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Characterization and Erodibility Evaluation of Soils of Wukari Metropolis Northeast Nigeria

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ABSTRACT

The study was aimed to characterize and evaluate the erodibility of soils of Wukari metropolis, Taraba State Nigeria. Three profile pits were cited in the study area using free survey technique. Soil samples were collected from profile pits based on horizon differentiation and were subjected to routine laboratory analysis. Data generated were analyzed statistically using the coefficient of variation. The result indicated that sand particle was predominant over other fine fractions as determined in both water and Calgon in all the pedons. Soil pH ranged from 6.35 to 6.90 across the pedons. Organic matter (OM) had mean of 1.73 %, 1.49 % and 2.12 % in pedons 1, 2 and 3. Cation exchange capacity (CEC) and available Zn were generally low while available Fe was high in all the studied pedons. The dispersion ratio (DR) ranged from 68.52 % - 90.25 %, clay dispersion index (CDI) ranged from 64.34 % - 90.69 % and clay flocculation index (CFI) ranged from 9.31 % - 35.66 % in pedons 1, 2 and 3. The soil pH, CEC, DR, and CDI had low variation among horizons of each pedon. Soil pH and OM correlated posi- tively ($\geq$ r = 0.190 $\leq$ r = 0.441) with available Fe and Zn. Organic matter corre- lated negatively with DR, CDI, and CFI. Hence the soils were erodible; there- fore sustainable management practices must be adopted, to ensure sustainable productivity and environmental protection in the studied area.

1. Introduction

There is a growing need for information relating to soil conditions, their current status, level of degradation, changes due to land use types and management practices and appropriate conservation measures to ensure sustainable and optimal land utilization. Soil characterization provides the information for our understanding of the physical, chemical, mineralogical and microbiological properties of the soils we depend on to grow crops, sustain forests and grasslands as well as support homes and society structures (Ogunkunle, 2005). It is through precise measurement and full understanding of the nature and properties of soils, as well as proper management of the nutrient and moisture requirements that one can elevate the inherent capability of the soils to withstand the menace of erosion.

Soils are usually affected and sometimes destroyed by the forces of rainfall and wind causing a phenomenon known as Erosion. Rainfall is the real agent of soil erosion by water in the tropics, by virtue of its role as the source of water or the only form of precipitation contributing to the hydrologic cycle. For most of the erosion in tropical Africa, it is also the source of water, as irrigation agriculture is not well developed even in semi-arid and arid regions where such is needed.

Soil erosion is one of the most severe forms of land degradation in the world (Nanna, 1996; Sohan and Lal, 2001). More than 56 % of land degradation is caused by soil erosion, raising a global concern on land productivity (Elirehema, 2001). The problems associated with erosion include eco- nomic, political, social and environmental which result due to on-site and off-site damages. It not only causes severe land degradation and soil productivity loss but also threatens the stability and health of society in general and sustainable development of rural areas in particular (Tang, 2004; Zheng *et al.*, 2004; Jing *et al.*, 2005).

Erosion changes soil properties, especially physical properties, mainly because it removes surface soil rich in organic materials and exposes lower soil layers. Soils are degraded because of erosion, but already degraded soils have a higher erosion risk. It is therefore difficult to separate which is the initial cause. Erosion causes the reduction in infiltration- and water-storage capacity, nutrient- and organic matter content, soil depth, productivity, vegetation growth and biodiversity.

These factors all interact with each other, and it is almost impossible to separate the impact one has on another.

Soil erodibility can be determined using various soil erodibility indices based on soil characteristics. Different workers have employed Erodibility indices like clay dispersion ratio, clay dispersion index, clay flocculation index (Igwe and Udegbunam, 2008; Oguike and Mbagwu, 2009; Chris-Emenyonu and Onweremadu, 2011) to assess the soil erodibility. Erodibil- ity varies with soil textures, aggregates stability, shear strength, soil structures, infiltration capacity, soil depth, bulk density, soil organic matter and chemical constituents (Agassi and Bradford, 1999).

Therefore, there are needs to provide the erodibility data which will enable agriculturist, engineers, and other land-users to know the areas that are prone to erosion. These will enable them to provide control measures and embrace sustainable land -use practices that will help to check the menace in future. Soil erosion constitutes great havocs to our immediate environment. These range from pollution of the environment to the destruction of lives and valuable properties worth a reasonable amount of money; hence, leaving people as victims of its operation. The Wukari community is not an exception of the menace of this commotion causing losses. Hence, soil characterization and erodibility evaluation of soils of Wukari are considered necessary.

2.0 Materials and Methods

2.1 Study Area

The study was carried out in Wukari in Wukari Local Government Area of Taraba State North East, Nigeria. It lies between latitude 7^0 51′ N to 7^0 85′ N and longitude 9^0 46' E to 9^0 78 E' of the Greenwich meridian. The entire area is a gently undulating plain, with a mean altitude of 200 m above sea level. The drainage systems drain northward and serve as tributaries network to the River Benue while eastward discharge of rivulets and other smaller tributaries from Wukari town drains towards the Donga River, which is a major tributary of River Benue.
The mean annual rainfall value ranges from 1000 - 1500 mm. The onset of the raining season is usually around April while the offset period is October. The mean maximum temperature is being experienced around April at about 40 ^{0}C while the mean minimum temperature occurs between the period of De- cember and February at about 20 ^{0}C (NIMET 2015).

