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MULTIVARIATE ANALYSIS OF THE PHYSICO-CHEMICAL PROPERTIES OF SOILS IN SELECTED LOCATIONS OF THE FLOODPLAIN OF RIVER KADUNA IN NIGER STATE, NIGERIA

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ABSTRACT

Multivariate statistics was used to analyse the physico-chemical properties of soil in the selected locations of the floodplain of River Kaduna in Niger State, Nigeria. Samples were collected in March and September of the same year and the levels of some important soil quality parameters analysed. The data was subjected to basic statistics, cluster analysis (CA), Principal Component Analysis (PCA), Correlation Analysis, and Discriminant Analysis (DA). Descriptive statistics shows that, with the exception of silt and clay other parameters analysed decreased in value after flooding, while the predominant textual class of the soil is clay-loam. The PCA for March and September sampling periods extracted three components each which explained 84.10% and 78.90% respectively of the total variance. Cluster analysis yielded five distinct clusters for March: cluster 1 (K, Ca, EA, and pH); cluster 2 (OM, CEC, TN, Silt content, Clay content, and OC); cluster 3 (Na); cluster 4 (P), and cluster 5 (Mg and Sand content); and five separate clusters for September. From DA, seven variables (pH, OC, OM, TN, P, K and Mg) were the most significant parameters which accounted for the expected spatial/temporal variations in the soil of March, while CEC, Na, Ca, silt, sand and clay become an important discriminator in September. Flood has significant influence on the soil of the study area as level and distribution of the parameters changed from March to September.

KEYWORDS: multivariate analysis, correlation, cluster, flood, PCA, basic statistics

1.0. INTRODUCTION

Soil supports the natural vegetation, agriculture and forestry upon which people and wildlife depend. Soil also plays an important role in the cycling of elements, such as carbon and nitrogen and in the water cycle through regulating run-off. Some of the chemical changes that can take place in flooded soils include variations in soil pH, electrical conductivity, redox potential, denitrification activities and production of organic acids (Imbellone *et al.,* 2001; Unger *et al*., 2009). Such chemical changes may over time alter soil properties including soil nutrient availability, enzyme activities and organic matter dynamics.

Singh *et al*., (2002) and Abowei and Sikoki, (2005) opined that periodic floods on many rivers usually renewed wetland surrounding known as floodplain, that hosts flora and fauna through bioaccumulation of sand, silt and debris after the flood water has receded thus making the soil fertile and productive. However, the alluvial soil nutrient dynamics in the floodplain ecosystems are highly complex as a result of flood pulses changing redoximorphic state (Dezzeo *et al*., 2000 and Gallardo, 2003). Flood water facilitates soil nutrient exchange between rivers and their associated floodplain through lateral flow which can lead to both increase or decrease in the soil nutrient content (Nadeu, *et al*., 2014 and Doetter *et al.*, 2016).

Floodplain plays a very important ecological function in mitigating flood speed, minifying flood flow, reducing the transportation of the mud and sands, and retaining nutrients and impurities. Ologunorisa and Diagi (2005) reported that frequency, duration and periodicity of flood appeared to be the most important factors influencing the nutrient distribution and the floodplain ecosystem dynamics.

The chemical analysis of soil can, therefore, provide a useful and convenient measure of environmental quality and is frequently incorporated into pollution monitoring surveys. However, it also plays an important part on impact assessment of environmental quality especially to assess the long term impacts of anthropogenic activity.

The declining productivity from upland agriculture poses a compelling need to expand arable cropping into the country‘s vast and hitherto little exploited

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wetland/floodplain resources which can provide the much needed sustainable production on account of their inherent soil fertility. Therefore, there is the growing need for information on soil quality following rapid flooding in the study area. It is noteworthy that no information is currently existing regarding the environmental impact of flooding in the area. The aim of this study is to use multivariate statistics to analyse the physico-chemical properties of soil in the selected locations of the floodplain of River Kaduna in Niger State, Nigeria.

2.0. MATERIALS AND METHODS

2.1. Collection of Floodplain Soil Samples and Pre-treatment

Soil samples were collected using soil Auger from the sampling points based on the location and distance from the floodplain. Six composite samples were collected from each sampling site with one sample collected from the surface (0-15 cm) and subsoil layer (15-30 cm) of each sampling point. The composite samples for each topsoil and subsoil were separately taken from the sample locations and manually mixed and transferred into glass bottles before it was transported to the laboratory. The samples were air – dried, lump samples gently crushed and sieved to a particle size of 2 mm. These were transferred into amber glass bottles sealed and labelled before storing in a refrigerator for further analysis (SAEFL, 2003).

2.2 Digestion of soil samples

The air-dried soil samples (5.00 g) portion of each of the samples were weighed into a beaker. To each of these was added 25 cm^3 of 3% nitric acid. The mixture was heated at 100 ^oC on a hot plate in a fume cupboard for 1 hr. It was then cooled to room temperature and filtered through filter paper into a clean 100 cm^3 volumetric flask. The residue on the filter was washed into the filtrate. The solution was then diluted to the 100 cm^3 mark with distilled water. It was then used for the determination of the heavy metals content (APHA, 1995).

