into which 5 drops of the mixed indicator solution was added. It was then be titrated with 0.2NHCl to a pink end point, at pH of 5.1 two hundred and fifty ml of the original extracting solution was titrated to precisely the same end point, using the same amount of the mixed indicator. The exchange acidity (EA) was then calculated using the formula:

$$\text{E.A.} = (B - S)\ 10N \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad (7)$$

Where:

B = volume of acid required to titrate 250mls of extracting solution

S = volume of acid required to titrate the soil extract

N = normality of acid.

Statistical Analysis

In this respect the SPSS Statistical packages and excel spread sheet were used to do analysis on different parameters. The statistical analysis considered is ANOVA to check for soil quality variations between and within catenary segments and profile pits. Simple descriptive statistics such as mean, standard deviation and standard error of the mean, were also used.

RESULTS AND DISCUSSION

Descriptive statistics

Chemical Properties of Gada-biyu Irrigation Area

The chemical properties of the soils are presented in Tables 1.1a and 1.1b for all the three soil units studied in the Gadabiyu Irrigation area and the findings are explained as follows.

Soil pH

The result of soil reaction for the upper slope section for both Pit (a) and Pit (b) (in H_2O) showed that the soil pH was moderately acidic having values ranging from 6.65 to 6.94 with a mean of 6.76 (SE±0.04). The pH values in KCl ranged from 3.03 to 3.28 with a mean value of 3.21 (0.02). Also, for both profile pits in the middle slope section, pH (in H_2O) ranged from 6.47 to 6.78 with a mean value of 6.68 (SE±0.06). The values in KCl ranged from 3.13 to

3.31 and a mean of 3.24 (SE±0.04). This value is rated as moderately acidic.

Moreover, both profile pits in the lower slope section of the toposequence, soil pH (in H_2O) ranged from 6.53 to 6.77 with a mean of 6.68 (SE±0.03), while in KCl the values ranged from 3.08 to 4.37 with a mean of 3.35 (SE±0.52). These values are rated as moderately acidic.

From the result above, the soils are generally moderately acidic. This implied that the practice of irrigation (in the middle and lower slope sections) did not influence the rate of soil reaction (pH).

Electrical conductivity (Ec μs cm^{-1})

The distribution of electrical conductivity in the soils of the pits of the upper slope section ranges from 1.00 to 9.00μs cm^{-1} with a mean of 3.00 μs cm^{-1} and standard deviation of 2.01 (SE±0.11). These values are rated as moderate. While in the middle slope pits, the EC values ranged from 1.00 to 2.00 μs cm^{-1} with a mean value of 0.60 μs cm^{-1}. These values are rated as very low.

Also, in the lower slope EC was rated as low with values that ranged from 1.00 to 3.00 μs cm^{-1} and a mean value of 1.33 μs cm^{-1} (SE±0.32).

Organic Carbon and Organic Matter

The distribution of organic carbon and organic matter in the soils of the study area showed that organic carbon in the soils of the upper slope profile pits ranged from 0.125 to 1.345% with a mean of 0.51% (SE±0.13) while organic matter varied from 0.21% to 2.319% with a mean value of 0.89% (SE±0.23).

In the middle slope soil pits, the values for organic carbon ranged from 0.672% to 2.117% having a mean of 1.45% (SE±0.26). The values for organic matter in this soil unit ranged from 1.159% to 3.650% having a mean of 2.50% (SE±0.44).

For the lower slope section of the toposequence, the soil organic carbon ranged from 0.423% to 3.735% having a mean of 1.72% (SE±0.46) while the organic matter ranged from 0.729% to 6.437% with a mean of 2.96% (SE±0.80).

Total Nitrogen

Total nitrogen in the soil of the upper slope pits ranged from 0.028% to 0.322% with a mean value of 0.14% (SE±0.04). These values fall within moderate to high.

In the middle slope section, total nitrogen varied from 0.168% to 0.576% having a mean value of 0.78% (SE±0.32). These values are rated as being moderate to very high. For the lower slope section, total nitrogen in the soil was also very high with values ranging from 0.098 to 0.910% having a mean of 0.54% (SE±0.14).

Available Phosphorus

Available phosphorus in the soil pits of the upper slope section ranged from 8.76 to 22.13mgkg^{-1} with a mean value of 15.83 mgkg^{-1} and standard deviation of 2.21 (SE±1.01). This is rated as high.

In the middle slope, available phosphorus ranged from 8.85 to 23.46 mgkg^{-1} with a mean of 16.02mgkg^{-1} and standard deviation of 3.72 (SE±0.77). This was also rated as being high.

In the lower slope section, the Available phosphorusranges from 7.80 to 49.40mgkg^{-1}with a mean of 20.92mgkg^{-1} and standard deviation of 10.22 (SE±4.21) and this is rated as very high (see table 1.1a and 1.1b).

Exchangeable bases (Ca, Mg, K, Na and Exc. Acidity)

The distribution of the basic cations in the soil showed that Ca and Mg were the most abundant. Ca in the soils of the upper slope ranged from 1.402 Cmol kg^{-1} to 3.628 Cmol kg^{-1} with a mean of 2.79 Cmol kg^{-1} (SE±0.28).

For the middle slope area, Ca ranged from 1.866 Cmol kg^{-1} to 5.339 Cmol kg^{-1} having a mean of 3.82 Cmol kg^{-1} (SE±0.59).

In the lower slope, the Ca content ranged from 1.752 Cmol kg^{-1} to 6.537 Cmol kg^{-1} having a mean of 4.29 Cmol kg^{-1} (0.56). These values fall within the rating of low.