2.2 Geology

Wukari is situated over Cretaceous sandstone which is possibly Bima-sandstone (TSMEUD, 2005).

2.3 Vegetation

The Wukari Local Government Area falls within the Southern guinea savannah zone. The vegetation manifest seasonal pattern and it is mainly of tree savannah in which the dominant species is the large red heart (*Hymeno cardia)* providing a limited amount of shade. The accompanying shrubs and grasses are Guinea grass (*Panicum maximum*), speargrass (*Imperata cylindrica*), Morning glory (*Ipomoea carnea*), Pignut (*Hyptis suaveolens*), Bahama grass (*Cynodon dactylon*), Spiderwort (*Commelina benghalensis*), Wiregrass (*Eleusine indica*), Lemon verbena (*Lippia dubai*), sedge flower (*Cyperus difformis*) etc. There are also restricted areas of hard wood (*Isoberlina)* savannah woodland, which forms the forest reserves of the area. Other species include Eucalyptus (*Eucalyptus camaldu- lensis*), Neem tree (*Azadirachta indica),* Gmelina (*Gmelina arborea*), Locust tree (*Parkia filicoidea),* Guava (*Psidium guajava),* mango (*Mangifera indica)* and Cashew (*Canarcadium occidentale)* among others.

2.4 Site Selection

The first site was located behind Federal University Wukari students' village (profile A). The coordinate of this site was N 07^0 50.446′ and E 09^0 46.694′ with an elevation of 141.8 m. Wukari mission quarters was designated to be the second site (profile B); it has the coordinate of N 07^0 51.269′ and E 09^0 46.693′ with an elevation of 157.3 m.
The third profile pit was located at Wukari rice mill. The coordinate was N 07^0 52.076′ and E 09^0 47.192′ with an elevation of 171.3 m.

2.5 Soil Sampling

A profile pit was dug on each of the selected sites. Soil samples were collected based on horizon differentiation according to Schoeneberger *et al.* (2012) guidelines. A total of 15 soil samples were collected from the three profile pits. The soil samples were subjected to routine and special laboratory analyses.

2.6 Laboratory Analyses

Particle size distribution was determined by Bouyoucos hydrometer method (Gee and Or, 2002). Soil pH was measured electrometrically using glass electrode pH meter in a solid-water ratio of 1:2.5 (Thomas, 1996). Total nitrogen was determined by the micro-Kjeldahl digestion technique method (Bremner, 1996). Exchangeable bases were determined by the neutral ammonium acetate procedure buffered at pH 7.0 (Thomas, 1982). Exchangeable acidity was got by a method described by (McLean, 1982). Total carbon was analyzed by wet digestion (Nelson and Sommers, 1996). Phosphorous was determined by Bray l method according to the procedure of (Olsen and Sommers, 1982). Cation Exchange Capacity was determined using neutral ammonium acetate leachate method (Summer and Miller, 1996). Available micronutrients (Fe and Zn) were extracted by Diethylene Triamine Penta Acetic acid (DTPA) as described by Sahlemedhin and Taye, (2000) and all these micronutrients were determined using atomic absorption spectrophotometer.
The clay-dispersion indices were calculated as follows;
Clay dispersion ratio (DR) = {(% silt + clay (H_2O)}/ {% silt + clay (Calgon)} × 100
Clay dispersion index (CDI) = {[% clay (H_2O)] / [% clay (Calgon)]} × 100
Clay flocculation index (CFI) = [% clay (Calgon)] - [% clay (H_2O)] / [% clay (Calgon)] × 100
The higher the CDR and CDI the more the ability of the soil to disperse while the higher the CFI, the better aggre- gated the soil. Clay dispersion ratio was used to determine the erodibility of the soils in which greater than 15 % are erodible and less than 15 % are not erodible (Middleton, 1930)

2.7 Statistical Analyses

The data generated were analyzed statistically using the Coefficient of variations as described by Wilding *et al.* (1994) to determine the degree of variation among horizons of each pedon. However, the correlation matrix was used to determine the relationship among the selected properties of the soil. Genstat statistical software versions 8.1 were used to run the statistical analysis.