However, the soil nitrogen digestion was done by pouring 0.2 g of finely ground soil into 30 cm^3 Kjeldahl digestion flask which was followed by adding a tablet of the catalyst and 4 cm^3 of conc.H_2SO_4. The mixture was thoroughly shaken and digested for 45 minutes, this was allowed to cool and the solution was filtered and made up to mark in a 100 cm^3 volumetric flask with distilled water.

2.3. Soil Saturation extract

Soil saturation with moisture was prepared by taking about 250 g of air dried soil in a 500 cm^3 plastic beaker. Distilled water was added while stirring with a spatula to make saturated paste. The paste was then kept overnight while properly covered to reduce loss of any water through evaporation. The saturation extract was obtained through a vacuum pressure apparatus. The paste was transferred to the suction funnel with filter paper in place and applied the vacuum pressure to suck water from the paste into the underlying tubes. The extracts collected are clearly labelled in plastic bottles and saved for analysis. Few drops of toluene were added to stop microbial activity in the solution.

All the soil quality parameters were analysed following standard methods (APHA, 1992; AOAC, 1998), while Soil textural class was calculated using United State Department of Agriculture (USDA) textual triangle.

3.0. RESULT AND DISCUSSION

3.1. Descriptive statistics

The soil samples were evaluated at depths of 0 - 15 cm and 15 - 30 cm and the result of the t-test showed that the depths were not statistically significant ($p>0.05$), which technically implies that they are homogeneous in nature. The descriptive statistics for soil quality parameters are shown in Tables 1 and 2 for March (before flooding) and September (after flooding) respectively.

The mean pH values for soil samples were found to vary from 5.91 ±0.66 to 5.29 ±0.46 for the period of investigation. The results indicate that the pH of the soil was slightly acidic during the period of investigation. The observed pH reduction after flooding is similar to the findings of Kalshetty *et al*., (2012) and Vincent *et al*., (2014), where pH of cultivated soil reduced on flooding from River Krishna in Southern India. The pH values obtained in this study slightly fell below the prescribed limit of 6.5 - 7.5 (Kalshetty *et al*., 2012). However, the trends of pH observed was similar to those reported by Oviasogie *et al*., (2007), Osakwe (2014) and Omotade *et al*., (2017), but are lower than the values reported by Obasi (2012) and Osakwe (2014).

The mean values for organic carbon (OC) are 1.62 ±1.34 and 0.78 ±0.33 % for the month of March and September respectively. Flood decreased levels of OC from all sites with highest recorded value at Nku (1.14%) and least value at Jifu (0.56%). Total organic carbon (TOC) is a measure of organic content in soils and contributes significantly to acidity through contributions from organic acids and biological activities (Doetter *et al*. 2016). A reduction in TOC observed could be adduced to the effect of flooding; as most organic acids and humus in the soil may have been leached out by the flood. Soil organic carbon is required to stimulate microbial respiration and activities. The reduced organic carbon content observed is at variance with the findings of (Kalshetty *et al*., 2014). The organic carbon content of the soil after flooding were greater than 0.75% and thus reveals that the soil samples were fertile (FAO, 2017).

The level of organic matter (OM) in March was 1.97 ±0.61 but decreased to 1.55 ±0.21 in September. The decrease in OM content in soil was believed to be due to heavy rain which detaches some of the organic matter from soil particles into river **(**Azlan *et al.,* 2012). Organic matter (Manures) is related to organic carbon and it correlates to the amount of plant cover in the area (Kalshetty *et al*., (2014). Organic matter contains humus, which supplies plant nutrients and it is essential in maintaining soil fertility. The results obtained at all the locations show that the soils would support agriculture with minimum or no use of fertilizers. The results are similar to the findings of Chen *et al*., (2005), Ubuoh *et al*., (2016), and Azlan *et al.,* (2012).

The percentage of total nitrogen (TN) decreased in September (0.22 ±0.08 to 0.16 ±0.04). The reduction in nitrate levels after flooding is similar to the findings of Kalshetty *et al*., (2014) and Vincent *et al*., (2014) where reduction in nitrate levels were observed on flooded soils. Nitrate content is an important soil parameter that enhances soil quality, fertility and productivity.

The levels of available Phosphorus (P) in the soil samples were found to be 9.15 ±3.26 mg/kg and 7.73 ±2.40 mg/kg for the month of March and September respectively. Possible leaching of available phosphorus as phosphate in the soil by the flood could account for the observed decrease, since in water columns, anaerobic conditions renders it soluble (Osakwe, 2014). These Phosphorus reductions after the flood event is in contrasts with the findings of Kalshetty *et al*., (2014) where increased phosphorus levels were recorded in flood affected cultivated soils in India.

Cation exchange capacity (CEC) of the soil samples also decreased from March (11.52 ±2.35) to September (10.11 ±1.60). Reduced organic matter after flooding could have also accounted for the reduction in CEC, since organic matter contributes to the cation exchange capacity of the soil by increasing adsorption sites for cations (Oorts, 2003). Reduced cation exchange capacity is not favourable for fertile soil because it limits the available positively charged nutrients to be adsorbed on soil particles, since few negatively charged sites will be available to attract them. This displacement of protons in the solution was in agreement with the results from pH measurements which also showed lower pH – values on the flooded soils. The reduction in CEC levels is similar to the findings of Kalshetty *et al*., (2014) where reduced levels were also observed on flooded soil from river Krishna in Southern India.

