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Soil Variability Assessment for Sustainable Agriculture in Katsina State, Northwest, Nigeria

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Abstract

Soil assessment is a valuable first field-approach to determine the land suitability for agriculture production. Thus, a study was conducted to determine the variability of selected physio-chemical properties of soils under agriculture practice in Katsina State, Nigeria. The agriculture area was divided into land units and a total of 5 soil profile pits were excavated corresponding to each unit. The different soil horizon in soil profile were described using soil taxonomy, with 500g of sample were collected from each soil horizon. A total of fifteen (15) samples were collected from the profile pits (three in each pit from three different horizons). GIS (Geographical Information System) techniques were integrated to the soil data from the laboratory soil analyses. Following that, ArcGIS 10.3 used to generate the physio-chemical characteristic thematic maps of the selected soil characteristic parameters. Climate condition; rainfall and temperature, plus physical properties; bulk density (BD), drainage, erosion, soil depth (SD), slope, water holding capacity, and chemical properties; organic carbon (OC), cation exchangeable capacity (CEC) and soil pH were determined and analyzed. The rainfall trend of the area increases at decreasing with the highest peak at 2017. All the land units were characterized with the required soil pH as ranged between (6.0-6.76). The highest CEC value was found in land unit 5 (9.02cmol/kg) with lowest in land unit 4 (4.03cmol/kg). The correlation analysis of soil properties of all the five land units was computed in (table 7). This shows that the parameters of the land units are not independent. The indications in this results is that some soil parameters of the land units are significantly correlated. The analysis reveals that there is a significant relationship among the land units in study area on OC, AWC and erosion activities while in terms of CEC, PH and soil depth there is no significant differences at p value of 0.05. As such knowledge on climate and physio-chemical properties of soil are very essential so as to help farmers and others land users in Katsina, North West zone to identify areas that are best for agricultural land uses.

Keywords: Physio-chemical properties, Spatial variability, Sustainable Agriculture.

I. INTRODUCTION

Soil is one of the most important natural resources (Tale &Ingole, 2016). The quantity of agricultural soil is limited and is decreasing for the most parts of the world. Soils in many areas have been degraded irreversibly and has become incapable for supporting agricultural production (Oluwatosin, Adeyolanu, Ogunkunle, &Idowu, 2006). Spatial variability of physio-chemical characteristics concerns on the evaluation of the factors such as climate, and physio- chemical characteristics of soil (Roslan, Shamshuddin, Fauziah, &Anuar, 2011). The reduction in soil nutrients affects agricultural productivity (Fasina, Raji, Oluwatosin, Omoju, &Oluwadare, 2015). Soil spatial variability focused on two types of soil characteristics; stable characteristic of soil such as texture, stoniness, slope, drainage, erosion and characteristic that are likely to influencing crop growth such as soil depth,

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water holding capacity and nutrient contents (Walter, 2007).

The productivity and sustainability of soil depends on dynamic equilibrium of its physical and chemical characteristics (Jamil, Sajjad, & Ashraf, 2016). The natural endowments such as soil, water and climatic elements influence the growth, patterns and distribution of plant species. Different plants require different soils and site condition for its optimum production. Hence the plant requirement is managed and controlled by the physio-chemical properties of the soil, therefore the growth and regrowth of plant species directly or indirectly is determined by such factors.