3.0 Results and Discussion

3.1 Soil Particle Distribution

The result (Table 1) of the particle size distribution showed that sand particles as determined in both water and Calgon dominated over other fractions of soil in all the pedons. The sand particles as determined in water and Calgon had low variation (≥4.48 % ≤ 11.33 %) in pedons 1 and 3 while it had moderate variation (≥16.22 % ≤ 17.73 %) in pedon 2. The sandiness of the study sites is not unconnected with the parent material. This conforms to the findings of (Weil and Brady, 2016) that parent material is a major determinant of soil textural composition. Sand particle increased down the pedon in no specific trend. This is contrary to the findings of (Osujieke *et al.*, 2017). The high sand particle in some subsurface could be associated to buried horizons as a result of runoff de- posit over time. The silt and clay particles as determined in Calgon was higher than those determined in water. This resulted due to the ability of Calgon to disperse particles efficiently more than water. The silt particle as determined in water had a mean of 11.03 %, 20.57 % and 19.49 % in pedons 1, 2 and 3, respectively. Silt fraction as determined in water and Calgon had low variation (11.03 %) in pedon 1 and moderate to high variation (≥19.49 % ≤ 40.80 %) in pedons 2 and 3. The silt fraction decreased down the pedons in no specific trend. According to the rating (10 – 25 %) of Hazelton and Murphy (2007), silt content of the pedons was low. However, silt particles are highly susceptible to erosion. Clay had moder- ate variation (≥16.37 % ≤ 24.70 %) in all pedons except the pedon 2 of Calgon determined which had low variation (4.23%). However, clay had no specific trend of increase in all the pedons. The pattern of clay distribution down the pedons indi- cates that the soils of pedons 1 and 2 are young. This is in line with the findings of Soil Survey Staff (2014).

Table 1: Particle Size Distribution of the Studied Pedons

Horizon	Depth (cm)	PSD in H_2O Sand	Silt (%)	Clay	TC	PSD in Calgon Sand	Silt (%)	Clay	TC
		PEDON 1 (N 07° 51.269′ and E 09° 46.693′, elevation= 157.3 m)							
A	0-35	66.4	17.28	16.32	SL	56.8	19.28	23.92	SCL
B1	35-59	68.4	11.28	20.32	SL	58.8	13.28	27.92	SCL
B2	59-117	80.4	7.28	12.32	LS	72.8	9.28	17.92	SCL
B3	117-200	74.4	8.28	17.32	SL	62.8	10.28	26.92	SCL
Mean		**72.40**	**11.03**	**16.57**		**62.80**	**13.03**	**24.17**	
CV		**8.74**	**40.80**	**19.94**		**11.33**	**34.54**	**18.62**	
		PEDON 2 (N 07° 51.269′ and E 09° 46.693′, elevation= 157.3 m)							
A	0-35	57.4	24.28	18.32	SL	45.8	27.28	26.92	CL
AB	35-46	71.4	14.28	14.32	SL	68.8	18.28	18.92	SCL
BA	46-56	65.4	19.28	15.32	SL	58.8	21.28	19.92	SCL
Bt1	56-62	51.4	24.28	24.32	SCL	42.8	29.28	27.92	CL
Bt2	62-112	51.4	20.28	25.32	SCL	46.8	25.28	27.92	SCL
Bt3	112-150	54.4	26.28	19.32	SCL	46.8	28.28	24.92	SCL
Bct	150-200	44.4	15.28	27.32	SCL	52.8	17.28	29.92	SCL
Mean		**56.54**	**20.57**	**20.21**		**51.80**	**23.85**	**25.21**	
CV		**16.22**	**22.58**	**24.70**		**17.73**	**20.52**	**4.23**	
		PEDON 3 (N 07° 52.076′ and E 09° 47.192′, elevation= 171.3 m)							
A	0-23	63.4	24.28	12.32	SL	55.8	27.28	16.92	SCL
B1	23-57	60.4	22.28	17.32	SL	50.8	24.28	24.92	SCL
B2	57-117	66.4	17.28	16.32	SL	58.8	19.28	21.92	SCL
B3	117-200	66.4	14.28	18.32	SL	56.8	15.28	27.92	SCL
Mean		**64.15**	**19.49**	**16.07**		**55.55**	**21.53**	**22.92**	
CV		**4.48**	**23.31**	**16.37**		**6.13**	**24.69**	**20.46**	

PSD= particle size distribution, TC= textural class, SCL= sandy clay loam, CL= clayey loam, CV= coefficient of variation, < 15= low variability, ≥15≤35= moderate variability, > 35= high variability.

3.2 Soil Chemical Properties and Micronutrients

The pedons (Table 2) were neutral to slightly acidic according to the ratings of Chude *et al.* (2011). The soil pH had a mean of 6.90, 6.48 and 6.66 in pedons of 1, 2 and 3, respectively. However, pH had low variation (≥0.98 % ≤ 2.08 %) in all the pe- dons. The low variation could be associated with homogeneity in parent material and similarity in climatic condition. Soil pH of the study sites could be associated to quantities of variable charge minerals, organic matter and amount and type of clay. However, the pedons were less acidic compared to the finding of Musa and Gililanbe (2017) in soils of Northeast Nigeria. Or- ganic matter was moderate in pedons 1 and 2 and high in pedon 3 according to the ratings of Esu (1991) and Landon (1991). Organic matter had high variation (≥40.08 % ≤ 83.14 %) in pedons 2 and 3 and low variation (13.70 %) in pedon 1. However, organic matter content was high compared to the finding of Tekwa *et al.* (2011) in soils of Northern, Nigeria. Organic matter improves the soil structure thereby reducing the erodi- bility rate of the soil.

Total nitrogen was very high while available phosphorus was very low in all the pedons according to the ratings of Landon (1991). However, phosphorus fertilizer should be added into the soil to enhance availability of phosphorus.