The levels of the metals Na, K, Ca and Mg also decreased from March to September. Lower values of these metals after flooding could be as a result of leaching and dilution (Conklin, 2005), since floodwater increases solubility of mineral nutrients (Mitsch and Gosselink, 2000). However, the results obtained in this study for Na and K are well above those reported by Ubuoh *et al*., (2016) with the exception of Ca and Mg, while the measured changes in the cations content were within the recommended range (Kalshetty *et al*., 2012).

In this study, silt and clay both increased after flooding while sand fractions evolved a different trend along the profile. The results for the average percentage sand, silt and clay contents of the soils from the study area showed that the soil belong to clay loam. The study also revealed that the trend in the textural class of the soils were clay loam, sandy loam and sandy clay loam from the three sampling sites. However, clay loam are noted to be predominant.

Table 1: Descriptive Statistics of Soil Quality Parameter for March

Parameter	Minimum	Maximum	Range	Mean	S D	CV %
pH	5.18	6.93	1.75	5.91	0.66	11.17
OC (%)	0.60	7.80	7.20	1.62	1.34	82.72
OM (%)	1.40	3.34	1.94	1.97	0.61	30.96
TN (%)	0.10	0.39	0.29	0.22	0.08	36.35
P (mg/kg)	2.77	13.9	11.13	9.15	3.26	35.62
CEC (mg/kg)	6.66	14.71	8.05	11.52	2.35	20.39
Na (mg/kg)	0.12	1.39	1.27	0.38	0.35	92.10
K (mg/kg)	0.12	0.77	0.65	0.35	0.20	57.14
Ca (mg/kg)	3.70	7.97	4.27	5.56	1.62	29.14
Mg (mg/kg)	2.04	6.91	4.87	4.13	2.02	48.91
Sand (%)	15.73	91.68	75.95	46.92	22.61	48.19
Silt (%)	3.56	54.04	50.48	31.31	13.34	42.61
Clay (%)	4.76	37.22	32.46	21.75	10.93	50.25

Table 2: Descriptive Statistics of Soil Quality Parameter for September

Parameter	Minimum	Maximum	Range	Mean	S D	CV %
P^H	4.74	6.17	1.43	5.29	0.46	8.69
OC (%)	0.21	1.29	1.08	0.78	0.33	42.30
OM (%)	1.27	1.98	0.71	1.55	0.21	13.55
TN (%)	0.10	0.24	0.14	0.16	0.04	25.00
Avail.P (PPM)	2.27	10.90	8.63	7.73	2.40	31.05
CEC (cmol/kg)	6.49	12.30	5.81	10.11	1.60	15.83
Na (cmol/kg)	0.12	1.26	1.14	0.35	0.33	94.29
K (cmol/kg)	0.13	0.48	0.35	0.26	0.10	38.46
Ca(cmol/kg)	4.16	6.52	2.36	4.98	0.73	14.66
Mg (cmol/kg)	1.22	6.15	4.93	3.48	1.75	50.29
Sand (%)	20.14	55.21	35.07	34.43	13.19	38.31
Silt (%)	20.84	52.27	31.43	34.53	11.15	32.29
Clay (%)	21.53	41.29	19.76	31.04	5.68	18.29

3.2. Correlation analysis (CA)

Correlation analysis was used to assess the strength and direction of relationship between the soil physicochemical parameters. The results of Karl Pearson’s product moment correlation coefficient (r) are presented in table 3 and 4 for March and September respectively.

A correlation coefficient of +1 indicates that the two variables are perfectly related in a positive (linear) manner, a correlation coefficient of -1 indicates that two variables are perfectly related in a negative (linear) manner, while a correlation coefficient of zero indicates that there is no linear relationship between the two variables being studied (Okoffo *et al*., 2016). In the month of March, there were significant positive correlations (at 0.01 level, two tailed) between pH and the following parameters: OM (r = 0.660), TN (r = 0.498), K (r = 0.714), Ca (r = 0.715), silt (0.690), and clay (0.494). pH has been described as the master soil variable (Nora, 2019) because of its influence on soil properties that control soil quality. Soil pH increases the solubility of organic matter by increasing the dissociation of acid functional groups, hence the observed positive correlation between pH and organic matter (Anderson *et al*., 2000; Evans *et al*., 2012). Soil pH is controlled by the leaching of basic cations such as Ca, Mg and K (Dora, 2019). The significant positive correlation between pH and fine soil texture (silt and clay) indicate that pH values increase with increasing fine texture of the soil. That also explains the negative correlation of pH with sand content (r = -0.647).