The distribution of Mg in the soils of the upper slope section of the catena ranged from 0.475 Cmol kg^{-1} to 0.720 Cmol kg^{-1} with a mean of 0.62 Cmol kg^{-1} (SE±0.03). In the middle slope of the catena, Mg ranged from 0.383 Cmol kg^{-1} to 1.996 Cmol kg^{-1} having a mean of 1.25 Cmolkg^{-1} (SE±0.30). For the lower slope section, Mg in the soil ranged from 0.758 Cmol kg^{-1} to 2.665 Cmol kg^{-1} with a mean of 1.54 Cmol kg^{-1} (SE±0.27). These range of values are all ranked as low.

Potassium (K) in the soils of the upper slope unit ranged from 0.077 Cmol kg^{-1} to 0.170 Cmol kg^{-1}having a mean value of 0.13 Cmol kg^{-1} (SE±0.02), While in the middle slope section, the distribution of K in the soil ranged from 0.075 Cmol kg^{-1} to 0.463 Cmol kg^{-1} having a mean of 0.21 Cmol kg^{-1} (SE±0.07). In the lower slope unit, K ranged between 0.108 Cmol kg^{-1} to 0.310 Cmol kg^{-1} with a mean of 0.21 Cmol kg^{-1} (SE±0.03). These values were rated as low to moderate (Values for the upper slope being very low).

Sodium (Na) in the soil of the upper slope ranged from 0.488 Cmol kg^{-1} to 0.761 Cmol kg^{-1} having a mean of 0.59 Cmol kg^{-1} (SE±0.02). This is rated as moderate to high.

In the middle slope section of the catena, Na ranged from 0.464 Cmol kg^{-1} to 0.787 Cmol kg^{-1} with a mean of 0.57 Cmol kg^{-1} (SE±0.06). These values also rated as low to moderate. For the lower slope section of the catena, Na was rated as being uniformly moderate with values ranging from 0.526 Cmol kg^{-1} to 0.648 Cmol kg^{-1} and a mean of 0.59 Cmol kg^{-1} (SE±0.02).

Exchangeable acidity in the soils of the upper slope ranged from 0.40 Cmol kg^{-1} to 4.60 Cmol kg^{-1} with a mean of 1.62 Cmol kg^{-1} (SE±0.04). This is rated as low to very high. For the middle slope section, the values for exchangeable acidity ranged from 0.80 Cmol kg^{-1} to 1.20 Cmolkg^{-1} having a mean of 0.88 Cmol kg^{-1} (SE±0.08). The lower slope section had values ranging from 0.40 Cmol kg^{-1} to 1.00 Cmol kg^{-1} with a mean of 0.75 Cmol kg^{-1} (SE±0.06). These values are ranked as low to moderate (see table 1.1a and 1.1b).

Cation Exchange Capacity (CEC)

Generally, the cation exchange capacity of the soils along the toposequence as recorded on table 1.1a and 1.1b was very low. In the upper slope section, the CEC values ranged from 3.78 Cmol kg^{-1} to 10.39 Cmol kg^{-1} having a mean of 5.98 Cmol kg^{-1} (SE±0.80). These values are ranked as very low to low.

In the middle slope soils, CEC ranged from 6.08 Cmol kg^{-1} to 8.96 Cmol kg^{-1} having a mean of 7.60 Cmol kg^{-1} (SE±0.56), all these values are rated as low.

In the lower slope section, CEC was in the range of 5.74 Cmol kg^{-1} to 11.37 Cmol kg^{-1} with a mean of 8.17 Cmol kg^{-1} (SE±0.82), also rated as very low to low.

Exchangeable Sodium Percentage (ESP)

The soils of the upper slope section of the catena had relatively higher values for ESP which ranged from 5.09% (low) to 20.13% (very high) having a mean of 11.42% (SE±0.62) as shown on table 1.1a and 1.1b.

In the middle slope section, ESP ranged from 6.25% to 9.92% with a mean value of 7.64% (SE±0.62). These values are rated as low as they fall within acceptable limit of ≤15.0%.

For the lower slope section, the ESP ranged from 5.20% to 9.16% having a mean of 7.67% (SE±0.68) rated as low.

The practice of irrigation in the middle and lower slope sections of the catena has reduced the concentration of soluble Na in the soil owing to high water content and the effect of leaching. Continues water application through irrigation could have leached out the excess Na compared to the upper slope where irrigation is not practiced and the soils tend to be drier than in the middle and lower slope.

High ESP above 15% leads to problem of soil salinity. Hence, the upper slope unit may pose potential salinity problem probably due to low moisture content in the soil. However, this is within the sub-surface horizons and may not be a serious problem for most arable crops with shallow rooting system [1].

Base Saturation Percentage

Base saturation percentage of the soils in the upper slope ranged from 46.11% to 93.47% with a mean of 75.67% (SE±5.80). These values for base saturation percentage are ranked as low to high according to USDA [24] standards.

In the middle slope, BSP ranged from 77.67% to 98.78% with a mean of 89.44% (SE±3.44). These values are all rated as high.

In the lower slope position, the BSP values ranged from 84.80% to 93.68% with a mean of 89.65% (SE±1.02) (see table 1.1a and 1.1b).

Analysis of Variance for Soil Chemical Properties Across Different Topographic Units

Soil pH

The result of analysis of variance showed that there was no significant difference ($p>0.05$) in the pH values of the soil determined in H_2O and in KCl. Test of homogeneity also showed that the non-significant variation in the values was also homogeneous across the two topo sequences studied in the GadaBiyu irrigation area.