Total nitrogen and available phosphorus had high variation (≥40.08 % ≤ 83.14 %) in all the pedons except in pedon 3 where total nitrogen had low variation (5.89 %). The total nitrogen was high while the available phosphorus was low compared to the find- ing of Tekwa *et al.* (2011) and Musa and Gililanbe (2017) in soils of Northeast Nigeria. The Table 2 showed that potassium was pre- dominant over other cations in pedons 1 and 2 while Magnesium was predominant in pedon 3. However, Ca was low; Mg was low while Na and K were high according to the ratings of Landon (1991). This indicates that Ca and Mg are below the critical limit hence there are need to improve their status. The distribution of the basic cation across the pedons was similar to the work of Gailyson and David (2013). Cation exchange capacity (CEC) ranged from 3.55 – 3.60 cmol/kg in pedon 1, 3.09 – 4.30 cmol/kg in pe- don 2 and 3.86 – 3.96 cmol/kg in pedon 3. The CEC was found to be below the critical limit according to the rating of Esu (1991). Cation exchange capacity was low and had no specific trend of decrease down the pedons. This agreed to the findings of Gailyson and David (2013). Mulima *et al.* (2015), also reported of low CEC in soils of Northeast Nige- ria. However, the CEC of the pedons were < 24 cmol/kg, this indicated that the pedons have low activity clays and highly weathered according to the finding of soil survey staff (2014). The highly weathered soils are more susceptible to erosion due to the formation of coarse particle which encour- ages poor aggregation.

Table 2: Selected Chemical Properties and Micronutrient Content of the Pedons

Horizon	Depth	pH	OM	TN	Av.P	Ca	Mg	Na	K	TEA	CEC	Fe	Zn
	(cm)	(H_2O) →	%	←	(mg/kg)	→			cmol/kg	←	→	mg/kg	←
PEDON 1 (N 07° 51.269′ and E 09° 46.693′, elevation= 157.3 m)													
A	0-35	6.98	2.05	0.11	1.29	0.50	0.88	0.97	0.96	2.09	3.58	20.08	1.90
B1	35-59	6.94	1.69	0.90	0.47	0.39	0.77	0.90	0.94	2.28	3.60	29.05	1.43
B2	59-117	6.81	1.69	0.76	0.93	0.41	1.06	0.99	0.99	2.17	3.60	16.23	1.08
B3	117-200	6.85	1.48	0.70	0.36	0.37	1.03	0.90	1.02	2.13	3.55	59.38	1.20
Mean		**6.90**	**1.73**	**0.62**	**0.76**	**0.42**	**0.94**	**0.94**	**0.98**	**2.17**	**3.58**	**31.18**	**1.40**
CV		**1.14**	**13.70**	**56.45**	**56.35**	**13.74**	**14.47**	**4.99**	**3.58**	**3.77**	**0.66**	**62.69**	**25.82**
PEDON 2 (N 07° 51.269′ and E 09° 46.693′, elevation= 157.3 m)													
A	0-35	6.43	2.42	0.10	1.19	0.90	0.40	0.88	0.77	2.00	3.51	6.83	18.78
AB	35-46	6.42	2.12	0.99	0.75	0.82	0.66	0.76	0.79	2.07	3.50	23.93	3.03
BA	46-56	6.61	1.00	0.85	0.72	0.82	0.70	0.66	0.76	2.03	4.30	13.68	2.75
Bt1	56-62	6.40	1.00	0.88	0.53	0.72	0.64	0.60	0.70	2.01	3.68	26.05	0.25
Bt2	62-112	6.45	1.33	0.81	0.43	0.66	0.69	0.70	0.75	2.01	3.75	2.13	1.03
Bt3	112-150	6.35	1.28	0.76	0.43	0.61	0.70	0.63	0.69	2.04	3.88	18.80	2.13
Bct	150-200	6.73	1.28	0.70	0.58	0.61	0.97	0.68	0.79	1.99	3.09	35.45	0.40
Mean		**6.48**	**1.49**	**0.73**	**0.66**	**0.73**	**0.68**	**0.70**	**0.75**	**2.02**	**3.67**	**18.12**	**4.05**
CV		**2.08**	**37.33**	**40.08**	**40.08**	**15.60**	**24.42**	**13.39**	**5.39**	**1.35**	**10.18**	**63.72**	**162.51**
PEDON 3 (N 07° 52.076′ and E 09° 47.192′, elevation= 171.3 m)													
A	0-23	6.65	2.59	0.99	0.45	0.77	1.02	0.99	0.88	2.21	3.86	26.93	1.03
B1	23-57	6.69	3.12	0.95	0.97	0.68	0.99	0.85	0.53	2.14	3.96	41.00	0.28
B2	57-117	6.72	1.39	0.88	0.24	0.64	0.85	0.87	0.44	2.07	3.86	21.35	0.15
B3	117-200	6.57	1.36	0.88	1.90	0.59	1.01	0.08	0.77	2.14	3.99	4.28	0.63
Mean		**6.66**	**2.12**	**0.93**	**0.89**	**0.67**	**0.97**	**0.70**	**0.66**	**2.14**	**3.92**	**23.39**	**0.52**
CV		**0.98**	**41.68**	**5.89**	**83.14**	**11.37**	**8.19**	**59.68**	**31.25**	**2.67**	**1.72**	**64.93**	**75.48**

OM = organic matter, TN = total nitrogen, Av. P = available phosphorus, TEA= total exchangeable acidity, CEC = cation exchange capacity, CV= coefficient of variation, < 15= low variability, ≥15 ≤35 = moderate variability, > 35= high variability.

