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Assessing The Effect Of Toposequence Position On Soil Physical Properties In Floodplain Irrigated Soils Of Gadabiyu Area Of Kwali Area Council, Abuja Federal Capital Territory, Nigeria.

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***Abstract*—This study investigated the effect of toposequence position on soil physical properties in flood plain irrigated soils of GADA BIYU area of KWALI Area Council, Abuja, FCT. Two catena (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 for Particle size distribution, Bulk density, Soil total porosity, saturated hydraulic conductivity (K_{sat}), and infiltration measurements was also carried out. Descriptive statistics and a One way Analysis of Variance were used to analyze the data. The result reveal that variations in soil physical properties found among the landscape segments were probably because of toposequence characteristics in soils. However, there was no consistent sequence in the distribution of particle size fractions from the upper slope to the foot slope. The soils in the area are dominated with sand fraction. Findings from the ANOVA revealed that the distribution of sand silt and clay along catena 'A' did not show any significant difference ($p>0.05$) however, in catena 'B' the distribution of clay was significantly different ($p<0.05$). furthermore, findings revealed that bulk density, total porosity, saturated hydraulic conductivity of the two toposequence studied showed that there was no significant difference ($p<0.05$), however, findings revealed thatthe distribution of soil water content varied significantly ($p<0.05$) in the SMC in all the slope positions across the two catenas. The study recommends that a detail soil survey of the area should be carried out to enable farmers employ precision agriculture to enhance food production.**

Keywords—Toposequence, Catena, Irrigation, Physical Properties.

Introduction

As in other parts of the tropics, rain-fed agriculture featuring different types of crops mainly for subsistence has continued to be plaque with plethora of problems. Prominent among them is soil fertility decline. Brown *et.al* (2004) cited geomorphological factors especially weathering and human activities as leading precursors to soil fertility degradation in the tropics. In addition, the increased pressure on fragile landscapes, with intensive tillage leads to severe soil degradation in tropical environments (Fungo, *et.al*, 2011; Lufafa, *et.al.* 2003).

The rapid rate of soil loss and fertility decline in tropical environments characterized by insidious topography exacerbates the problem of food insecurity in developing countries. Though not all soils are strongly correlated with terrain attributes, much less can be linked to them in a straightforward functional way (Sobieraj, *et.al*, 2002); this is even more complex within an agricultural field where different types of land use types are practiced. The management of an agricultural landscape has a functional relationship with the fertility status of the soil. But in a landscape characterized by intense geomorphological processes of weathering, mudflow, rock fall, and soil erosion the existing relationship may not be clear-cutin such a situation. Webster (2000), reports that under such conditions soil variability thus seems to be random.

The randomness of soil fertility in an agricultural field calls for innovative techniques in ensuring environmental sustainability and high food yields. One of such approaches is precision agriculture (ACPA, 2002). Precision agriculture is a concept that is geared toward site specific crop management (SSCM). It is defined as matching resource application and agronomic practices with soil and crop requirements as they vary in space and time within a field (Whelan and McBratney, 2000). An understanding of the fertility status of each land unit (LU) can be linked to the site-specific management technique especially in Gadabiyu agricultural fields where the combined problems of traditional farming tools and rugged topography challenges food production.

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 (CIFIIIP, 2013).

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 (Balogun, 2001). Rainfall play a vital role with respect to agricultural activities within the study area and most farming activities highly depend on rainfall (Balogun, 2001).

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 (Balogun, 2001).