GIS approach play a vital role in the field of soil physio-chemical properties and their spatial variability. It is used as a tool for analyzing and solving multiple problems involving combined spatial and non-spatial information, viewing capabilities as well as allow users to interact and modify solution to perform sensitive analyses (Lunkapis& Ahmad, 2002). GIS is equally used in making models using different principles (Keshavarzi, Bagherzadeh, Omran, &Iqbal, 2016). Therefore, GIS can be seen as a useful technique that could provide a wide range of flexibility on effective and efficient planning in decision making (Kahsay, Haile, Gebresamuel, Mohammed, & Moral, 2018). Nigeria is one of the countries with high declining soil fertility, the major soil types are Entisols, Inceptisols, fluvisols, regosols, gleysols, and vertisols which are highly susceptible to erosion and low productive (Gisilanbe, Musa, Lebbiso, Bilayabu, & Ali, 2017). The productivity of the soils in study area have declined due to fertility depletion, imbalance in soil nutrients, and reduction of organic matter (Ahmed, 2015). The soils of Katsina State have been reported to be low in cation exchange capacity, low pH and high aluminum which affect the growth and production of food crops (Lawal, Adeboye, Tsado, Elebiyo, &Nwajoku, 2012). Natural resources should be managed in a sustainable manner so that the changes proposed to meet the needs of development are brought without diminishing the potential for their future use (Kanwar, 1994). The spatial variability of physical and chemical characteristic of soil contributes immensely in controlling agents of stability of soil structure, nutrient availability for plant growth, soil pH, soilreaction to fertilizer as well as gases in soil. Therefore, monitoring physical and chemical variability of soil despite been time consuming and costly has become very imperative.

II. MATERIALS AND METHODS

Katsina State is located in the Sudan Savannah Zone of Nigeria between latitude $12^{\circ}\ 27^{\prime}\ 16.00^{\prime\prime}$ N to $12^{\circ}59^{\prime}\ 26.95^{\prime\prime}$N and longitude on $7^{\prime\prime}12^{\prime}6.20^{\prime\prime}$ E to $7^{\circ}12^{\prime}6.37^{\prime\prime}$E. The state is characterized by long dry season and short rainy season. Katsina central senatorial zone as the name implied, is a political entity located in the central part of Katsina state and the extreme north - western part of the state. It comprises of eleven local Government areas of Katsina, Kaita, Kurfi, Jibia, Batagarawa, Rimi, Batsari, Dutsin-ma, Safana, Danmusa, and Charanchi with land coverage of about 7, 893 km sq. It is relatively bounded by Funtua senatorial zone of the state to the South, Zamfara state to the west, Niger republic to the North, Kano and Jigawa states to the East. The zone has a total population of about 2, 667,000 in 2006 census figure based on growth rate of 3 %.

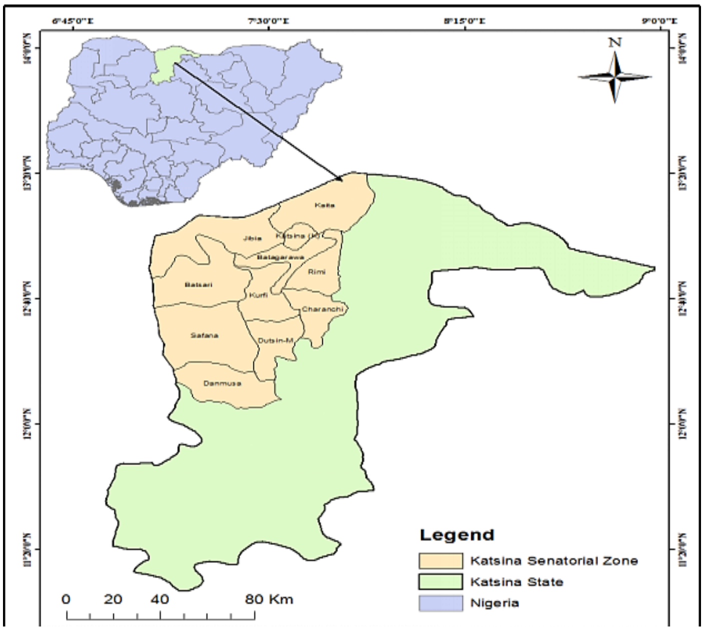

Figure 1 study area

Data Collection

A total of 5 profile pits were excavated one from each land unit. Soil samples were collected from each of the soil horizons identified, from five land units which gave a total of fifteen samples. The samples were air- dried and gently crushed with