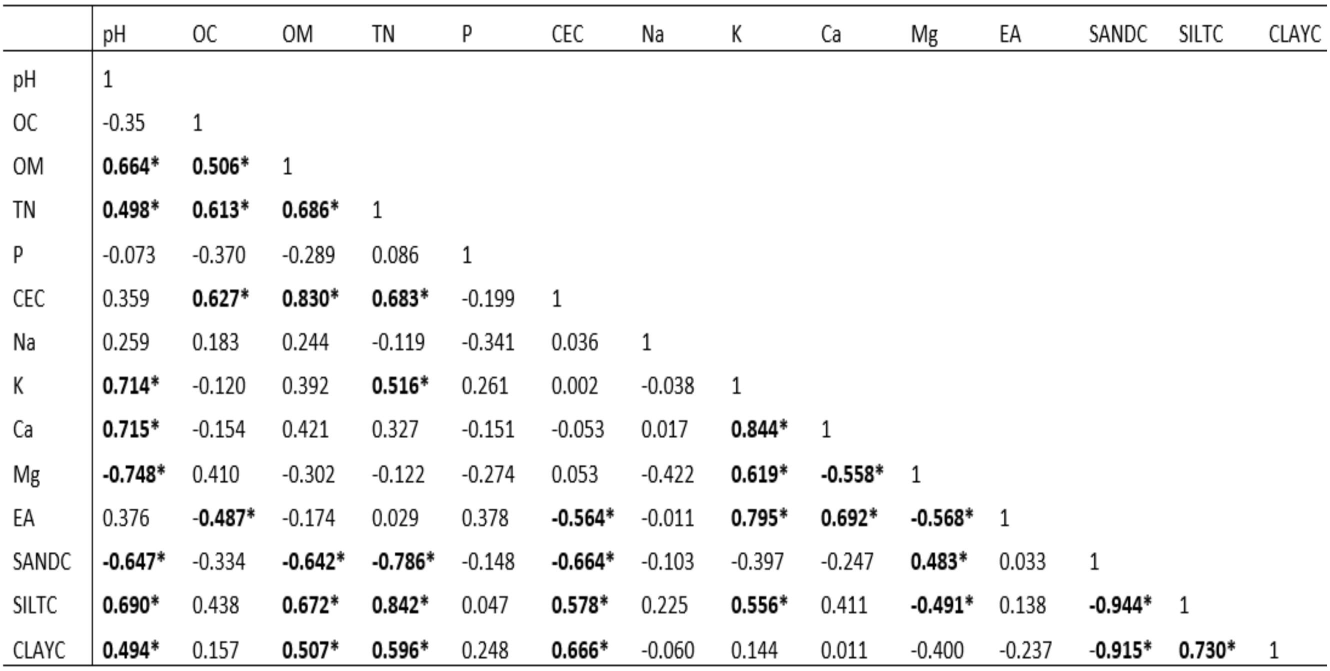
Sand content also showed negative correlation with most of the soil quality parameters except Mg. sandy soil has very low cation exchange capacity and tend to loose substantial quantity of these parameters due to leaching (John, 2013). Hence, the higher the sand content, the lower the quantity of these parameters. Coarse textured soils tend to naturally have lower levels of organic matter due in part to rapid microbial decomposition (Carter, 1996). Organic matter binds soil particles and contributes to aggregate stability (Zhang, 1994). It has also been observed that fine soil textures possess hundreds of times more surface area (hence more electrostatic adsorption capability) than sand. This enables the soil to store many more nutrients (McLean, 1981).

Significant positive correlations exist between OM and OC (r = 0.506), TN (r = 0.686) and CEC (r = 0.830). It has been observed that the content of OM increases with pH (Anderson *et al*., 2000; Evans *et al*., 2012), and consequently mineralizable C and N (Curtin, 1998). CEC on the other hand is largely determined by the charge of the soil particles and OM (Wang *et al*., 2005), hence the observed correlation.

CEC also correlated significantly positive with TN (r = 0.683) and K (0.516), and negatively with EA (r = -0.564). As the CEC of the soil increases, both the total nitrogen content (TN) and K also increase, while the exchangeable acidity (EA) decreases.

There were also significant positive correlations between K and Ca (r = 0.844), K and Mg (r = 0.519) and K and EA (r = 0.795). High Ca and Mg levels in the soil solution may reduce K uptake by the plant roots (Brady and Weil, 2002). Exchangeable acidity is a measure of the amount of CEC that is occupied by the acidic cations (Al^{3+} and H^+) (Hamza, 2008). The value of EA increased with increase in K content in this study.

Table 3: Correlation coefficients between soil quality parameters for March (before flooding)



	pH	OC	OM	TN	P	CEC	Na	K	Ca	Mg	EA	SANDC	SILTC	CLAYC
pH	1													
OC	-0.35	1												
OM	**0.664***	**0.506***	1											
TN	**0.498***	**0.613***	**0.686***	1										
P	-0.073	-0.370	-0.289	0.086	1									
CEC	0.359	**0.627***	**0.830***	**0.683***	-0.199	1								
Na	0.259	0.183	0.244	-0.119	-0.341	0.036	1							
K	**0.714***	-0.120	0.392	**0.516***	0.261	0.002	-0.038	1						
Ca	**0.715***	-0.154	0.421	0.327	-0.151	-0.053	0.017	**0.844***	1					
Mg	**-0.748***	0.410	-0.302	-0.122	-0.274	0.053	-0.422	**0.619***	**-0.558***	1				
EA	0.376	**-0.487***	-0.174	0.029	0.378	**-0.564***	-0.011	**0.795***	**0.692***	**-0.568***	1			
SANDC	**-0.647***	-0.334	**-0.642***	**-0.786***	-0.148	**-0.664***	-0.103	-0.397	-0.247	**0.483***	0.033	1		
SILTC	**0.690***	0.438	**0.672***	**0.842***	0.047	**0.578***	0.225	**0.556***	0.411	**-0.491***	0.138	**-0.944***	1	
CLAYC	**0.494***	0.157	**0.507***	**0.596***	0.248	**0.666***	-0.060	0.144	0.011	-0.400	-0.237	**-0.915***	**0.730***	1

*correlation is significant at 0.01 level (two tailed)

Correlation coefficient shown in table 5 indicates that there are appreciable redistribution of the parameters after the flood of September as the relationship pattern is different from that observed in March result. Contrary to what was observed in March, pH correlated positively (0.01 level, two tailed) with only P (r = 0.764) and K (r = 0.526), while sand content did not show significant correlation with any of the soil quality parameters. Silt content, however, correlated positively with: OC (r = 0.769), OM (r = 0.668) and TN (r = 0.500), while CEC showed significant positive correlations with the following parameters: OM (r = 0.675), OC (r = 0.668), and TN (r = 0.621).