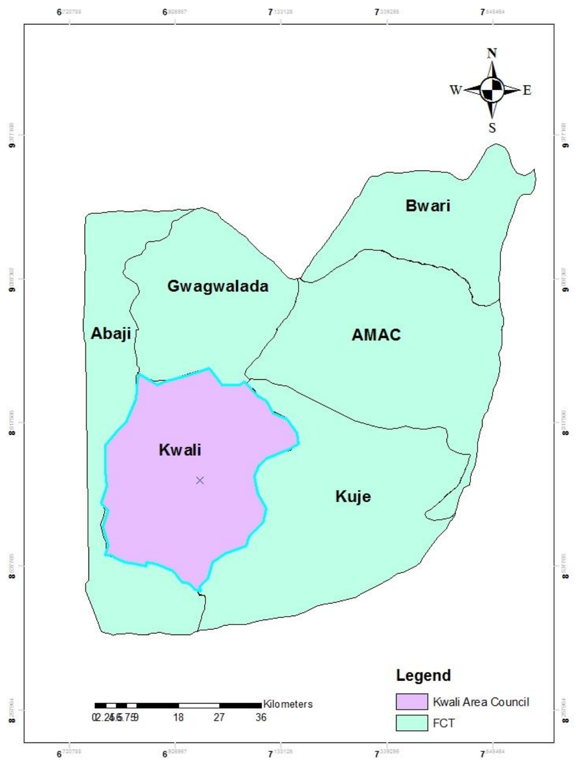

Figure 1.1: Map of Fct Showing Kwali Area Council

Source: UniAbujaGis Lab

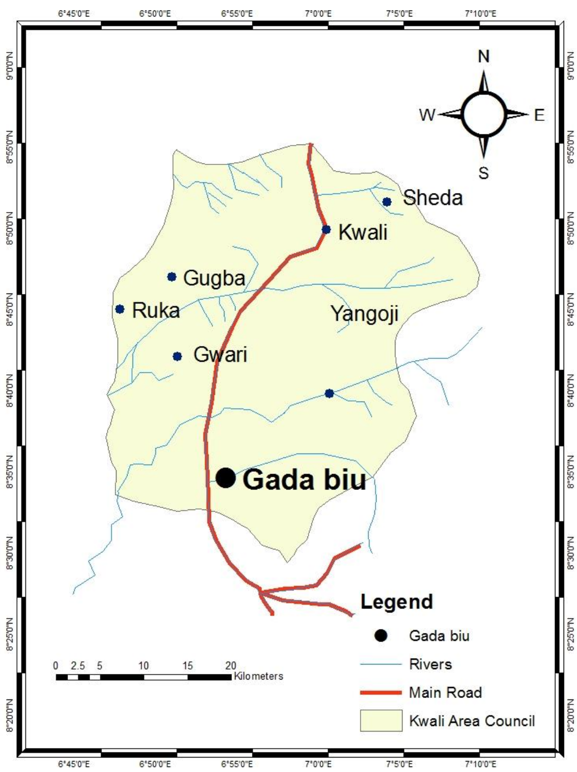

Figure 1.2: Map of Kwali Area Council showing the Study Area

Source: UniabujaGis Lab

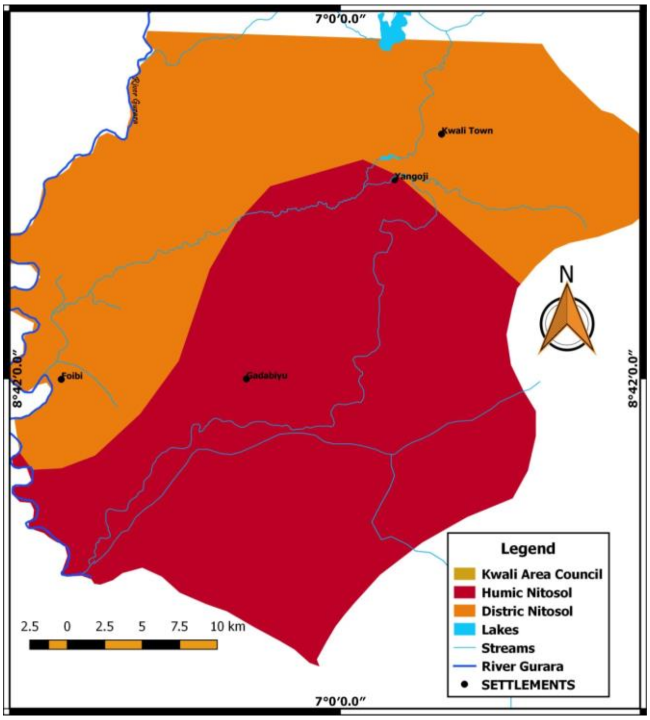

Figure 1.3: Soil Map of the Study area**,**

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 (CIFIIIP, 2013).

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 (CIFIIIP, 2013). 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 (CIFIIIP, 2013).

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 1.1:

Table 1.1: Toposequence slope segments Elevation, Interval Distance and Coordinates.

SYMBOL OF SLOPE	SLOPE	ELEVATION/ HIGHT	INTERVAL HORIZONTAL DISTANCE	COORDINATES Of SLOPE SEGMENTS		COORDINATES OF PROFILE PITS			
						CATANA A		CATANA B	
MU1	Upper slope	96m	0-200	N08°36'753"	E 006^{0} 55'165"	E6.919432	N 8.61257	E6.920833	N8.612515
MU2	Mid-slope	85m	200-700	N08^{0}36'649"	E 006^{0} 55'134"	E6.918897	N8.610845	E6.920262	N8.610763
MU3	Lower slope	78m	700-1000	N08^{0} 36" 385"	E 006^{0} 54'835"	E6.9139	N8.606472	E6.915265	N8.60633