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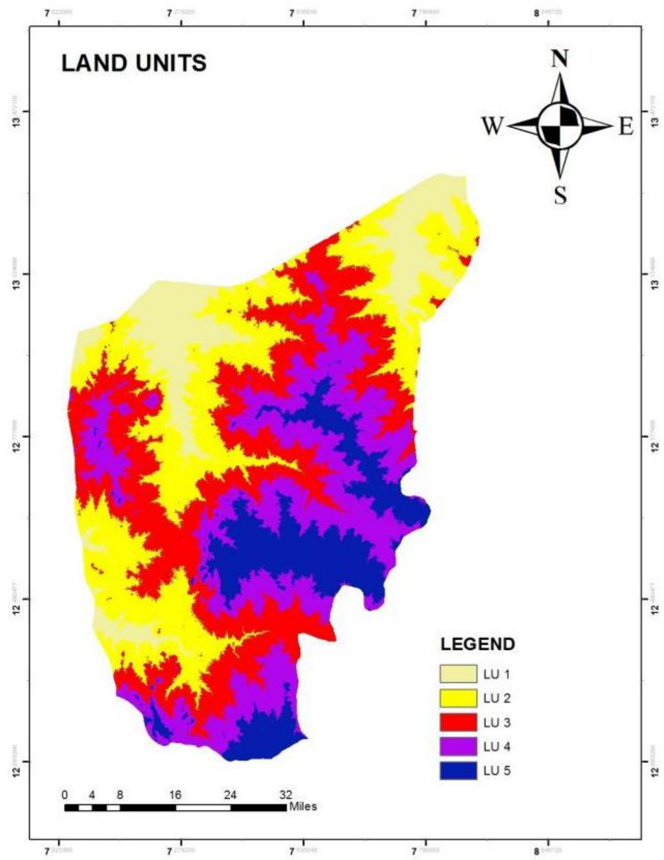
porcelain pestle and mortar after which they were sieved through 2mm sieve in order to remove coarse particles. The fine particles of the samples which are less than 2mm were taken to standard laboratory analyses. The parameters determined included CEC, pH, AWC, and OC) while physical properties such as particle size distribution, bulk density, soil depth, moisture content and drainage, erosion characteristics were determined. The soil depth was measured using a tape marked in meters (Davidson 1992). The stoniness of the study area was also an important variables determined in the field. The surface stoniness was determined by the number of stones per square meter. The study area was divided in to three in terms of stoniness. Land unit with average of 25 stones per sq. is said to be severe. Where less than 25 stones measured is regarded as slight and areas or land facet with no stones found is considered as nil (Bock et al., 2018).