Soil Electrical Conductivity

The values for electrical conductivity (Ec) studied showed that the values were not significantly different ($p>0.05$) using ANOVA. However, the description of homogeneity showed that the distribution of values was highly non-homogeneous across the different slope positions along the two topo sequences in GadaBiyu Irrigation area.

Soil Organic matter

The result of analysis of variance for values obtained that depict the distribution of organic carbon and organic matter generally, did not show significance difference ($p>0.05$) in all the soil units of the two catenas. However, while the distribution in the soils of catena 'A' were highly non-homogenous, the distribution along catena 'B' showed that the values distribution was homogeneous (Table 1.3a and b).

Total Nitrogen

The analysis of variance for the distribution of total nitrogen was not significant different ($p>0.05$) for the soil units along topo sequence 'A' but showed a significant difference ($p<0.05$) in the distribution of TN in the soils along the different slope units of catena B. Test of homogeneity also showed that the level of non-significance in TN for topo sequences 'A' and 'B' was highly non homogeneous ($p<0.05$).

Available Phosphorus

The result for analysis of variance for available phosphorus (AP) showed that there was no significant difference ($p>0.05$) in the values obtained for AP. Also, the values were highly homogenous across all the soil units of the two catenas studied ($p>0.05$) (Table 1.3a and b).

Exchangeable Bases

The result of ANOVA for Ca distribution showed that the values were not significantly different ($p>0.05$) across all the slope positions of the two topo sequences. Also, a test of homogeneity showed that the Ca values across the soil units of the two topo sequences were homogeneous.

The distribution of Mg showed a significance difference ($p>0.05$) across the soil units of topo sequences 'A' but showed a significant variation ($p<0.05$) in the values obtained from the soil units of catena 'B'. The test of homogeneity also showed that the values for Mg in topo sequence 'A' were non homogeneous ($p<0.05$) while the values for topo sequence 'B' were highly homogeneous ($p>0.05$).

The result of analysis of variance showed that there was no significant variation ($p>0.05$) in the values of K across the different soils sampled from the two topo sequences. The test of homogeneity however, showed that the distribution of the values were not homogeneous across the soil units of the area.

The result for Na showed that the ANOVA was not significantly different ($p>0.05$) for values recorded from topo sequence 'A', but for topo sequence 'B', there was significant difference ($p<0.05$) in the distribution of Na. Test of homogeneity showed that the values were not homogeneous ($p<0.05$) in all the soil units studied.

The analysis of variance showed that there was there was no significant variation ($p>0.05$) in the exchangeable acidity values of the soils from the two topo sequences. Also, test of homogeneity showed that the non-significance in the values recorded was uniformly homogeneous across the two topo sequences studied (Table 1.3a and b)

Cation Exchange Capacity

The distribution of CEC showed that there was no significant difference in the CEC values of the soils from the different soil units of the two topo sequences. The values were also homogeneous in their distribution ($p>0.05$) (Table 1.3a and b)

Exchangeable Sodium Percentage

The result for analysis of variance showed that there was no significant difference ($p>0.05$) in the values for exchangeable sodium percentage for all the soil units studied. The values were uniformly homogeneous ($p>0.05$) across all the slope positions of the two topo sequences (Table 5.5a and b).

Base Saturation Percentage

The result for analysis of variance showed that there was no significant difference ($p>0.05$) in the distribution of base saturation percentage (BSP) of the soils across the different slope positions of the topo sequence. The test of homogeneity showed that the values were not homogenous ($p<0.05$) across the slope positions of topo sequence 'A', while the values for topo sequence 'B' were generally homogenous ($p>0.05$) across the slope positions of the catena (Table 1.3a and b)