Source Field Work 2017/2018

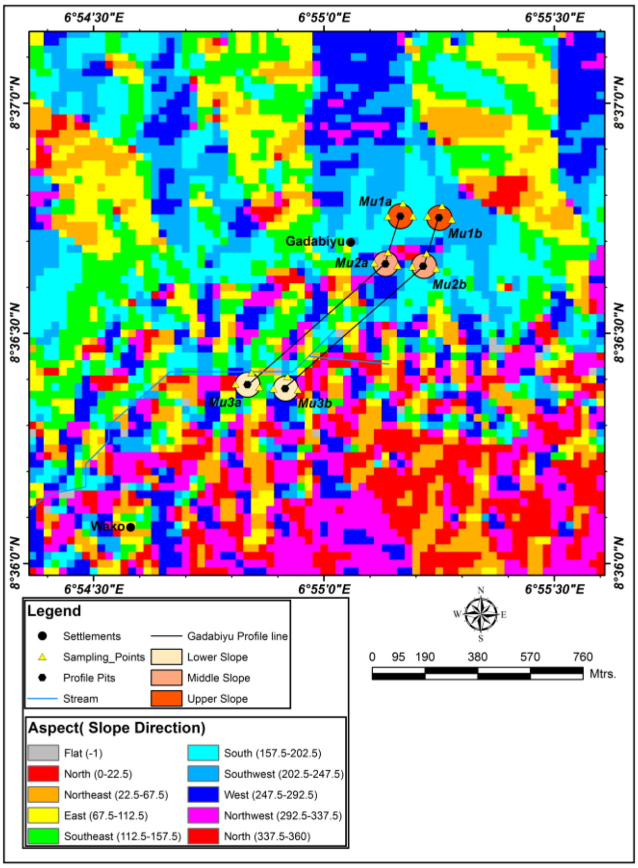

Figure 1.4: **Aspect Map of the Profile Pits**

Source: Field work

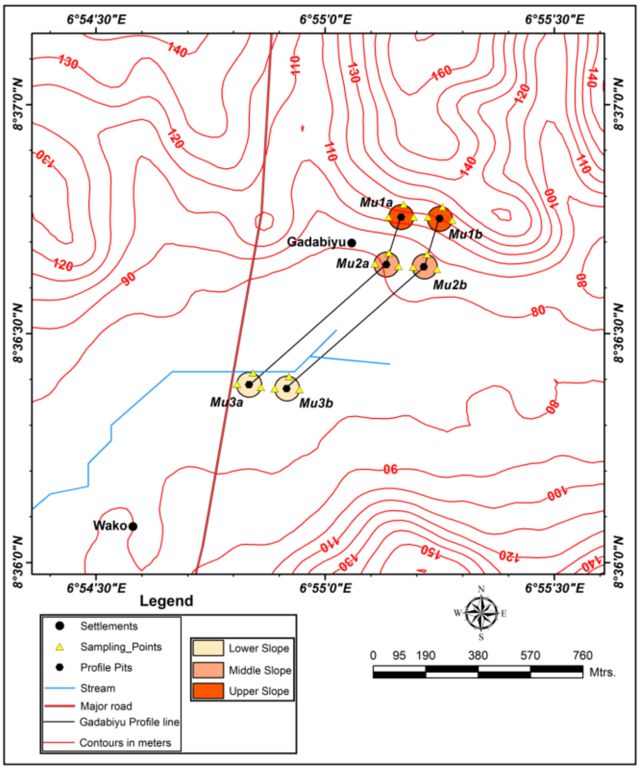

Figure 1.5: Topography of the Study area also showing the Sampling Pits

Source: Field work

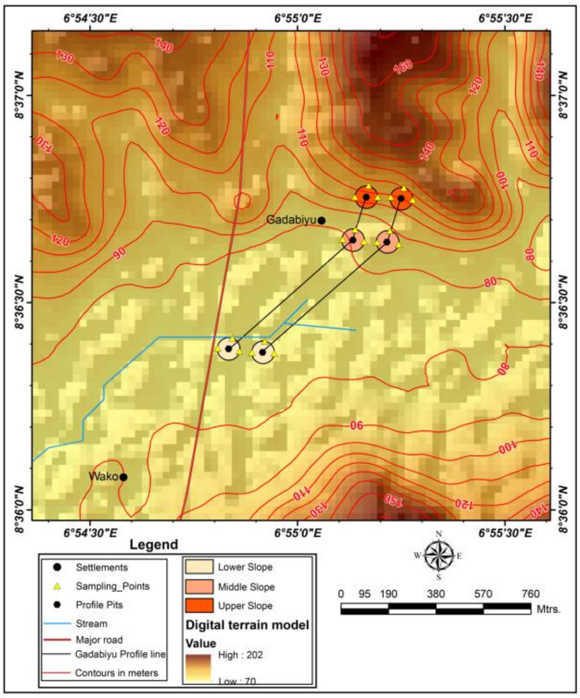

Figure 1.6: Digital terrain modeling of the study area also showing the sampling pits

Source: Field work

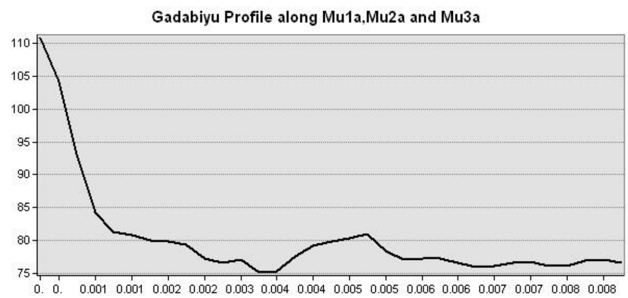

Figure 1.7: Gada-biyu Profile along Catana 'A'

Source: Field Work 2017/2018

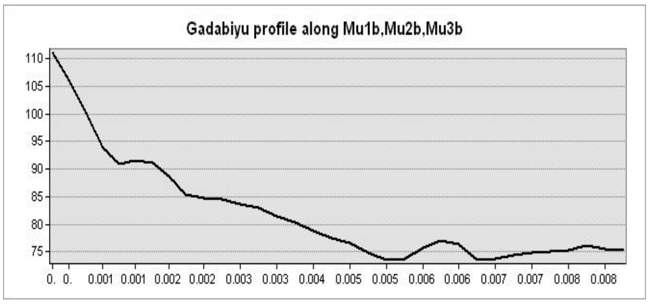

Figure 1.8: Gada-biyu Profile along Catana 'B'

Source: Field Work 2017/2018

Soil samples collection

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*, (1992). 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 (Aweto and Enaruvbe, 2010).Deep auger borings were made in each of the profile pits beyond 200cm to determine the nature of the underlying substrata (Plate 1 to3).

Plate 1: Researcher and her field assistants taken Measurements of Transects at GadabiyuIrrigattion Area.

Source: Fieldwork

Plate 2: Researcher and her field assistants taken Soil samples in Upper slope Profile Pits AtGadabiyu Irrigation Area.

Source: Fieldwork

Plate3: Taking reading of Infiltration s at Gadabiyu Irrigation Area.