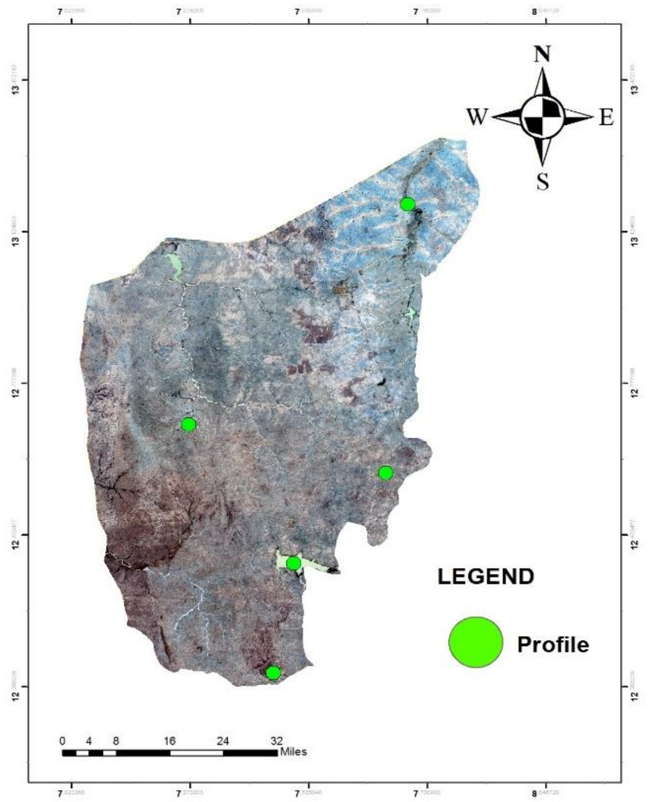


Figure 2 land units and Distribution map of profiles

The drainage condition of the study area was determined through field observation. The land unit is said to be well drained if there is no surface water. The erosion was also determined through field observation (Maw, 2016). the most common method of measuring soil BD is by collecting a known volume of soil using a metal ring pressed into the soil (intact core), and determining the weight after drying (McKenzie *et al.*, 2004).

The CEC was determined from the summation of the exchangeable bases by 1M NH_4OAC extraction while the exchangeable acidity by IM KCI extract as ECEC (cmol/kg^{-1}) = $\sum (K^{+}+Ca^{++}+Mg^{++}+Na^{+}+\text{Acidity})$ (Aune, Bryn, &Hovstad, 2018). The exchangeable sodium percentage was calculated as the proportion of CEC (NH_4OAC) occupied by the exchangeable sodium. In determining the pH 10gm the soil is taken into a beaker, 25ml of distilled water were added in to the beaker container stirred the suspension for 30minsthen allowed to stand for a while after which the reading were taken with pH meter (Nanganoa et al., 2019). Total nitrogen was determined through Micro-Kjedhal method and organic carbon content was determined by wet digestion? Oxidation?method (Ajeigbe, Akinseye, Kunihya, Abdullahi, &Kamara, 2019).

Geospatial analysis Geospatial analysis was conducted using ArcGIS 10.3 version in which all the data were analyzed and gave the effective ranges among the samples points. Inverse distance weighted (IDW) interpolation was applied to determine the values at un sampled locations.

Recorded land resources data

A topographical sheet on a scale of 1: 50 000 which served as a base map was obtained from Ministry of Land and Survey Katsina state of Nigeria. The climate and temperature data were gathered from Nigerian Meteorological agency (NIMET, 2019).

III. RESULTS AND DISCUSSION

The data of rainfall, maximum and minimum temperature of the study area of 10 years (2010 – 2019) were obtained from NIMET. The cruel yearly precipitation was assessed with evapotranspiration for the assessment of land capability in the study area. However, to specific the nature of precipitation within the study area a comparison of variability of the mean, median precipitation and their coefficient of variation was done in Excel sheet (XLSTAT 2016) software.

The descriptive statistics of rainfall variables such as the maximum, minimum, mean, SD, coefficient of variation, kurtosis and skewness are presented in (table 1). From the results presented in table, January had the lowest mean while the August had the highest mean of rainfall distribution. The average monthly coefficient of rainfall variation falls within 30.30 – 316.23%. The highest values of coefficient of kurtosis was found for the month of June which is 1.72 and also the skewness was found to be high in the month of April which was about 1.78. In terms of SD four months (February, March, November and December) had nil SD, January with the lowest SD and August read highest SD. (Figure 4) explains the monthly rainfall pattern, Minimum and Maximum temperature of study area which reveals that maximum amount of rainfall occur from April to October with highest peak in August.

Table 1 Descriptive statistics of rainfall and temperature of study area.

Month	Mean (R/F)	SD	CV	Skewness	Kurtosis	Mean (T)	SD	CV	Skewness	Kurtosis
January	0	0	0	0	0	30.43	1.39	4.56	0.02	-1.25
February	0	0	0	0	0	34.35	1.12	3.26	-0.74	-0.26
March	0	0	0	0	0	36.76	1.6	4.35	0.34	0.14
April	6.44	13.29	206.44	1.78	1.42	39.01	1.33	3.41	-0.07	-0.7
May	34.44	22.75	66.06	0	-0.56	38.77	0.88	2.27	0	-0.37
June	121.41	36.79	30.3	-1.26	1.72	35.28	1.47	4.17	-0.69	0.89
July	179.74	70.11	39	0.39	-1.89	32.13	1.19	3.71	-0.55	-0.77
August	248.87	74.22	29.82	0.65	-1.09	30.69	1.07	3.49	1.46	3.01
September	83.36	15.36	18.42	0.67	-0.94	32.29	1.35	4.17	-0.86	-0.15
October	15.31	18.2	118.9	1.51	1.13	34.21	2.35	6.86	-1.14	0.98
November	0	0	0	0	0	34.33	1.51	4.41	-2.09	4.82
December	0	0	0	0	0	30.44	1.71	5.63	-1.97	5.22