Table 1.3a: Soil chemical properties of Gadabiyu irrigation area

Location	Horizon/depth (cm)	pH KCl	pH H_2O	EC µscm^{-1}	Org.C %	O.M %	TN %	Av.P Mg/L	Ca Cmol kg^{-1}	Mg	K	Na	Ex.Ac	CEC	ESP %	Bsat %
MU1 (Upland) Upper slope	Ap 0 – 16	3.23	6.88	1.00	1.35	2.32	0.32	21.84	3.63	0.72	0.17	0.58	0.60	5.69	10.16	89.50
N8.61257	AB 16 – 48	3.18	6.71	1.00	0.25	0.43	0.06	10.40	3.37	0.67	0.10	0.65	5.60	10.24	6.24	46.11
E6.919432	Bt1 48 – 67	3.08	6.60	7.00	0.13	0.22	0.03	18.20	2.66	0.57	0.08	0.57	1.00	4.87	11.70	79.47
Alt.= 85m	Bt2 67 – 106	3.28	6.65	9.00	0.55	0.95	0.14	8.76	1.40	0.70	0.12	0.76	0.80	3.78	20.13	78.78
	C1 106 – 153	3.24	6.94	7.00	0.35	0.60	0.08	14.56	2.11	0.48	0.10	0.62	0.60	3.89	15.86	82.52
	C2 153 – 175	3.21	6.65	ND	0.25	0.43	0.06	14.56	2.15	0.52	0.13	0.65	1.40	4.45	14.56	68.54
	C3 173+	3.15	6.76	ND	0.48	0.83	0.11	14.56	2.40	0.51	0.13	0.57	1.60	5.21	10.84	69.29
	Augered (0 - 15)	3.32	6.87	1.00	0.95	1.64	0.31	22.13	3.62	0.72	0.17	0.49	0.60	5.97	8.22	93.47
	Augered (15 - 30)	3.21	6.77	1.00	0.32	0.56	0.12	17.42	3.43	0.66	0.13	0.49	0.60	9.58	5.09	55.33
	Mean	*3.21*	*6.76*	*3.00*	*0.51*	*0.89*	*0.14*	*15.83*	*2.79*	*0.62*	*0.13*	*0.59*	*1.62*	*5.98*	*11.42*	*75.67*
	Std.Dev	*0.07*	*0.12*	*2.01*	*0.39*	*0.68*	*0.11*	*2.21*	*0.84*	*0.10*	*0.09*	*0.07*	*0.11*	*2.39*	*4.80*	*17.39*
	SE±	*0.02*	*0.04*	*0.11*	*0.13*	*0.23*	*0.04*	*1.01*	*0.28*	*0.03*	*0.03*	*0.02*	*0.04*	*0.80*	*1.60*	*5.80*
MU2 (Backswamp) Middle slope	Ap1 0 – 11	3.31	6.78	ND	2.12	3.65	0.52	8.85	5.34	2.00	0.18	0.65	0.80	8.98	7.23	91.02
N8.610845	Ap2 11 – 27	3.16	6.77	ND	1.33	2.29	2.02	13.00	1.87	0.38	0.08	0.46	0.80	6.52	7.12	87.79
E6.918897	Bt1 27 – 42	3.13	6.47	2.00	0.67	1.16	0.17	15.60	3.62	1.83	0.46	0.79	1.20	8.59	9.92	77.67
Alt.= 85m	Augered (0 - 15)	3.30	6.70	ND	1.90	3.29	0.61	19.21	4.66	1.08	0.17	0.49	0.80	7.83	6.25	91.92
	Augered (15-30)	3.26	6.70	1.00	1.21	2.09	0.58	23.46	3.63	0.98	0.14	0.47	0.80	6.08	7.66	98.78
	Mean	*3.23*	*6.68*	*0.60*	*1.55*	*2.50*	*0.78*	*16.02*	*3.82*	*1.25*	*0.21*	*0.57*	*0.88*	*7.60*	*7.64*	*89.44*
	Std.Dev	*0.08*	*0.13*	*0.07*	*0.58*	*0.99*	*0.72*	*3.72*	*1.31*	*0.66*	*0.15*	*0.14*	*0.18*	*1.26*	*1.38*	*7.70*
	SE±	*0.04*	*0.06*	*0.02*	*0.26*	*0.44*	*0.32*	*0.77*	*0.59*	*0.30*	*0.07*	*0.06*	*0.08*	*0.56*	*0.62*	*3.44*
MU3 (levee) Lower slope	Ap1 0 – 16	3.28	6.77	ND	3.74	6.44	0.91	7.80	6.54	2.67	0.31	0.66	0.80	10.97	6.03	92.76
N8.606472	Ap2 16 – 34	3.34	6.69	1.00	3.64	6.27	0.88	18.12	3.55	0.97	0.12	0.59	0.80	7.90	7.43	84.80
E6.9139	Bt 34 – 58	4.37	6.53	1.00	0.45	0.77	0.11	17.60	1.75	0.76	0.27	0.65	1.00	6.03	10.75	86.75
Alt.= 78m	C1 58 – 79	3.08	6.68	1.00	1.27	2.19	0.31	10.92	3.57	1.14	0.11	0.53	0.40	5.74	9.16	93.68
	C2 79 – 92	3.19	6.74	3.00	0.95	1.63	0.22	22.36	3.56	1.12	0.14	0.53	0.60	6.01	8.75	90.00
	C3 92+	3.33	6.66	3.00	0.42	0.73	0.10	49.40	3.84	1.15	0.12	0.62	0.80	7.32	8.43	89.13
	Augered (0 - 15)	3.30	6.69	ND	1.92	3.31	0.91	22.46	5.88	2.66	0.31	0.59	0.80	11.37	5.20	90.04
	Augered (15-30)	3.20	6.66	ND	1.35	2.33	0.87	18.71	5.61	1.82	0.31	0.57	0.80	10.01	5.72	91.05
	Mean	*3.35*	*6.68*	*1.33*	*1.72*	*2.96*	*0.54*	*20.92*	*4.29*	*1.54*	*0.21*	*0.59*	*0.75*	*8.17*	*7.68*	*89.65*
	Std.Dev	*1.47*	*1.31*	*1.07*	*1.31*	*2.26*	*0.38*	*10.22*	*1.59*	*0.76*	*0.10*	*0.05*	*0.18*	*2.31*	*1.93*	*2.89*
	SE±	*0.52*	*0.03*	*0.32*	*0.46*	*0.80*	*0.14*	*4.21*	*0.56*	*0.27*	*0.03*	*0.02*	*0.06*	*0.82*	*0.68*	*1.02*

NB: EC = electrical conductivity, org.c = organic carbon, O.M = organic matter, TN = total nitrogen, Av.P = available phosphorus, Ca = calcium, Mg = magnesium, K = potassium, Na = sodium, Ex.Ac = exchangeable acidity, CEC = cation exchange capacity, ESP = exchangeable sodium percentage, Bsat = base saturation. Source: Fieldwork 2017/2018