Source: Fieldwork 2017/2018

LABORATORY METHODS

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

I. Particle size distribution

Particle size distribution (PSD) was determined using the Bouyoucos (Hydrometer) method as described by Udo *et al*., (2009). Fifty grams of the soil sample was treated with 50ml of 5% calgon (sodium hexametaphosphate) to aid dispersion. The treated samples were stirred with the multimix machine for 15 minutes. The dispersed suspension was then transferred into a glass cylinder and the cylinder filled with distilled water to mark. After that, the top of the cylinder was covered with hand and inverted several times until the dispersion was properly stirred. A plunger was also used to ensure proper stirring of the suspension. Hydrometer and thermometer readings were taken at intervals after mixing to determine the percentage composition of the suspended materials.

The first hydrometer reading was taken at 40 seconds and this measured the amount of silt and clay in suspension. The second reading was taken after 3 hours and this indicated the percentage of total clay in suspension. The soil textural classes were determined using the USDA textural triangle.

II. Bulk Density

The soil dry bulk density was determined using the core method. The core soil samples collected using core samplers of known dimensions from the field were trimmed in the laboratory to the height of the core and weighed. The core together with the soil sample was oven dried at 105°C for 24 hours and weighed again, while the weight of each of the core samplers was noted. The mass of the dry soil alone was noted after oven drying and the bulk density calculated from the following relationship:

$Bd = \frac{g}{V}$------(1)

Where
Bd = Bulk density
g = weight of oven dried soil in grams
V = volume of core cm^3
But volume of core = $\pi r^2 h$ -----(2)

r = Radius of core

h = length or height of core.

Where π = 3.142

III. Soil total porosity

The total porosity of the soil was calculated from the relationship:

$\mathrm{Ft} = \left(1 - \frac{Bd}{Pd}\right) 100$ ------(3)

Where;

Ft = total porosity

Bd = bulk density (g/cm^3)

Pd = particle density of the soil = 2.65g/cm^3

IV. Saturated Hydraulic Conductivity (K_{sat}.)

In this study, the constant head method was used to determine K_{sat}. Water was allowed to move through the soil under constant head condition and the quantity (volume) of water flowing through the soil column was measured over a period of time. By knowing the quantity (Q) of water discharged, the height (h) of the soil column in the cell, the cross-sectional area (A), the time (T) and the hydraulic head (H), K_{sat} was then calculated using transposed Darcy's equation:

$$Ksat = \frac{Q}{AT} \cdot \frac{h}{H} \text{------(4)}$$

Where:

K_{sat} = saturated hydraulic conductivity (cm $^{-1}$)

Q = volume of water discharged (cm^3)

H = height of the sample in the cell (cm)

A = cross sectional area of the cell (cm^2)

H = change in hydraulic head (cm)

T = time (seconds)

RESULTS AND DISCUSSION

Descriptive statistics

Soil Physical Properties of GadaBiyu Irrigation Area

Soil Texture

As describe on table 1.2a and 1.2b, the result showed that the sand content of the upper slope for both Pit (a) and Pit (b) within the profile ranged from 36.0% to 84.0%) with a mean of 73.94% (SE±4.84). The silt content ranged from 1.4% to 55.4% with a mean of 14.76% (SE±5.36). Clay ranged from 6.0% to 19.4% with a mean of 11.07% (SE±1.48). The textural class of the soil was silty loam at the surface and sandy loam to loamy sand in the sub surface horizons.

For both Pit (a) and Pit (b) in the middle slope section of the toposequence, sand content ranged from 31.2% to 83.2% with a mean of 61.45% (SE±8.81), while the silt content ranged from 11.4% to 47.4% with a mean of 21.64% (SE±6.65). The clay content ranged from low to moderately high ranging from 4.6% to 27.0% with a mean of 16.88% (SE±4.94). The soil textural class varied between loamy sand to sandy clay loam and clay within the profile and in the composite samples.

For the lower slope Pit (a) and Pit (b), sand content ranged from 29.2% to 83.2% with a mean of 66.84% (SE±6.08). Silt was moderate to high with values ranging from 11.4% to 51.5% having a mean of 24.35% (SE±4.40). Clay was very low in the soil with values that ranged from 3.4% to 19.4% having a mean of 8.21% (SE±1.87). The textural class of the soil was uniformly sandy loam at the surface horizon and varied between silty loam, loamy sand and sandy loam in the sub surface horizons.

One common trend in all the soil units was high sand content with some horizons having high silt content sandwiched between soil horizons with high sand content and low clay. This characteristic is attributing of floodplain soils (Especially the levee and back swamp sections).

Bulk density

The result of bulk density is presented in Tables 1.2a and 1.2b for both Profile Pit (a) and Pit (b). Bulk density values for the upper slope soil unit ranged from 1.33gcm^{-3} to 1.55gcm^{-3} with a mean value of 1.42gcm^{-3} (SE±0.03) for the different horizons and composite samples. These values for bulk density are low.

In the middle slope unit, bulk density was also low with values ranging from 131gcm^{-3} to 1.54gcm^{-3} having a mean of 1.40gcm^{-1} (SE±0.04).

The lower slope soil unit along the toposequence had bulk density values for the different horizons and composite samples ranging from 1.30gcm^{-3} to 1.53gcm^{-3} with a mean of 1.37gcm^{-3} (SE±0.02). These values are all rated as low and did not vary significantly across the three slope units of the toposequence.