As was observed in March, there were also significant positive correlations between the following: OM and OC (r = 0.725), OM and TN (r = 0.563), OM and Ca (r = 0.646), OC and TN (r = 0.690), and Ca and K (r = 0.670). The result also showed significant negative correlations between: Na and P (r = -0.710), Mg and K (r = -0.710), Mg and Ca (r = -0.582).

Table 4: Correlation coefficients between soil quality parameters for September (after flooding)

	pH	OC	OM	TN	P	CEC	Na	K	Mg	EA	Ca	SILTC	SANDC	CLAYC
pH	1													
OC	-0.250	1												
OM	-0.028	**0.725***	1											
TN	-0.187	**0.690***	**0.563***	1										
P	**0.764***	-0.261	-0.164	-0.265	1									
CEC	-0.200	**0.688***	**0.675***	**0.621***	-0.197	1								
Na	-0.392	0.377	0.466	0.419	**-0.751***	0.138	1							
K	**0.526***	-0.097	-0.050	-0.143	0.480	-0.287	-0.137	1						
Mg	-0.157	0.009	-0.007	0.246	0.018	0.406	-0.273	**-0.710**	1					
EA	0.000	0.119	0.149	0.049	-0.399	0.205	0.440	0.248	-0.458	1				
Ca	0.418	0.368	**0.646***	0.220	0.252	0.213	0.273	**0.670**	**-0.582**	0.295	1			
SILTC	0.266	**0.769***	**0.668***	**0.500***	0.207	**0.731***	-0.012	0.020	0.124	0.099	0.453	1		
SANDC	-0.078	-0.144	-0.192	-0.036	-0.003	-0.133	-0.123	-0.100	0.196	-0.212	-0.276	-0.109	1	
CLAYC	-0.081	0.291	-0.099	0.481	-0.034	0.210	0.055	-0.127	0.397	-0.118	-0.254	0.138	0.123	1

3.3. Principal Component Analysis (PCA)

PCA was conducted on the soil dataset to determine factors contributing to the difference between seasons. The PCA on the soil quality parameters for March sampling period extracted three components (with eigenvalues >1), which together explained 84.10% of the total variance (Table 5). PC1 explained as much as 40.42% of the variance and has strong loading on soil pH, K, Ca, Mg, Sand and Silt. In this component there is evidence of either the presence of organic matter from plant and animal residues or may be linked with mineral soil reaction in the area. PC2 explained 31.96% of the total variance and has strong loadings on soil CEC, EA and Clay in this decreasing order of importance. In this component, these soil quality parameters indicates the presence of substantial levels of acid cations on the CEC as a result of pronounced variation in clay content due to residual organic wastes in the soil; while P was the only informative parameter on PC3 explaining 11.76% of the total variance, which indicates the presence of organic and inorganic components containing phosphate due to either fertilizer run-off or colloidal phosphate in the area.

PCA identified three components with significant sources of variation for the September sampling periods, explaining 78.90 % of the total variance of the parameters analysed (Table 5). This was different from what was observed in March; OC, OM, TN, CEC and EA now becomes important contributors. It can be noted that there was a slight decrease in the percentage variance after flooding (September) which suggest a decrease in correlation structure among the parameters and could be due to some environmental effects. The values of communalities show that the variances expressed by the variables were well described. The high communality explained by OC suggest strong correlation matrix among the parameters and could be a strong soil quality indicator in the study area during the period of sampling. OC could be traced to residual decomposition of organic matter in the soil. However, low communality explained by clay (0.570%) suggests that a substantial portion was not accounted for by the PCA. The first component loading (PC1) accounts for as much as 36.66% of the total variance and the distribution of soil quality was most strongly controlled by OC, OM, TN, CEC, Ca, EA, Sand and Silt. The result indicates that the first PC has correlation with soil productivity which is associated with substantial levels of both organic and inorganic wastes in the soil hence can be denoted productively factorial component. It can be noted that Ca is the only overlapping variable that also form part of the significant components that make up the second component (PC2). The second component which accounts for 22.52% of the total variance strongly correlated with soil pH, P, K, Ca and Mg, which was also observed during March sampling period. PC3 explained 19.73% of the total variance and has positive loading of Mg and Clay as it can be associated with most organic residues.