Table 1.1b: Soil chemical properties of Gadabiyu irrigation area

Location	Horizon/depth (cm)	pH KCl	H_2O	EC µscm^{-1}	Org.C %	O.M %	TN %	Av.P Mg/L	Ca Cmol kg^{-1}	Mg	K	Na	Ex.Ac	CEC	ESP %	Bsat %
MU1 (Upland) Upper slope	Ap 0 – 19	3.33	6.64	1.00	1.02	1.76	0.21	22.43	4.21	1.17	0.15	0.50	0.60	7.82	6.39	84.78
N8.612515	AB 19 – 68	3.23	6.70	1.00	0.52	0.90	0.15	10.22	4.07	2.10	0.14	0.65	0.60	8.81	7.38	85.81
E6.920833	Bt1 68 – 103	3.21	6.52	1.00	0.24	0.41	0.15	19.30	2.96	1.57	0.11	0.47	0.60	6.27	7.50	91.07
Alt.= 96m	Bt2 103 – 152	3.30	6.65	1.00	0.19	0.33	0.14	10.11	2.11	0.92	0.12	0.65	0.80	5.69	11.42	66.78
	C1 152 – 181	3.24	6.66	2.00	0.15	0.26	0.07	14.50	2.11	1.00	0.11	0.58	0.60	5.16	24.77	73.64
	C2 181 – 200	3.20	6.65	1.00	0.11	0.19	0.07	13.56	2.23	0.79	0.11	0.59	0.60	4.84	12.19	76.86
	Augered (0 - 15)	3.22	6.92	1.00	0.87	1.50	0.25	22.13	2.97	0.72	0.14	0.50	0.60	6.33	7.90	68.40
	Augered (15-30)	3.20	6.67	1.00	0.55	0.95	0.15	25.16	3.56	1.36	0.13	0.50	0.60	6.53	7.66	84.99
	Mean	*3.24*	*6.68*	*1.13*	*0.46*	*0.79*	*0.15*	*17.18*	*3.03*	*1.20*	*0.12*	*0.56*	*0.63*	*6.43*	*10.65*	*79.04*
	Std.Dev	*0.49*	*0.11*	*0.35*	*0.35*	*0.60*	*0.06*	*5.84*	*0.85*	*0.46*	*0.04*	*0.07*	*0.07*	*1.33*	*6.07*	*8.91*
	SE±	*0.17*	*0.04*	*0.13*	*0.21*	*0.21*	*0.02*	*2.07*	*0.30*	*0.16*	*0.01*	*0.03*	*0.03*	*0.47*	*2.14*	*3.15*
MU2 (Backswamp) Middle slope	Ap1 0 – 17	3.28	6.65	1.00	1.52	2.62	0.50	18.57	5.04	2.96	0.12	0.62	0.40	11.26	5.51	77.62
N8.610763	Ap2 17 – 41	3.22	6.71	2.00	1.21	2.09	0.56	23.01	3.76	1.33	0.10	0.56	0.40	6.98	8.02	79.22
E6.920262	Bt1 41 – 67	3.23	6.45	2.00	0.42	0.72	0.27	27.20	3.54	1.53	0.40	0.60	0.60	6.84	8.77	88.74
Alt.= 85m	Bt2 67 - 76	3.21	6.66	1.00	0.31	0.53	0.21	20.14	2.98	0.98	0.15	0.54	0.60	6.77	7.98	68.69
	Augered (0 - 15)	3.18	6.56	1.00	1.23	2.13	0.55	29.10	5.27	0.99	0.11	0.51	0.40	8.91	5.72	77.22
	Augered (15-30)	3.24	6.67	1.00	1.21	2.09	0.50	23.00	3.22	1.04	0.13	0.51	0.40	6.82	7.48	72.73
	Mean	*3.23*	*6.62*	*1.33*	*0.98*	*1.70*	*0.43*	*23.50*	*3.97*	*1.47*	*0.17*	*0.56*	*0.47*	*7.93*	*7.23*	*77.37*
	Std.Dev	*0.03*	*0.10*	*0.52*	*0.49*	*0.86*	*0.15*	*4.03*	*0.96*	*0.76*	*0.11*	*0.05*	*0.10*	*1.83*	*1.33*	*6.78*
	SE±	*0.01*	*0.04*	*0.21*	*0.20*	*0.35*	*0.06*	*1.64*	*0.39*	*0.31*	*0.05*	*0.02*	*0.04*	*0.75*	*0.54*	*2.77*
MU3 (levee) Lower slope	Ap1 0 – 20	3.28	6.69	1.00	2.05	3.53	0.67	16.51	5.22	2.11	0.13	0.50	0.40	10.24	4.88	77.73
N8.60633	Ap2 20 – 44	3.34	6.69	1.00	1.86	3.21	0.48	17.53	3.50	1.86	0.12	0.52	0.40	8.03	6.48	79.70
E6.915265	Bt 44 – 72	4.37	6.63	1.00	0.60	1.03	0.12	17.50	2.34	1.32	0.13	0.47	0.60	6.77	6.94	65.88
Alt.= 78m	C1 72 – 98	3.08	6.72	1.00	0.56	0.97	0.12	21.52	2.21	0.97	0.13	0.46	0.60	5.45	8.44	80.73
	C2 98 – 117	3.19	6.72	1.00	0.55	0.95	0.12	24.44	2.04	0.91	0.13	0.49	0.60	4.82	10.17	74.07
	C3 117+	3.33	6.79	1.00	0.42	0.72	0.09	32.13	3.01	1.22	0.11	0.53	0.60	6.56	8.08	74.24
	Augered (0 - 15)	3.30	6.63	1.00	1.12	1.93	0.66	20.11	5.06	2.03	0.20	0.50	0.60	10.37	4.82	75.12
	Augered (15-30)	3.20	6.63	1.00	1.03	1.78	0.66	28.17	4.91	1.99	0.15	0.52	0.60	9.83	5.29	77.01
	Mean	*3.39*	*6.69*	*1.00*	*1.02*	*1.77*	*0.67*	*22.24*	*3.53*	*1.55*	*0.14*	*0.50*	*0.55*	*7.76*	*6.89*	*75.56*
	Std.Dev	*0.41*	*0.06*	*0.00*	*0.63*	*1.08*	*0.28*	*5.61*	*1.36*	*0.50*	*0.03*	*0.02*	*0.09*	*2.91*	*1.91*	*4.61*
	SE±	*0.14*	*0.02*	*0.00*	*0.22*	*0.38*	*0.10*	*1.98*	*0.48*	*0.17*	*0.01*	*0.01*	*0.03*	*0.65*	*0.68*	*1.63*