Total Porosity

Total porosity and bulk density are known to be inversely related. The values for total porosity (Tables 1.2a and 1.2b) i.e for Profile Pit (a) and Pit (b) in the upper slope unit varied between 41.51% to 49.81% and a mean of 46.33 (SE±1.06).

In the middle slope soil unit, total porosity ranged from 41.89% to 50.57% and a mean value of 47.01 (SE±1.55) and standard deviation of 3.46.

For the lower slope soil unit, total porosity ranged from 42.26% to 50.94% and a mean of 48.44% (SE±0.94).

Saturated Hydraulic Conductivity (*Ksat*).

The values for hydraulic conductivity of the soils (Tables 1.2a and 1.2b) ranged from 0.945cmhr^{-1} to 4.725cmhr^{-1} with a mean value of 3.47cmhr^{-1} (SE±0.40) for the upper slope soil unit.

In the middle slope section of the toposequence, hydraulic conductivity varied from 0.342cmhr^{-1} to 4.932cmhr^{-1} with a mean of 3.35cmhr^{-1} (SE±0.79). The values did not change significantly in the lower slope section of the two toposequences where *Ksat* values ranged from 0.720 cmhr^{-1} to 4.932 cmhr^{-1} and a mean of 3.35 cmhr^{-1} (SE±0.52). These values are rated as low to moderate.

Soil Moisture Content

Moisture content of the soil is shown in tables 1.2a and 1.2b. The result for Upper slope segment of the Toposequence showed that the soil moisture content of the soils varied from 5.71% to 6.99% and a mean of 6.38% (SE±0.17). This is rated as low.

For the middle slope section, the soil moisture content ranged from 10.17% to 29.94% and a mean value of 17.69% (SE±4.31). These values are rated as moderate to high.

For the lower slope section, the moisture content ranged from low to high with values 6.62% to 16.53% and a mean value of 11.44% (SE±1.76).

Table 1.2a: Physical properties of Gadabiyu irrigation Area

Location	Horizon/depth cm	Sand (%)	Silt (%)	Clay (%)	Tex. Class	Bd (gcm^{-3})	TP (%)	Ksat (Cmhr^{-1})	SWC (%)
MU1 (Upland) upper slope	Ap 0 – 16	36.0	55.4	8.6	Silty loam	1.55	41.51	0.945	5.71
N8.61257	AB 16 – 48	75.2	15.4	9.4	Sandy loam	1.36	48.68	2.592	5.89
E6.919432	Bt1 48 – 67	77.2	5.4	15.4	Sandy loam	1.48	44.15	4.103	6.47
Alt.= 85m	Bt2 67 – 106	80.0	9.4	10.6	Sandy loam	1.33	49.81	3.984	6.48
	C1 106 – 153	82.0	9.4	8.6	Loamy sand	1.34	49.43	4.322	6.96
	C2 153 – 175	84.0	1.4	14.6	Loamy sand	1.36	48.68	4.725	6.96
	C3 173+	75.2	5.4	19.4	Sandy loam	1.38	47.92	2.592	6.99
	Augered Sample (0 - 15)	78.0	16.0	6.0	Sandy loam	1.50	43.40	3.976	5.91
	Augered Sample (15 - 30)	78.0	15.0	7.0	Sandy loam	1.50	43.40	3.992	6.01
	Mean	*73.96*	*14.76*	*11.07*		*1.42*	*46.33*	*3.47*	*6.38*
	Std.Dev	*14.53*	*16.07*	*4.85*		*0.08*	*3.17*	*1.19*	*0.51*
	SE±	*4.84*	*5.36*	*1.88*		*0.03*	*1.06*	*0.40*	*0.17*
MU2 (Backswamp) Middle slope	Ap1 0 – 11	74.0	21.4	4.6	Loamy sand	1.31	50.57	4.132	11.79
N8.610845	Ap2 11 – 27	83.2	11.4	5.4	Loamy sand	1.33	49.81	4.932	26.33
E6.918897	Bt1 27 – 42	31.2	47.4	21.4	Silty Clay	1.54	41.89	0.342	29.94
Alt.= 85m	Augered Sample (0 - 15)	60.0	14.0	26.0	Sandy clay loam	1.42	46.41	3.672	10.17
	Augered Sample (15 - 30)	59.0	14.0	27.0	Sandy clay loam	1.42	46.41	3.660	10.22
	Mean	*61.45*	*21.64*	*16.88*		*1.40*	*47.01*	*3.35*	*17.6*
	Std.Dev	*19.71*	*14.88*	*11.05*		*0.09*	*3.46*	*1.76*	*9.64*
	SE±	*8.81*	*6.65*	*4.94*		*0.04*	*1.55*	*0.79*	*4.31*
MU3 (levee) Lower slope	Ap1 0 – 16	62.0	29.4	8.6	Sandy loam	1.30	50.94	3.602	6.81
N8.606472	Ap2 16 – 34	75.2	19.4	5.4	Sandy loam	1.36	48.68	1.524	6.99
E6.9139	Bt 34 – 58	29.2	51.4	19.4	Silty loam	1.53	42.26	0.720	15.72
Alt.= 78m	C1 58 – 79	81.2	13.4	5.4	Loamy sand	1.32	50.19	4.571	15.38
	C2 79 – 92	75.2	21.4	3.4	Sandy loam	1.37	48.30	4.044	16.27
	C3 92+	83.2	11.4	5.4	Loamy sand	1.33	49.81	4.932	16.53
	AugeredSample (0 - 15)	65.5	22.8	11.7	Sandy loam	1.36	48.68	3.711	6.62
	AugeredSample (15 - 30)	63.2	25.6	11.2	Sandy loam	1.36	48.68	3.715	6.71
	Mean	*66.84*	*24.35*	*8.21*		*1.37*	*48.44*	*3.35*	*11.44*
	Std.Dev	*17.19*	*12.43*	*5.22*		*0.07*	*2.66*	*1.47*	*4.49*
	SE±	*6.08*	*4.40*	*1.87*		*0.02*	*0.94*	*0.52*	*1.76*