Table 5: Communality and Cumulative Variance of PCA for Soil Quality Parameters

BEFORE FLOOD (March)					**AFTER FLOOD (September)**				
Parameters	**PC1**	**PC2**	**PC3**	Comm.	**Parameters**	**PC1**	**PC2**	**PC3**	**Comm.**
pH	**0.904**	0.095	0.116	0.839	pH	0.223	**0.781**	0.371	0.798
OC (%)	0.115	0.528	0.424	0.472	OC (%)	**0.852**	0.355	0.237	0.908
OM (%)	0.537	0.586	0.361	0.879	OM (%)	**0.810**	0.094	0.325	0.771
TN (%)	ND	ND	ND	ND	TN (%)	**0.741**	0.410	0.150	0.739
P (mg/kg)	0.196	0.314	**0.792**	0.764	P (mg/kg)	0.103	**0.688**	0.528	0.763
CEC(mg/kg)	0.234	**0.903**	0.083	0.877	CEC (mg/kg)	**0.750**	0.455	0.0.40	0.771
Na (mg/kg)	ND	ND	ND	ND	Na (mg/kg)	0.046	0.519	0.582	0.609
K (mg/kg)	**0.825**	0.365	0.170	0.842	K (mg/kg)	0.342	**0.855**	0.045	0.849
Ca (mg/kg)	**0.726**	0.417	0.414	0.871	Ca(mg/kg)	**0.616**	**0.655**	0.311	0.904
Mg (mg/kg)	**0.791**	0.241	0.171	0.713	Mg (mg/kg)	0.004	**0.655**	**0.639**	0.838
EA (mg/kg)	0.502	**0.844**	0.066	0.968	EA (mg/kg)	**0.690**	0.543	0.080	0.778
Sand (%)	**0.764**	0.536	0.266	0.941	Sand (%)	**0.881**	0.180	0.310	0.905
Silt (%)	**0.826**	0.410	0.035	0.852	Silt (%)	**0.916**	0.020	0.060	0.843
Clay (%)	0.570	**0.605**	0.510	0.960	Clay (%)	0.250	0.379	**0.603**	0.570

3.4. Cluster Analysis (CA)

Cluster analysis was used to classify the soil quality parameters into groups that are similar. Dendogram of the hierarchical cluster analysis of the March samples is shown in Figure 1. Five distinct clusters were observed at a rescaled distance of 10, namely: cluster 1 (K, Ca, EA, and pH); cluster 2 (OM, CEC, TN, Silt content, Clay content, and OC); cluster 3 (Na); cluster 4 (P), and cluster 5 (Mg and Sand content). Although, factors controlling soil variables can be complex, pH seems to be the major factor controlling all the variables in cluster 1. These variables also showed significant positive correlations with pH. Cluster 2 are variables that exerts major influence on the CEC of the soil. CEC depends on the relative amount of colloids in the soil (OM, and silt + Clay) (Hamza, 2008), while OM is directly related to OC (Kalshetty *et al*., 2014). Na and P in cluster 3 and 4 respectively did not show significant relationship with other parameters, hence exist as cluster of their own, while cluster 5 showed negative relationship with most of the soil quality parameters.

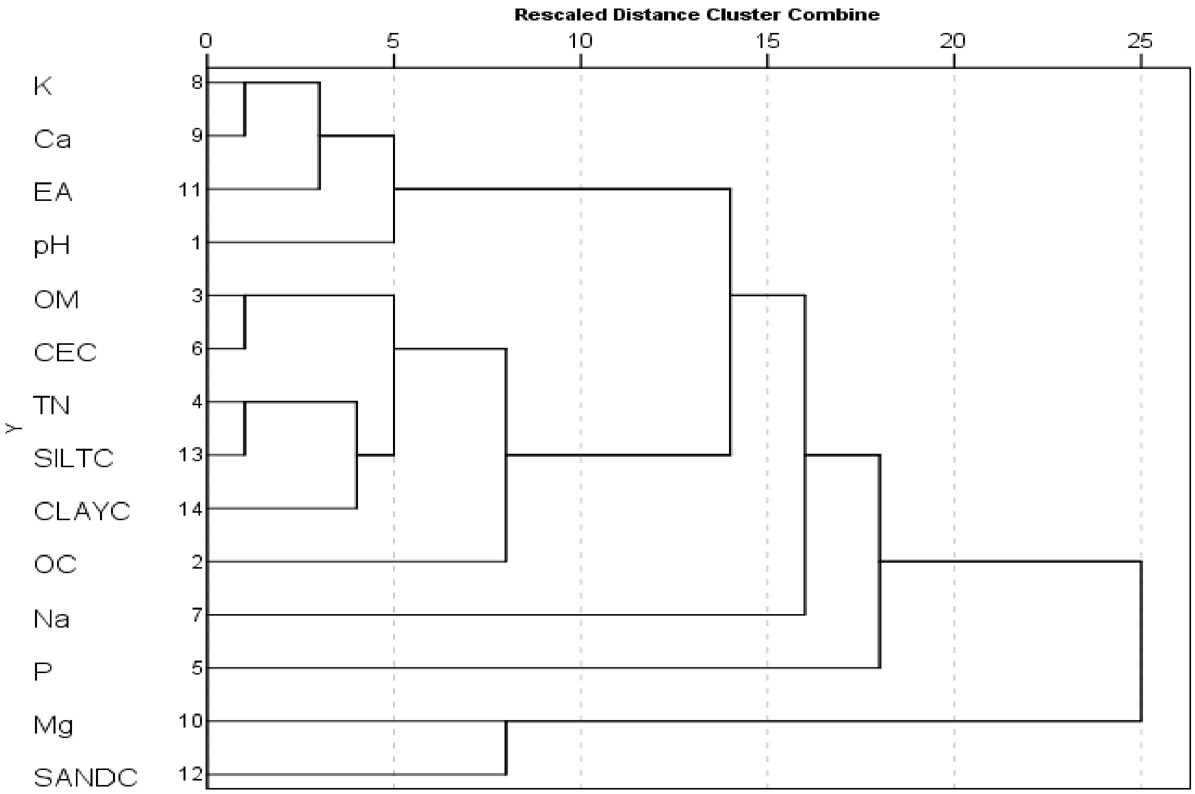


Figure 1: Dendogram of the hierarchical cluster analysis of soil quality parameters in March (before flooding)