Available Fe had a mean of 31.18 mg/kg in pedon 1, 18.12 mg/kg in pedon 2 and 23.39 mg/kg in pedon 3. However, Fe content had a high variation (≥62.69 % ≤ 64.93 %) in all the pedons. The available Fe was high according to the ratings (>10 mg/kg) of Esu (1991), and also, it was above the critical level 2.5 – 5.8 recommended by Deb and Sakal (2002) . The available Fe was high compared to the findings of Mulina *et al*. (2015) but similar to the finding of Mustapha *et al.* (2010) in soils of North-east Nigeria. The level of available Fe could be associated with its availability in the parent material. Available Fe increased down in an irregular trend in pedons 1 and 2 while it decreased down in an irregular trend in pedon 3. The available Zn ranged from 1.08 – 1.90 mg/kg (mean= 1.40 mg/kg) in pedon 1, 0.28 – 18.78 mg/kg (mean = 4.05 mg/kg) in pedon 2 and 0.15 – 1.03 mg/kg (mean = 0.52 mg/kg) in pedon 3. The available Zn had a high variation (≥75.48 % ≤ 162.51 %) in pedons 1 and 2 while it had moderate variation (25.82 %) in pedon 1. However, available Zn was below the critical limit recommended by Esu, (1991) in pedon 1, moderate in pedon 2 and high in pedon 3. Generally, with the exception of Ap horizon of pedon 2, the available Zn obtained from other horizons fell below the critical available level of 3.3 mg/kg as reported by Pam (1990). Available Zn of the pedons was low compared to the finding of Shehu and Ja- mala (2010) in soils of Northern Nigeria. Zn decreased down the pedons following no specific trend which is in line with the findings of Ahukaemere *et al*. (2017). However, researchers (Bassirani *et al*., 2011; Mustapha *et al.*, 2011) have reported on the irregular pattern of distribution of Fe and Zn in pedons in Northeast, Nigeria. Variation of Zn and Fe among the horizons could be associated to soil pH level, organic matter level and phosphate level of the pedons.

3.3 Soil Erodibilty Indices

The dispersion ratio (DR) had a mean of 68.53 % in pedon 1, 81.04 % in pedon 2 and 70.59 % in pedon 3. However, the DR had low variation (5.55 % 8.45 %) in all the pedons. The DR is greater than 15 % indicating that the horizons of the pedons are erodible. The DR decreased down the pedons 1 and 3 while it increased down in pedon 2. Soils with high DR are known to be weak structurally and can easily erode. Many researchers have used this index in predicting soil erosion by water (Bajracharya *et al*., 1992; Igwe, 2005). Clay dispersion index (CDI) had means of 68.53 %, 81.04 % and 70.55 % in pedons 1, 2 and 3, respectively. The CDI had low variation (5.04 % 10.83 %) in all the pedons. The CDI followed the similar trend like DR in distribution down the pedons. Clay flocculation index (CFI) ranged from 27.22 – 35.66 % in pedon 1, 8.69 – 31.95 % in pedon 2 and 25.55 – 30.50 % in pedon 3. However, CFI had low variation (8.60 % 10.97 %) in pedons 1 and 3 while it had high variation (46.29 %) in pedon 1. The CFI increased down the pedons 1 and 3 in no specific trend while it decreased done the pedon 2 in no specific trend. The clay-flocculation index (CFI) is also another index that shows the ability of the soils to resist dispersion in water. The CFI of the soils are low and a direct inverse of CDR. The result of the research, when com- pared to the finding of Oguike and Mbagwu (2009) in soils of Southern Nigeria shows that DR and CDI were high while CFI was low. Igwe and Udegbunam (2008), also reported that the DR, CDI, and CFI were high when compared to the soils of Southern Nigeria.

Table 3: Erodibility Indices used for the Pedons

Horizon	Depth (cm)	DR	CDI	CFI
		→	%	←
	PEDON 1 (N 07^{o} 51.269′ and E 09^{o} 46.693′, elevation= 157.3 m)			
A	0-35	77.78	68.23	31.77
B1	35-59	76.70	72.78	27.22
B2	59-117	72.06	68.75	31.25
B3	117-200	68.82	64.34	35.66
Mean		**73.84**	**68.53**	**31.47**
CV		**5.64**	**5.04**	**10.97**
	PEDON 2 (N 07^{o} 51.269′ and E 09^{o} 46.693′, elevation= 157.3 m)			
A	0-35	78.60	68.05	31.95
AB	35-46	76.88	75.69	24.31
BA	46-56	83.98	76.91	23.09
Bt1	56-62	84.97	87.11	12.89
Bt2	62-112	86.69	90.69	9.31
Bt3	112-150	85.71	77.53	22.47
Bct	150-200	90.25	91.30	8.69
Mean		**83.87**	**81.04**	**18.96**
CV		**5.55**	**10.83**	**46.29**
	PEDON 3 (N 07^{o} 52.076′ and E 09^{o} 47.192′, elevation= 171.3 m)			
A	0-23	82.81	72.81	27.19
B1	23-57	80.49	69.50	30.50
B2	57-117	81.57	74.45	25.55
B3	117-200	68.52	65.62	30.38
Mean		**78.35**	**70.59**	**28.41**
CV		**8.45**	**5.53**	**8.60**

DR= dispersion ratio, CDI= clay dispersion index, CFI= clay flocculation index, CV= coefficient of variation, < 15= low variability, ≥15≤35= moderate variability, > 35= high variability.