NB: Bd = bulk density, TP = total porosity, Ksat = saturated hydraulic conductivity, SWC = soil water content, std.Dev = standard deviation, SE± = standard error of mean

Source: Fieldwork: 2017/2018

Table 1.2b: Soil physical properties of Gadabiyu irrigation Area

		%				gcm^{-3}	%	$Cmhr^{-1}$	%
Location	Horizon/depth cm	Sand	Silt	Clay	Tex. Class	Bd	TP	Ksat	SWC
MU1 (Upland) upper slope	Ap 0 – 19	49.0	50.4	9.6	SiL	1.35	49.10	0.945	5.71
N8.612515	AB 19 – 68	70.2	15.4	14.4	SL	1.36	48.68	2.592	5.89
E6.920833	Bt1 68 – 103	62.0	18.6	19.4	SL	1.48	44.15	4.103	6.47
Alt.= 96m	Bt2 103 – 152	55.4	17.4	27.2	SCl	1.52	42.64	3.984	6.48
	C1 152 – 181	52.5	19.4	28.1	SCl	1.54	41.89	4.322	6.96
	C2 181 – 200	50.0	15.4	34.6	SCL	1.66	37.36	4.725	6.96
	Augered Sample (0 - 15)	67.8	26.0	6.2	SL	1.50	43.40	3.976	5.91
	AugeredSample (15 - 30)	64.0	25.0	11.0	SL	1.50	43.40	3.992	6.01
	Mean	*58.88*	*23.45*	*18.81*		*1.49*	*43.83*	*3.58*	*6.26*
	Std.Dev	*8.22*	*11.60*	*10.22*		*0.10*	*3.76*	*1.23*	*0.49*
	SE±	*2.91*	*4.10*	*3.61*		*0.04*	*1.33*	*0.43*	*0.17*
MU2 (Backswamp) Middle slope	Ap1 0 – 17	60.0	19.4	20.6	SCl	1.31	49.62	4.132	11.79
N8.610763	Ap2 17 – 41	53.2	21.4	25.4	SCl	1.35	49.10	4.932	26.33
E6.920262	Bt1 41 – 67	43.2	27.4	29.4	Cl	1.44	45.66	0.342	29.94
Alt.= 85m	Bt2 67 – 76	40.0	27.4	32.6	Cl	1.51	56.98	0.246	30.44
	Augered Sample (0 - 15)	60.0	14.0	26.0	SCl	1.45	45.28	3.672	10.17
	Augered Sample (15 - 30)	55.0	18.0	27.0	SCl	1.46	44.91	3.660	10.22
	Mean	*51.90*	*21.27*	*26.83*		*1.42*	*45.84*	*2.83*	*19.74*
	Std.Dev	*8.48*	*5.33*	*4.04*		*0.07*	*3.35*	*2.02*	*9.98*
	SE±	*3.46*	*2.18*	*1.65*		*0.03*	*1.37*	*0.82*	*4.07*
MU3 (levee) Lower slope	Ap1 0 – 20	61.3	28.4	10.3	SL	1.30	50.94	3.602	6.81
N8.60633	Ap2 20 – 44	65.5	24.4	10.1	SL	1.36	48.68	1.524	6.99
E6.915265	Bt 44 – 72	41.2	41.4	18.4	L	1.53	42.26	0.720	15.72
Alt.= 78m	C1 72 – 98	64.5	23.4	12.1	SL	1.53	42.26	4.571	15.38
	C2 98 – 117	75.4	21.4	3.4	SL	1.55	41.51	4.044	16.27
	C3 117+	72.2	11.4	16.4	SL	1.55	41.51	4.932	16.53
	Augered Sample (0 - 15)	60.2	20.2	19.6	SL	1.33	49.81	3.711	6.62
	Augered Sample (15 - 30)	61.2	22.4	16.4	SL	1.35	49.10	3.715	6.71
	Mean	*62.78*	*24.15*	*13.34*		*1.44*	*45.76*	*3.35*	*11.38*
	Std.Dev	*9.08*	*8.49*	*5.39*		*0.11*	*4.20*	*1.47*	*4.93*
	SE±	*2.87*	*3.00*	*1.19*		*0.04*	*1.49*	*0.52*	*1.74*

NB: SiL= silty loam, SL Sandy Loam, SCL = sandy clay loam, Cl = clay loam, Bd = bulk density, TP = total porosity, Ksat = saturated hydraulic conductivity, SWC = soil water content, std.Dev = standard deviation, SE± = standard error of mean, source: Fieldwork, 2017/2018

Analysis of Variance for Soil Physical Properties Across Different Topographic Units

Soil Texture

The analysis of variance on (Table 1.4a and b) showed that the distribution of sand in the soils along catena ‘A’ and Catena ‘B’ did not show any significant difference (p>0.05). Also, the distribution of silt in the soils of the two catenas did not show any significant difference (p>0.05). The distribution of clay in catena ‘A’ did not differ significantly, however, in catena ‘B’ the distribution of clay was significantly different (p<0.05). The test of homogeneity showed that the level of non-significance in the distribution of sand and silt in the soils of the two catenas was relatively homogenuous (p>0.05). However, the variation in clay content was not homogeinuous across the soil units in all the two toposequences.