Dendogram of the hierarchical cluster analysis for the September result is shown in Figure 2. Five clusters were also observed. However, these clusters are different from the ones observed in March, as new relationships pattern were observed. Cluster 1 includes: OC, silt content, CEC, OM and TN. Variables in this cluster control the CEC of soil after flood of September. Variables in cluster 2 (Na and EA) and cluster 3 (Mg and Clay content) showed weak relationship with each other, while sand content is clustered independently in cluster 4. P and pH combined with K and Ca to form cluster 5. These clusters show that the flood has significant influence on the content and distribution of the soil quality parameters.

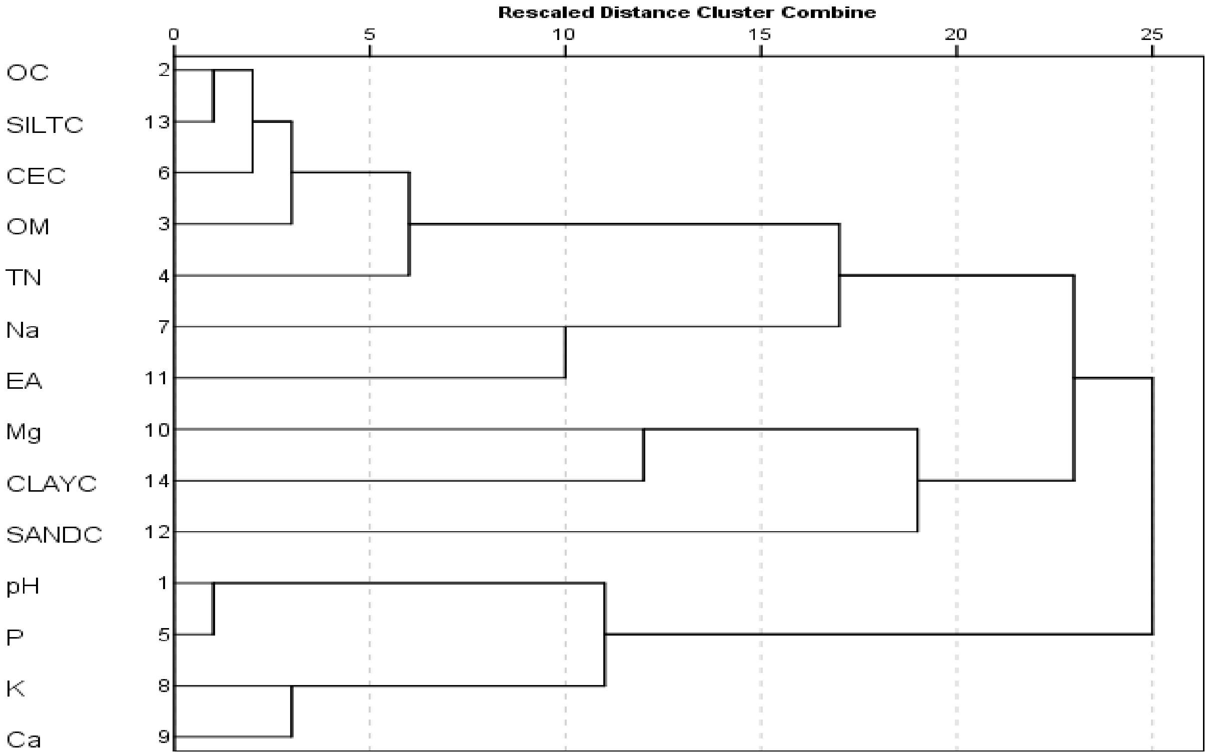


Figure 2: Dendogram of the hierarchical cluster analysis of soil quality parameters in September (after flooding)

3.5. Discriminant Analysis (DA)

Table 6 shows the classification functions coefficients for discriminant analysis of soil sample in March. Discriminant functions were obtained for standard, forward and backward stepwise selection mode. In the standard mode, all the variables were inclusive or entered into the models while seven variables (pH, OC, OM, TN, P, K and Mg) were significant ($P<0.05$) out of the fourteen soil parameters in the forward and backward selections. This implies that these seven variables were the most significant parameters which accounted for the expected spatial/temporal variations in the soil of March with high reliability and accuracy for the standard ($R = 0.99$; lambda = 0.0036 and $P = 0.001$), forward ($R = 0.99$; lambda = 0.0031 and $P = 0.001$) and backward ($R = 0.95$; lambda = 0.047 and $P = 0.001$**).**

Figure 3 represent the canonical plot of March samples and all the significant parameters had an intermediate effect without variables discrimination at different sites.