The maximum and minimum temperature of the study area were found to change in a similar manner. For instance, the result shows that both maximum and minimum temperature are very low in months of January and December while the months of April, May and June recorded high values. The CV varies of the two temperatures in terms of periods, the low CV is observed in the months of May of Maximum temperature while the low CV is found in September in Minimum temperature (table 1). The temperature changes of both minimum and maximum on monthly and seasonal are not very significant. As it has been found the rainfall and temperature distribution are not normally distributed as some part of the data skew to different direction depending on trend of the variables. The temperature of any region play a great role in climate variability (Ghasemi 2015).

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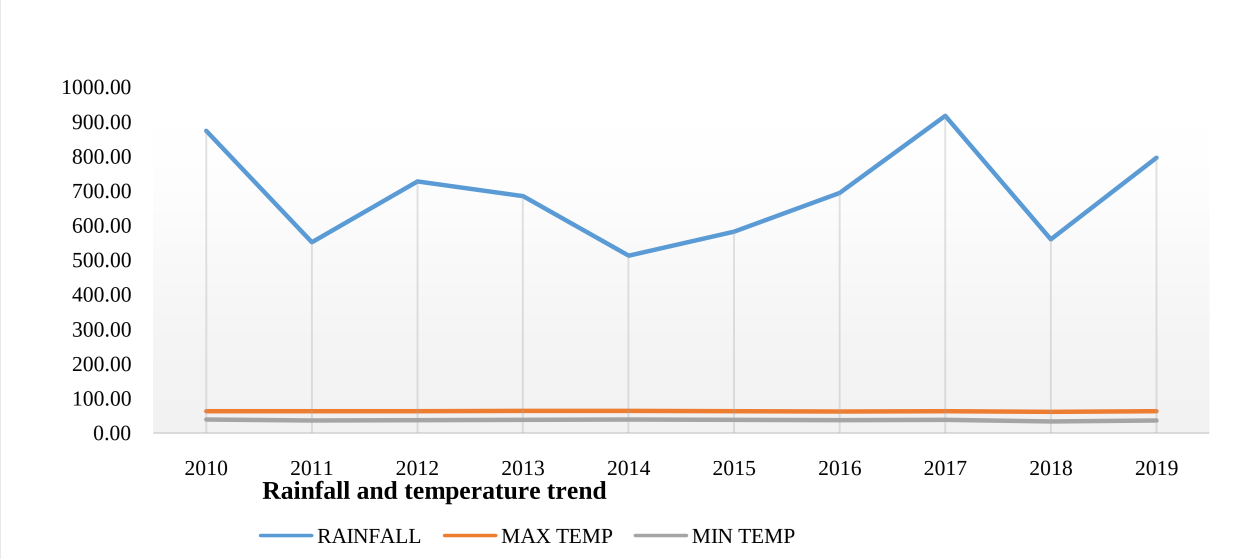

Figure 4 Rainfall and temperature trend

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Physical characteristics of land units