NB: EC = electrical conductivity, org.c = organic carbon, O.M = organic matter, TN = total nitrogen, Av.P = available phosphorus, Ca = calcium, Mg = magnesium, K = potassium, Na = sodium, Ex.Ac = exchangeable acidity, CEC = cation exchange capacity, ESP = exchangeable sodium percentage, Bsat = base saturation. Source: Fieldwork 2017/2018

Table1.3a: Summary of ANOVA Analysis for Catena 'A

S/ N	PROPERTY	CALCULATED F	SIGNIFICANT VALUE	ALPHA LEVEL	SIGNIFICANCE DIFFERENCE	TEST OF HOMOGENITY SIGNIFICANT VALUE OF HOMOGENITY	DESCRIPTION OF HOMOGENITY
	SOIL CHEMIICAL PROPERTIES						
1	KCL	1.120	.347	0.05	NS	.109	NS
2	H2O	1.508	.247	0.05	NS	.278	NS
3	EC	1.059	.380	0.05	NS	.000	S
4	Carbon	4.319	.028	0.05	NS	.012	S
5	OrgM	4.326	.028	0.05	NS	.012	S
6	TN	4.441	.026	0.05	NS	.006	NS
7	P	.869	.435	0.05	NS	.344	NS
8	Ca	3.357	.056	0.05	NS	.164	NS
9	Mg	6.065	.009	0.05	S	.001	S
10	K	2.232	.135	0.05	NS	.007	S
11	Na	.133	.876	0.05	NS	.019	S
12	ExAc	.950	.404	0.05	NS	.081	NS
13	CEC	2.360	.121	0.05	NS	.367	NS
14	ESP	3.268	.060	0.05	NS	.034	NS
15	Bsat	5.813	.011	0.05	NS	.007	S

	SOIL CHEMIICAL PROPERTIES						
1	KCL	.943	.407	0.05	NS	.060	NS
2	H2O	1.165	.333	0.05	NS	.604	NS
3	EC	1.646	.219	0.05	NS	.001	S
4	Carbon	3.060	.070	0.05	NS	.276	NS
5	OrgM	3.051	.071	0.05	NS	.275	NS
6	TN	4.492	.025	0.05	S	.000	S
7	P	2.907	.079	0.05	NS	.337	NS
8	Ca	1.308	.294	0.05	NS	.171	NS
9	Mg	.808	.460	0.05	NS	.645	NS
10	K	3.078	.070	0.05	NS	.022	S
11	Na	5.521	.013	0.05	S	.003	S
12	ExAc	1.527	.243	0.05	NS	.192	NS
13	CEC	2.172	.141	0.05	NS	.165	NS
14	ESP	.493	.618	0.05	NS	.081	NS
15	Bsat	.943	.407	0.05	NS	.080	NS

Table 1.3b: Summary of ANOVA Analysis for Catena 'B'

DISCUSSION OF RESULTS

The pH range of soils in this report may not be unconnected to the soil texture, low status of basic cations, nutrient biocycling and parent materials from which the soils are formed. Also, acidic soils are mostly commonly associated with climatic regimes, for example where rainfall is high and temperatures are warm, increased biological activities may lead to the production of organic acids thereby increasing soil pH (Wapa, *et al.*, 2015). Also, free drainage favours leaching of exchangeable cations, thus increasing the concentration of H^+ in the soil solution. This is particularly true for the soils of the study area which is predominantly silty loam, thus favoring excessive leaching of minerals and nutrients. This assertion agrees with Barnabas *et al*, [6]. The surface horizons recorded higher values of pH than the lower horizons, this is probably due to biocycling of nutrients in the soil (Idoga and Azagaku, 2005). Also, the ANOVA result showed that there was no significant difference ($p>0.05$) in the pH values of the soil determined in H_2O and in KCl.Test of homogeneity also showed that the non-significant variation in the values was also homogenuous across the two toposequences study area. The general uniformity in the pH distribution of the soil could be function of landuse pattern and uniform parent material from which the soils developed. Barnabas andBarnabasandNwaka (2014) reported similar findings in the soils of Jiwa a suburb of Abuja. The soils were formed generally from basement complex materials, primarily granites, migmatites and schists (Table 1.3a and b).

The study further revealed that the EC values were rated low to moderate. EC is a soil quality indicator that gives information on the amount of soluble salts in a soil. It is a measure of how easily an electric current can flow through the soil. The range of EC values and pH in these soils is tending towards neutrality especially where EC is above 1.00 µs cm^{-1}. This may not be unconnected to the seasonal/periodic inundation by flood water during peaks of the river flow. Different salt materials are transported in the flowing water which when deposited on the soil increases the electrical conductivity of the soil (Chude*et al.*, 2011; 2005).Also, the middle and lower slope units had lower EC values probably due to their poorly drained nature and aquic moisture regimes that could have leached out most of the soluble salts in the soil. This explains why areas farther from the lower slope (middle slope and Upland) had EC values that are relatively higher. The lower values of EC in the middle and lower slopes suggest effect of continues irrigation which dissolved most salts in the soil and leached them out. This assertion agrees with Agbede (2009) who noted that drier soils have high salt content than wet soils. The higher EC values in the upper slope are attributed to the dry soil condition which is often associated with higher salt deposits. The moisture regime in the upper slope was suggesting that the soils were dry for longer periods than the lower slope sections of the toposequences, hence may show higher dissolvable salts content.