The DA for soil samples in September is shown in Table 7 and was conducted on the soil dataset. In order to identify variables that significantly contributed to the discrimination, stepwise variable selection was carried out. The variables selected into the final discriminant model showed that in the standard mode, all the variables were inclusive into the models while twelve variables (without TN and EA) for forward selection and eleven variables (without OM, TN and EA) for backward mode were significant ($P < 0.05$) out of the fourteen soil parameters. This implies that they were the most significant parameters which accounted for the expected spatial/temporal variations in the soil of September with high reliability and accuracy. This again was different from what was observed in March, as CEC, Na, Ca, silt, sand and clay now become an important discriminator. Meanwhile, it was also noted that pH, OC, OM, P, K and Mg form part of the significant discriminators during March period. However, the Wilk‘s Lambda has value from 0.00014 - 0.017 with correlation coefficient of 0.99, 0.99 and 0.99 respectively. The value of P in each mode was 0.001 indicating that the DA was reliable on the discriminatory ability of the selection mode. Figure 4 represent the canonical plot of September and all the significant parameters had an intermediate effect without variables discrimination at different sites.

Table 6: DA of Soil quality parameters in March

	Standard	Forward	Backward	
Constant	76408			
pH	55404	44.34	37.10	
OC	-29204	46.33	48.46	
OM	7250	77.91	85.85	
TN	-94003	34.89	34.89	
P	22905	87.26	95.87	
CEC	84303			
Na	8430			
K	68605	74.51	78.12	
SILT	15272			
Ca	18505			
Mg	25505	97.74	99.78	
EA	11605			
SAND	15307			
CLAY	15407			
Wilks' lambda and Chi-Square test of DA				
Modes	Fun.(s)	R	Wilks' lambda	*P* level
Standard	1	0.99	0.0036	0.001
Forward	1	0.99	0.0031	0.001
Backward	1	0.95	0.047	0.001

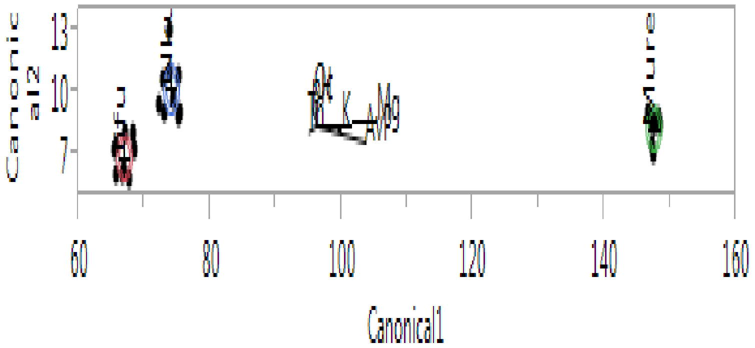


Figure 3: Canonical Plots for Soil quality parameters in March

Table 7: DA of Soil quality parameters in September

	Standard	**Forward**	**Backward**	
Constant	-30009			
pH	36488	30.70	42.36	
OC	-8.157	37.38	39.57	
OM	10966	80.87		
TN	51504			
P	14205	51.61	86.65	
CEC	69805	76.69	82.16	
Na	18306	63.88	88.84	
K	60007	28.35	28.35	
SILT	59964	51.10	71.81	
Ca	653528	57.22	92.14	
Mg	83404	93.14	88.07	
EA	-14405			
SAND	60007	51.10	71.11	
CLAY	60019	62.93	5.05	
Wilks' lambda and Chi-Square test of DA				
Modes	**Fun.(s)**	**R**	**Wilks' lambda**	***P* level**
Standard	1	0.99	0.0009	0.001
Forward	1	0.99	0.00014	0.001
Backward	1	0.99	0.017	0.001

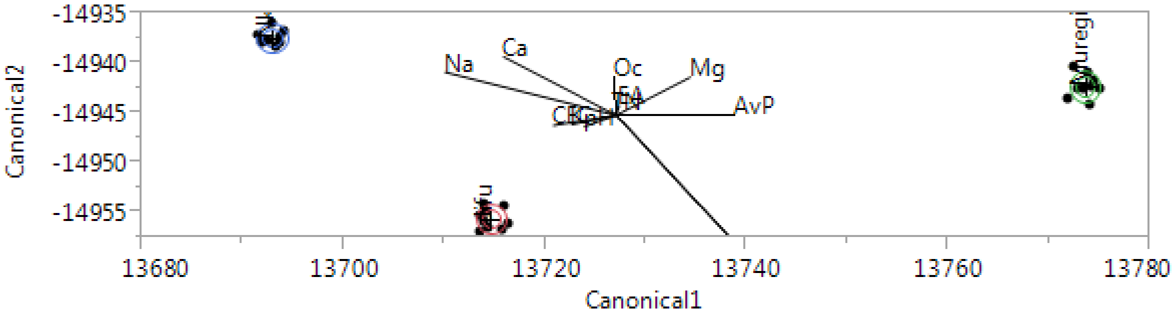


Figure 4: Canonical Plots for Soil quality parameters in September

4.0. CONCLUSION

Most of the analysed parameters decreased in values after flooding which may be attributed to leaching effect. The soil textual class revealed predominantly clay loam, while Multivariate statistics underscores significant influence of flooding on the soil of the study area.

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