3.4 Correlation Matrix between Selected Soil Properties and Erodibility Indices

Table 4 shows the result of the correlation matrix between selected soil properties and erodibility indices. Sand particle had highly significant negative relationship (r= -0.674, r= -0.817, r= -0.759, r= -0.769, p= 0.01) with silt, clay, DR, CDI, and CFI. Clay particle had positive relationship (r= 0.526) with DR; highly significant positive relationship (r= 0.743, p= 0.01) with CDI and highly significant negative relationship (r= -0.765, p= 0.01) with CFI. However, DR had a positive relationship (r= 0.836) with CDI but a highly significant negative relationship (r= -0.802, p= 0.01) with CFI. CDI had a highly significant negative relationship (r = -0.993, p = 0.01) with CFI. Organic matter had a negative relationship (r = -0.166, r = -0.462, r = -0.462) with DR, CDI, and CFI. Igwe and Udegbunam (2008), also reported on the highly significant relationship between CFI and clay.

Table 4: Relationship between Selected Soil Properties and Erodibility Indices

	Sand	Silt	Clay → %	← DR	CDI	CFI	OM
Sand	1						
Silt	-0.674**	1					
Clay	-0.809**	0.188	1				
DR	-0.817**	0.653**	0.526	1			
CDI	-0.759**	0.323	0.743**	0.836	1		
CFI	-0.769**	-0.313	-0.765**	-0.802**	-0.993**	1	
OM	0.175	0.185	-0.445	-0.166	-0.462	-0.462	1

OM= organic matter, DR= dispersion ratio, CDI= clay dispersion index, CFI= clay flocculation index.

3.5 Correlation Matrix between Selected Soil Properties and micronutrients

Table 5 shows the correlation matrix between selected soil properties and micronutrients. Available Fe had a positive relationship (r = 0.441, r = 0.190, r = 0.192) with pH(H_2O), OM and total nitrogen. Available Fe also had a negative relationship (r = -0.013, r = -0.415, r = -0.302) with clay, available phosphorus and cation exchange capacity. Available Zn correlated negatively (r = -0.074, r = -0.169, r = -0.329) with clay, CEC and Fe while it had a highly significant negative correlation (r = -0.656, p = 0.01) with total nitrogen. However, available Zn correlated positively (r = 0.308, r= 0.299, r = 0.273) with pH(H_2O), OM and available phosphorus. Iyaka and Kakulu (2009), have reported that Zn correlated positively with pH and organic matter. The negative correlation between Fe and Zn was contrary to the finding of Oyinlola and Chude (2010).

Table 5: Relationship between Selected Soil Properties and Micronutrient

	Clay (%)	pH (H_2O)	OM → %	← TN	Av.P (mg/kg)	CEC (cmol/kg)	Fe → mg/kg	← Zn
Clay	1							
pH(H2O)	-0.227	1						
OM	-0.445	0.141	1					
TN	-0.048	-0.174	-0.140	1				
Av.P	-0.183	0.028	0.236	-0.373	1			
CEC	-0.391	-0.199	-0.046	0.354	0.114	1		
Fe	-0.013	0.441	0.190	0.192	-0.415	-0.302	1	
Zn	-0.074	0.308	0.299	-0.656**	0.273	-0.169	-0.329	1

OM = organic matter, TN = total nitrogen, Av. P = available phosphorus, TEA= total exchangeable acidity, CEC = cation exchange capacity.

4. Conclusion

The result obtained showed that the study sites were generally sandy and neutral to slightly acidic. The organic matter was moderate, total nitrogen was high, available phosphorus was very low, and CEC was low in all the sites. Available Fe was above recommended critical limit while Zn was below the recommended critical limit. However, the result as indicated by the dispersion ratio, clay dispersion index and clay flocculation index showed that the soils of the study area are erodible.

The detrimental effects of erosion on agriculture and infrastructural development in any place cannot be overemphasized. However, sustainable soil management practices such as cover cropping, conservation tillage, terracing of slopes, grassing of bare areas, windbreak and construction of conveyance have to be adapted to control the established gullies, as well as to prevent further deterioration.

References

Agassi, M. and Bradford, J. M. (1999). Methodologies for inter rill soil erosion studies. *Soil Tillage Research*. 49(4): 277 – 287.

Ahukaemere, C.M., Osujieke, D.N. and Ndukwu, B.N. (2017). Horizon Differences in Micronutrient Contents of Soils of the Coastal Plain Sands in Imo State, South-East Nigeria. *Bulgarian Journal of Soil Science*. Vol 2(2): 112 – 122.