Organic carbon and soil organic matter showed the same trend in the soils. The values recorded indicated a moderate to very high distribution within the profiles and along the toposequence with much higher values in the middle and lower slope sections. The values were higher at the surface and decreases with increasing soil depth within the profile see table 1.1a and 1.1b.

There is evidence of organic matter illuviation in some sub surface horizons in all the three locations. Amhiakhian and Osemwata, (2012) reported similar trends. The high values of organic matter content in the soil can be attributed to constant use of organic manure by farmers (especially in the middle and lower slopes) as a means of maintaining soil fertility and for improved crop performance and yield. A trend observed in the organic matter distribution in all the three locations was a decrease in organic matter content with increasing soil depth.

The percentage organic matter content was moderately high in the surface horizons and also in the lower slopes adjacent to the river course. This is so probably because of the aquic moisture condition of the soil which reduce soil temperature and consequently lower the rate of organic matter decomposition. Also, leaching and washing away of nutrients from higher slope units and the subsequent deposition in the lower slopes may be responsible for the higher organic matter content at the lower slope unit than the other units on the higher slopes (Wapa*et al.*, 2015; Barnabas and Nwaka, 2014 and Idoga and Azagaku, 2005).

Another reason for the very high organic matter content in all the soils of the units studied could be attributed to continuous use and application of organic materials, especially cow dung, poultry droppings and wood ash as nutrient/manures for crop production. This was a common practice by all the farmers in the study area.

Upper slope sections had lower values than the middle and lower slope sections of the toposequences. The increase in organic matter along the toposequence from upper to lower section suggest influence of gradient that warrant migration of soil organic carbon and subsequent deposition in the lower slope sections.

The total nitrogen values within the profiles decreased with increasing soil depth, however, the distribution of nitrogen within the profile followed the same trend as organic matter.It is observed that the horizons with high organic matter content also showed high N content. This attests that there is synergy in the distribution of organic matter and total nitrogen in the soil. This trend is also a confirmation that soil organic matter is a store house of soil nutrients. Ogbodo, (2011) also reported a positive correlation between organic matter and soil nitrogen. Sanni (2012) reported a similar trend in the soils of Dobi a suburb of Gwagwalada Area Council in the FEDERAL CAPITAL TERRITORY.

Though nitrogen in the surface soils (especially) tended to be very high, but it is prone to loses by leaching, percolation, volatilization and plant uptake. This is attributed to the porous nature of the soil coupled with high temperatures associated with the area. The soils were sandy and leaching of nutrients and other basic cations in the soil would be high.

The high availability of P in the soil is attributed to the soil reaction being generally slightly acidic to near neutral and also the high moisture content of the soil especially at the middle and lower slope sections of the toposequence. These pH range favours availability of P in the soil (Agbede, 2009). Also, Ogbodo (2011) reported high available P in some depressed wetlands in south-eastern Nigeria and attributed the high available soil P to high moisture content of the soil. He noted that one of the ways to enhance the availability of P in soils is to increase the water/moisture content of the soil. (Uzoho*et al*, (2004) noted that low P content in most soils is attributed to soil acidity. In this case, soil texture becomes significant in determining P availability. In this study area, the soils are mostly sandy, and available P increased with increasing profile depth even though the pattern of increase was not consistent all through the profile depth. This may be explained by the high moisture content in the lower horizons within all the profiles [14]. P is less mobile and can still be observed in the soil after cropping, this could still be responsible for the high P values of the surface horizon in the upper slope section, considering the fact that the floodplain soils are cultivated for various crops and SSP fertilizers are often added as inorganic fertilizer.

The distribution of the basic and acidic cations in the soil did not show any regular pattern of distribution within the profiles. However, soils that are mostly wet (middle and lower slopes) with high water tables showed relatively stable values within the profiles.

The very low range of values for all the basic cations in the soils of the area is likely the result of excessive leaching of these basic cations in the soil.This is true considering the high sand content of the soils. Sandy loam, single grained sand and loamy sand are porous and aggravate leaching by water. This low status of basic cations in the soil also correlates with the near acidic reaction (low pH) of the soil.Osuji*et al*, (2002), reported that soils formed from coastal plain sands/floodplain soils are deep, acidic, and coarse textured and generally of low CEC and low inherent natural fertility.

The preponderance of Ca and Mg in the soils is common to most tropical soils even though the exchangeable cations were relatively very low.Foth, (2006) stated that the exchange site of most tropical soils are dominated by calcium and magnesium. The exchangeable cations decrease with increasing depth due to nutrient biocycling (Ogunwale*etal*., 2002; Akamigbo, 1986).

The distribution of exchange acidity in the soil did not follow any definite pattern of occurrence. It is mostly believed that H^+ and Al^{3-} which are the constituents of exchange acidity are in equilibrium in acid soils [1]. Higher contents of exchangeable acidity is associated with high clay content, hence the result of the study shows that values of exchange acidity in the soils are low probably due to the sandy texture of the soil.

The low CEC of the soils may be due to the very low amount of clay content of the soil. The low CEC implies low ability of the soil to hold cations. CEC is strongly dependent on physical and chemical variables of the soil [2]. Practices of bush burning in the area has affected the concentration of aluminum in the soil making the soil temporarily acidic with high level of ionic elements. Generally, soils with low CEC values have colours that are bright arising from low organic matter and low clay content. The soils' CEC is low and is an indication of the nutrient holding potential of the soil.The trend in the CEC of the soil is similar to the distribution of basic exchangeable cations in the soil.