Bulk density

The bulk density of the soils across the two toposequences studied did not show any significance difference (p>0.05) in their distribution. Also, when tested for homogeneity, there was no significant difference in the level of variability across the soil units studied.

Total porosity

The result of analysis of variance (ANOVA) showed that the distribution of total porosity in the soils did not differ (p>0.05) significantly. The level of non-significance in the analysed values was homogeinuous across the soil units studied. Sara (2009) reported a similar finding in the Embu district of Kenya. The trend can be attributed to the bulk density values of the soil. This is because bulk density and total porosity are inversely proportional in all soils (Table 1.4 a and b).

Saturated hydraulic conductivity

The analysis of variance for hydraulic conductivity values showed that there was no significant difference (p>0.05) in the distribution of *Ksat* in all the soil units studied along catenas ‘A’ and ‘B’. Further test of homogenity also showed that the variability in the distribution of the values was relatively homogenuous in all the two catenas observed.

Soil Moisture Content

The distribution of soil water content in the soils of the two toposequences studied showed that there was significant difference (p<0.05) in the SMC in all the slope positions across the two catenas. Also, further test showed that the variation was highly non-homogenous (p<0.05) across all the soil units. This implied that the distribution was highly variable. Soil moisture content changes significantly along the toposequence and across the diferenttoposequences.

Table 1.4a: Summary of ANOVA Analysis for Catena ‘A’

						TEST OF HOMOGENITY	
S/N	PROPERTY	CALCULATED F	SIGNIFICANT VALUE	ALPHA LEVEL	SIGNIFICANCE DIFFERENCE	SIGNIFICANT VALUE OF HOMOGENITY	DESCRIPTION OF HOMOGENITY
A				PHYSICAL PROPERTIES			
1	Sand	2.437	.114	0.05	NS	.987	NS
2	Silt	.177	.839	0.05	NS	.561	NS
3	Clay	5.845	.011	0.05	S	.017	S
4	Bd	.963	.399	0.05	NS	.199	NS
5	TP	2.262	.132	0.05	NS	.510	NS
6	Ksat	.407	.671	0.05	NS	.210	NS
7	SWC	8.801	.002	0.05	S	.000	S

Table 1.4b: Summary of ANOVA Analysis for Catena ‘B’

						TEST OF HOMOGENITY	
S/N	PROPERTY	CALCULATED F	SIGNIFICANT VALUE	ALPHA LEVEL	SIGNIFICANCE DIFFERENCE	SIGNIFICANT VALUE OF HOMOGENITY	DESCRIPTION OF HOMOGENITY
A				PHYSICAL PROPERTIES			
1	Sand	.959	.401	0.05	NS	.697	NS
2	Silt	.970	.397	0.05	NS	.945	NS
3	Clay	2.316	.126	0.05	NS	.002	S
4	Bd	1.031	.376	0.05	NS	.288	NS
5	TP	1.030	.376	0.05	NS	.289	NS
6	Ksat	.019	.982	0.05	NS	.852	NS
7	SWC	7.270	.005	0.05	S	.000	S

DISCUSSION OF RESULTS

The distribution of sand in the profiles did not show any particular trend as some silty horizons are sandwiched between sandy layers at different depths within the profiles. The relative high proportion of sand in the upper layers and subsurface layers within the profiles can be attributed to erosion due to runoff which carried away fine particles (Brady and Weil, 2002).

Also, the high sand and very low clay content may be due to alluvial parent material and deposition by flowing water as well as underlying geology (Idoga and Azagaku, 2005). Soils of the floodplain are known to have varied textures ranging from sand to sandy clay loam. Also, sorting of soil materials by biological and/or agricultural activities, clay migration or surface erosion by runoff or a combination of these, may be responsible for the varying textures of the soil along the toposequence (Malgwi*et al*., 2000; Ojanuga 1975). Hence, the middle slope was more clayey in texture indicating movement of fine materials from the upper slope and the consequent deposition in the low land section of the toposequence. This movement of materials is primarily a function of relief (slope) and soil hydrology (water movement on and within the soil solum).

The range of values for bulk density in these soils is considered as low, taking into account the texture of the soil which is predominantly sandy (sandy loam, loamy sand, and sand). It is observed that the bulk density in all the three locations studied were fairly uniform (within the same range). This may also not be unconnected with the texture as well as type of cultivation and crops grown in the area. This assertion agrees with Alao (2014). Bulk density may exert significant influence on the rate of water infiltration, root growth and development, and ease with which the soils are worked (Brady and Weil, 2002). Considering the texture of the soils of this area, this explains the relatively low bulk density and corresponding high total porosity recorded in this result.