Bajracharya, R. M., Elliot, W. J. and Lal, R. (1992). Interrill erodibility of some Ohio soils based on field rainfall simulation. *Soil Science Society of America Journal*. Vol. 56: 267 –272.

Bassirani, N., Abolhassani, M. and Galavi, M. (2011). Distribu tion of Available Micronutrients as related to the soil characteristics of Hissar; Haryana (India). *Africa Journal of Agricultural Research*, Vol. 6 (18): 4239 – 4242.

Bremner, J.M. (1996). Nitrogen total. In: Sparks, D.L. (ed) *Methods of Soils Analysis, parts, Chemical method*. 2nd ed, SSSA Book Series No. 5, SSSA, Madison, W1 1085– 1125.

Chris-Emenyonu, C.M. and Onweremadu, E.U. (2011). Indicat ors of erodibility of soils under different land-use types in Imo state. *Nigerian Journal of Agriculture, Food and Environment.* 7(4): 38 – 45.

Chude, V.O., Malgwi, W.B., Amapu, I.Y. and Ano, A.O. (2011). Manual on Soil Fertility Assessment. Federal Fertilizer Department. FAO and National Programme on Food Security, Abuja, Nigeria. 62p

Deb, D.L. and Sakal, R. (2002). Micronutrients. In: Indian Soci ety of Soil Science. Indian Research Institute, New Delhi. Pp. 391 – 403

Elirehema, Y.S. (2001). Soil Water Erosion Modeling in Select ed Watersheds in Southern Spain. IFA, ITC, Enschede.

Esu, I. E. (1991). Detailed Soil Survey of NIHORT farm at Bunkure Kano State, Nigeria. Institute of Agricultural Research, Zaria. Pp.72

Gailyson, Y.J. and David, O.O. (2013). Soil profile characteris tics as affected by land use systems in the Southeastern Adamawa state, Nigeria. *Journal of Agriculture and Veterinary Science* Vol. 6 (4) 04 - 11.

Gee, G.W. and Or, G. (2002). Particle size, In: Dane J.H. & Topp, G.C. (eds). *Methods of Soil analysis. Part 4 Physical methods.* Soil Science Society of America Madison, WI, Book Series No. 5 ASA and SSA 255 – 293.

Hazelton, P.A. and Murphy, B. W. (2007). *Interpreting soil test results: what do all the numbers mean*? (2nd Ed). CSIRO Publishing Collingwood VIC 3066 Australia. 151p.

Igwe, C. A. and Udegbunam, O. N. (2008). Soil properties influencing water-dispersible clay and silt in an Ulti sols in Southern Nigeria. *International Agrophysics*, 22, 319 – 325.

Igwe, C.A. (2005). Erodibility in relation to water-dispersible clay for some soils of eastern Nigeria. *Land Degra dation and Development.* 16, 87 – 96.

Iyaka, Y. A. and Kakulu, S. E. (2009). Copper and Zinc Con tents in Urban Agricultural Soils of Niger State, Ni geria. *African Research Review* Vol. 3 (3) 23 – 33.

Jing, K., Wang, W.Z. and Zheng, F.L. (2005). *Soil erosion and environment in Beijing*, China. Science Press.

Landon, J. R. (Ed) (1991). *Booker tropical soil manual: A Handbook for soil survey and Agricultural land Eval uation in the tropics and subtropics*, Longman Scien tific and Technical, Essex, New York. 474p.

McLean, E. O. (1982). Aluminum. In: C.A. Black (Ed.). *Methods of soil analysis*. Agran. No. 9. Part II. Am. Soc. Agron, Madison, Wisconsin USA.

Middleton, H. E. (1930). *Properties of soils which influence soil erosion.* Tech. Bull. no. 178. Washington, DC: USDA

Mulima, I.M., Ismaila, M., Benisheikh, K.M. and Saminu, I. (2015). Assessment of micronutrients status of soils under millet cultivation in Geidam Local Govern ment Area of Yobe state, Nigeria, *Asian Journal of Basic and Applied Sciences*, Vol. 2 (2): 32 – 41.

Musa, H. and Gisilanbe, S.A. (2017). Differences in physical and chemical properties of soils on Yelwa-Dobora toposequence in Ganye Local Government Area, Adamawa State, Nigeria. *Sky Journal of Soil Science and Environmental Management* Vol. 6(1): 011 – 018.

Mustapha, S., Mamman, H.K. and Abdulhamid N.A. (2010) Status and distribution of extractable micronutrients in Haplustults in Yamaltu-*Deba Local Government Area, Gombe state, Nigeria. Journal of Soil Science and Environmental Management*, Vol. 1 (8): 200 – 204.

Mustapha, S., Voncir, N. and Abdullahamid, N.A. (2011). Status of some Available Micronutrients in the Hap lic usters of Akko Local Government Area of Gombe State, Nigeria. *International Journal of Soil Science*, Vol. 6: 267 – 274.

Nanna, S. (1996). A geo-information theoretical approach to inductive erosion modeling base on terrain mapping units. A Ph.D Wageningen Agriculture University Wageningen.