The relationship between clay content and CEC can be highly variable because different clay minerals have different cation exchange capacity [3], thus the soils of three different slope sections have low specific capacity to exchange cations. This is because in terms of particle size fraction, clay sized particles have a wide range of CEC, while that of silt is smaller, but sand has virtually low exchange capacity. The soils having very low clay content affected the cation exchange capacity. The relative higher values of CEC at the surface horizons, however, may be due to influence of high organic matter in the soil, hence the decrease in lower horizons corresponds with decrease in organic matter.

The distributions of all the extractable micronutrients (Mn, Fe, Cu and Zn) in the soils along the catena were very high. This is not unconnected to the inherent nature of the parent material. Mn and Zn is major constituent of parent materials formed from undifferentiated basement complex such as granites, basalts, magmatic schists and gneisses. This explains why Mn and Fe were so abundant in the soils along the toposequence. This assertion agrees with [11]. Also, it would be observed that the middle slope and lower slopes had relatively higher values for all the extractable micronutrients than the upper slope section. This can be attributed to higher moisture content in the lower slopes where water table is high. Evidence of all these was confirmed in the field where as a result of high-water table and the rate of redox reaction, iron II is reduced to iron III oxides liberating the sesquioxides of Fe, Mn and Cu. This is a common phenomenon in most floodplain soils, being the case with the Gadabiyu irrigation area. This situation was also reported in a study of similar soils in South Eastern Nigeria by Akamigbo, [3].

In all the units studied, Pb was decreasing with increase in soil depth suggesting that surface horizons of the soils had higher Pb values except for the middle slope unit which had much higher values in the sub surface horizons than in the surface. This can be attributed to effect of erosion and deposition by water during irrigation. Hence, the upper slope with low moisture content had much lower values of extractable Pbinthe soil. This finding is consistent with the report of Bhattachariyya*et al*, (2008) and further added that increased levels of Pb in the soils may decrease soil productivity resulting in phytotoxicity and reduced nutrient uptake by plants. Also, Jordao*et al*, (2006) noted that cultivation of crops on contaminated soils represents a potential risk and a source through which vegetable tissues can accumulate heavy metals.

The trend in the distribution of Ni in the soil showed that Ni decreased with increase in soil depth within the profiles. The decrease however, did not follow a regular pattern. Also, the lower slope position had higher values of Ni indicating effect of erosion and deposition of materials that moved from higher elevations, thus giving higher concentration in lower or depressed units. This result agreed with Okoli*et al*, (2017) findings but disagrees with their conclusion, they studied some coastal plain soils and reported higher values were found at the surface horizons than in the subsurface which they attributed to the agricultural activities practiced in the area. However, Ayodele and Mohammed, (2011) had noted that Ni is generally not distributed uniformly throughout most profiles.

Cobalt was lower in the upper slope position where irrigation was never practiced. In the middle and lower slope sections however, Co increased significantly. This finding agrees with Ayorinde and Dallatu (2017) and is attributed to erosion consequent of irrigation practice in the area. Distribution within the profile showed that cobalt in the profiles decreased with profile depth.

CONCLUSION AND RECOMMENDATIONS

This study aimed at assessing the impact of topography on chemical properties of soil along a toposequence in GadabiyuArea of Kwali area council, AbujaFederalCapitalTerritory, Nigeria. The study revealed that landscape position significantly influenced variation in soil chemical properties. Generally, the values of organic carbon and organic matter indicated a moderate to very high distribution within the profiles and along the topo sequence with much higher values in the middle and lower slope sections. The high values of organic matter content in the soil can be attributed to constant use of organic manure by farmers (especially in the middle and lower slopes) as a means of maintaining soil fertility and for improved crop performance and yield. The increase in organic matter along the topo sequence from upper to lower section suggest influence of gradient that warrant migration of soil organic carbon and subsequent deposition in the lower slope sections. The total nitrogen values within the profiles decreased with increasing soil depth, however, the distribution of nitrogen within the profile followed the same trend as organic matter. It is observed that the horizons with high organic matter content also showed high N content. The soil pH was moderately acidic in all the soil profile studied. The general uniformity in the pH distribution of the soil could be function of land use pattern and uniform parent material from which the soils developed. The study also showed that the EC values were rated low to moderate. This may be due to the seasonal/periodic inundation by flood water during peaks of the river flow. Different salt materials are transported in the flowing water which when deposited on the soil increases the electrical conductivity of the soil. The distribution of the basic cations in the soil showed that Ca and Mg were the most abundant. the preponderance of Ca and Mg in the soils is common to most tropical soils even though the exchangeable cations were relatively very low. The very low range of values for all the basic cations in the soils of the area is likely the result of excessive leaching of these basic cations in the soil. This is true considering the high sand content of the soils. Sandy loam, single grained sand and loamy sand are porous and aggravate leaching by water. This low status of basic cations in the soil also correlates with the near acidic reaction (low pH) of the soil.CEC was rated as low. The low CEC of the soils may be due to the very low amount of clay content of the soil. The low CEC implies low ability of the soil to hold cations. CEC is strongly dependent on physical and chemical variables of the soil. The soils' CEC is low and is an indication of the nutrient holding potential of the soil. The addition of an organic material will likely increase the soil CEC over time. The trend in the CEC of the soil is similar to the distribution of basic exchangeable cations in the soil.Based on this study finding, some specific recommendations are forwarded as follows:

- organic matter should be continuously applied to the soil as a means of improving soil structure, and the nutrient capital reserve of the soil.
- This study therefore, recommends toposequence specific soil management in order to avoid blanket conclusion and inorder to attain sustainability of such delicate ecosystems.

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