The lower values in the surface horizons (middle and lower slope units) could be due to good aggregation of the horizons probably caused by relatively high organic matter content. In the subsurface, the influence of repeated wetting and drying and the weight of overlying horizons makes the bulk density to rise up to 1.54 gcm^{-3} in the subsurface layers (middle slope) and 1.53gcm^{-3} (lower slope unit). The relatively higher bulk density values on the surface of the upper slope unit may be attributed to history of land use. The unit is cultivated most frequently and coupled with annual bush burning and animal grazing which eat up plant residues, organic matter is depleted, thus making the soil more compact. This assertion agrees with Idogaand Azagaku(2005), Agbede (2009) and Yakubu, *et al* (2013). The bulk density values tend to be higher in the upper slope compared to the lower slope. This could be the impact of continuous cultivation and lower organic matter content of the soil. Bulk density is an index of soil compaction and could influence water entry into the soil, workability of the soil, root penetration, seed germination and total porosity of the soil which in turn also reduces the degree of soil respiration.The relatively low bulk density values accounts for the high total porosity suggesting that the soils are well porous. The porosity suggests that the soil can maintain a balanced proportion of air to water. However, in the surface samples of the upper slope, total porosity was lower suggesting reduction in micro and macro pore spaces in the soil. Along the toposequences however, total porosity was moderately high in the middle and lower slopes.

The saturated hydraulic conductivity values increased with increase in sand content of the soils. In other words, soil texture influences hydraulic conductivity of the soil. Increase in clay content reduces the rate of water movement into the soil. Also, Stella, (2017) reported an increase in *Ksat* with increase in soil depth and soil moisture content. The value for hydraulic conductivity was moderate (Landon, 1991). This was not unconnected to the sandy texture of the soil which allows for ease of water movement through the soil. This result agrees with the findings of Akamigbo and Asadu (1986) and Barnabas, *et al* (2015).

Knowledge of the hydraulic conductivity for soil materials provides the ability to properly design water control structures, earthen storage facilities, and provide improved flood and runoff forecasting. Topography or slope gradient, pore-size distribution and pore continuity, and land use are among the main soil and management factors that affect hydraulic properties of surface soils. Thus, knowledge of surface soil hydraulic properties with respect to these soil and management factors is essential for efficient use of land and better water management. The low variability in *Ksat* values at the different slope sections of the catenas studied can be attributed to relative uniformity in soil texture and the extent of soil bulk density as well as total porosity as observed.

The soils of the upper slope where crops have been harvested showed very much lower values for moisture content. This implied that plant cover influenced the moisture content of the soil (evident in the middle and lower slope sections). This result agrees with Ekwoanya and Ojanuga (2001)who reported that irrigated soils under plant cover gave higher soil moisture content when tested at field capacity. Soil moisture is likely affected by texture and land use type.

The low moisture content status of soils in the upper slope also suggests moisture movement from upper gradient areas to lower gradient areas. However, this is a function of some other factors such as soil texture, relief and drainage pattern of the area.

The implication of the infiltration assessments for irrigation here is that due to the soil texture that is generally medium, water infiltration tends to be rapid and very rapid specifically in soils of the upper and lower slope units. Irrigation frequency should be kept short depending on crop types and their moisture requirement. As water moves rapidly into the soil, leaching may be high. However, there is little problem with water stagnation on the surface after irrigation. The soils are well drained and in case of excess application of water during irrigation or heavy down pour, the soil is well able to absorb the excess with minimal surface run-off. Another implication is that more water is required to irrigate the soil at any given time depending on the crop water requirement.

Infiltration of water is normally controlled by the permeability of both the surface and subsoil. Measurement of infiltration rates form vital part of many surveys involving irrigation development or soil conservation and is designed to enhance the sustainability of the use of soils at optimum. It is described as a pivotal process in landscape hydrology that greatly influences the moisture regime for plants and the potential for soil degradation, chemical run-off and down valley flooding (Brady and Weil, 2002).

The upper slope soils that were initially drier in terms of moisture content tend to have higher infiltration rate that was rapid and chaotic in the early hours of the process. Soils that were already saturated (middle slope) had slow rate of infiltration. Soil texture, bulk density, topography and moisture content of the soil are factors that influence infiltration.

findings from the study also revealed that in catena ‘B’ the distribution of clay was significantly different ($p<0.05$), this finding is consistent with the works of Barnabas and Nwaka (2014) which reported significant difference in the distribution of clay along two toposequences in Jiwa, a suburb of Abuja in the FEDERAL CAPITAL TERRITORY. This can be attributed to movement of fine materials as conditioned by slope as well as biocycling of fine minerals within the solum.

CONCLUSIONAND RECOMMENDATIONS

The proportion of sand fractions in these soils exhibit little to moderate variability within the study area. This is presumably because all the soils are derived from basement complex parent materials across the slope segments of the catena. In contrast, the middle slope was more clayey in texture indicating movement of fine materials from the upper slope and the consequent deposition in the low land section of the toposequence. This movement of materials is primarily a function of relief and soil hydrology. Since the inorganic soil particles such as sand, silt, and clay cannot be altered or changed by man, there is need for a detail soil survey at the farm level in the study area. Also, the range of values for bulk density in these soils is considered as low, considering the texture of the soil which is predominantly sandy (sandy loam, loamy sand, and sand). It is observed that the bulk density in all the three locations studied were fairly uniform which may also not be unconnected with the texture as well as type of cultivation and crops grown in the area. Also, the implication of the infiltration assessments for irrigation here is that due to the soil texture that is generally medium, water infiltration tends to be rapid and very rapid specifically in soils of the upper and lower slope units. Irrigation frequency should be kept short depending on crop types and their moisture requirement. We recommend further that since the soil is predominantly sand fractions, the use of crop residues after harvest should be encourage. This again will increase soil water holding capacity and boost food production.

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