Nelson, D.W and Sommers, L.E. (1996). Total Carbon, Or ganic Carbon Organic Matter. In: O. L. Sparks (ed). *Methods of Soil Analysis* Part 3, *Chemical Methods*. Soil Science Society of America Book Series Num ber 5. American Society of Agronomy, Madison WIE, Pp. 960 – 1010.

NIMET (Nigerian Meteorological Agency. (2015). Climate, Weather and Water Information for Sustainable De velopment and Safety.

Oguike, P. C. and Mbagwu, J. S. C. (2009). Variations in some physical properties and organic matter content of soils of coastal plain sand under different land use types. *World Journal of Agricultural Sciences*, 5 (1): 63 – 69.

Ogunkunle, A.O. (2005). Soil Survey and Sustainable Land Management. Invited paper at the 29th Annual Conf. of SSSN held at University of Nigeria, Abeokuta, from 6th to 10th Dec. 2004.

Olson, S.R and Sommers, L.E. (1982). Phosphorous. In: *Meth ods of Soil Analysis.* A. L. Page, R. H. Miller and D. R. Keeney (eds). Madison, WI. American Society of Agronomy: 1572 pp.

Osujieke, D. N., Imadojemu, P. E., Ndukwu, B. N and Okeke, O. M. (2017). Properties of Soils in relation to Soil depth, Land-use and Landscape position on Soils of Ikeduru area of Imo State, Southeastern Nigeria. *Inter national Journal of Agriculture and Rural Develop ment.* Vol. 20(2): 3132 – 3149.

Oyinola, E.Y. and Chude, V.O. (2010). Status of available mi cronutrients of the basement complex rock – derived al fisols in Northern Nigeria savanna. *Tropical and Sub tropical Agroecosystems,* 12: 229 – 237.

Pam, S.G. (1990). Correlation and calibration studies for Zn rec ommendation on maize (*Zea mays* L.) in some upland soils of Northern Nigeria . M.Sc. Thesis, Faculty of Agriculture. ABU, Zaria, Nigeria. 127 p

Sahlemedlin, S. and Taye, B. (2000). Procedures for soil and plant analyses. National Soil Research Centre, Ethiopi an Agricultural Research Organization, Addis Ababa, Ethiopia. 110p.

Schoeneberger, P.J., D.A. Wysocki, E.C. Benham, and Soil Survey Staff. (2012). *Field book for describing and sampling soils,* Version 3.0. Natural Resources Con servation Service, National Soil Survey Center, Lin coln, NE.

Shehu, H.E. and Jamala, G.Y. (2010). Available Zn Distribu tion, Response and Uptake of Rice (O*ryza sativa*) to Applied Zn along a Toposequence of Lake Gerio Fadama Soils at Yola, North-eastern Nigeria. *Journal of American Science,* Vol. 6 (11) 1013 – 1016.

Soil Survey Staff. (2014). *Soil Survey Field and Laboratory Methods Manual*. *Soil Survey Investigations Report* No. 51, Version 2.0. R. Burt and Soil Survey Staff (ed.). U.S. Department of Agriculture, Natural Re sources Conservation Service.

Solan, W and Lal, S. (2001). Extraction parameters and model ing soil erosion using GIS in a grid environment centre for remote imaging, sensing and processing.

Summer, M.E. and Miller, W.P. (1996). Cation Exchange Ca pacity. In: D.L. Sparks (eds) *Methods of Soil Analysis. Part 2: Chemical Properties* (3rd ed), ASA, SSSA, CSSA, Madison, W.I. Pp 1201 – 1229.

Tang, K.L. (Ed) (2004). *Soil and Conservation in Beijing, Chi na.* Science Press.

Taraba State Ministry of Environment and Urban Development (TSMEUD) 2005. Environmental impact assessment of Taraba State.

Tekwa, I.J., Shehu, H.E and Maunde, S.M. (2011). Soil nutrient status and productivity potentials of lithosols in Mubi Area, North-eastern Nigeria. *Agriculture and Biology Journal of North America,* Vol. 2(6): 887 – 896.

Thomas, G. W. (1982). Exchangeable Cations. In: A. L. Page; R. H. Miller and D. R. Keeney (eds.). *Methods of Soil Analysis, Part 2, Chemical and Microbiological prop erties.* Madison, Wisconsin. Pp. 159 – 164.

Thomas, G.W. (1996). Soil pH and soil acidity. In: *Methods of soil analysis, part 3- Chemical methods.* L. D. Sparks (eds) SSSA book series 159 – 165.

Weil, R.R and Brady, N.C (2016). *The Nature and Properties of Soils.* (15th Ed) Pearson Education. ISBN: 978-0133254488.

Wilding, L.P., Bouma, J. and Boss, D.W. (1994). Impact of spatial variability on interpretative modeling. In: *Quantitative modeling of soil forming processes*. Bry ant, R.B. and Amold, R.W. SSSA. Special Publica tion. No.39: 61.

Zheng, F., Stephen, D.M., Huang, C., Tanaka, D.L., Darboux, F., Liebig, M.A and Halvorson, A.D. (2004). Runoff, soil erosion and erodibility of Conservation Reserve Program land under crop and hay production. *Soil Science Society of American Journal,* Vol. 68 (4): 1332 – 1341.