The particle size distribution of different land units is shown in (table 4). The sand, clay and silt percentages of the soil samples for the profiles of 0-100cm deep ranged from 57.28-87.37, 11.68-34.77 and 2-5.03% respectively. The analysis of ANOVA test conducted to compare the significant difference between sand, clay and silt across the five land units not shown any significant difference at 0.05 level. However, there were negligible difference in the particle size distribution composition of the analyzed soil of the different land units. Sand $F(4,55) = 0.72$, $p = .051$. Clay $F(4,55) = 0.60$, $p = .51$ and silt $F(4,55) = 0.50$, $p = .63$ respectively. Despite the fact texture is an inherent soil characteristics management practice that can be helps directly or indirectly to modify the particle size distribution surface layer caused by erosion (Tilahun, 2007). For sustainable agricultural management the effect of soil tillage on soil particle size could be studied (Gulser et al, 2016). Soil drainage may determine which types of plants grow best in an area. Many agricultural soils need good drainage to improve, sustain production and to manage water supplies (Haroun, 2004). The descriptive statistic of drainage pattern of the study area is presented in (table 4). The results show means, standard deviation and coefficient of variance of each land units. Land unit 1 and 3 has the same mean (M =1; SD=0.48; CV 48), land unit 2 and 4 also has the same (M =2; SD = 0.24; CV = 12) while land unit 3 with different (M = 3; SD = 0.96; CV = 32). The land unit 1 and 3 have the lowest mean but land unit 5 has the highest mean (M =3; SD = 0.96; CV = 32). The standard deviation of both drainage and erosion falls within the range of 0.24-0.96. land unit 2 and 4 has the lowest scores which shows that the drainage for these land units are more consistent. The CV of the soil drainage showed more variability among the land units as it ranges 12-48, this large variation may be due to variability of slope. These mean values were significantly different across the five land units at $p \leq 0.05$ level (table 4). The drainage

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condition of the study area falls in to three, well drained covered 14.81%, moderately drained 77.94% and poorly drained with 7.25% respectively.

Table 4 Descriptive statistic of particle size distribution, drainage and erosion of the land units

LAND UNIT	SAND			CLAY			SILT			DRAINAGE			EROSION		
	MEAN	SD	CV	MEAN	SD	CV	MEAN	SD	CV	Mean	SD	CV	Mean	SD	CV
1	82.37[a]	7.76	9.42	11.68[b]	6.51	55.74	5.95[a]	5.03	84.54	1a	0.48	48	1a	0.48	48
2	63.04[b]	5.57	8.84	32.34[a]	3.38	10.45	4.61[a]	2.31	50.11	2b	0.24	12	2b	0.24	12
3	57.28[b]	5.57	9.74	34.77[a]	3.16	9.09	7.28[a]	3.46	47.53	1a	0.48	48	1a	0.48	48
4	62.61[b]	8.52	13.61	32.11[a]	6.98	21.74	5.28[a]	2	37.88	2b	0.24	12	2b	0.24	12
5	64.37[b]	1.41	2.21	30.34[a]	3.16	10.42	5.28[a]	2	37.88	3c	0.96	32	3c	0.96	32
p - value	0.51			0.51			0.63			P<0.0001			P<0.0001		

Means with the same letter within same column are not significantly different at P> 0.05 using LSD.

The mean values of erosion were also highly significant difference at five land units (table 4) and this might be due to the different in elevation. This result is in line with the studies of (Foster, 1982; Jordan 2005 and Maw, 2016;) who found soil erosion increased exponentially with increasing slope gradient, but with the different magnitude depending on the slope conditions, land forms, soil types and other related factors. The thematic map of erosion activities in the study area is classified in to three, slightly erosion 22.72%, moderately 72.56% and severely erosion with 4.72% respectively.

The Bulk density result obtained from data analysis of the physical soil properties in the study area is presented in (table 4) the mean values of BD across the five land units are 1.55, 1.31, 1.5, 1.49, and 1.42 respectively. The mean values of AWC are 56.76, 96.2, 90.74, 63.18 and 84.58 respectively. The mean value of BD density showed no significant difference among the land units in terms of BD at $p \geq 0.05$. However, the mean value of AWC shows significant difference among the land units at $p \leq 0.05$. This shows that there is decrease of AWC with increase of elevation. The SD of bulk density ranged between 0.05-0.21 while available water capacity falls in the range of 3.12-32.68 respectively. The CV of BD ranged between 3.33-13.55 and that of AWC ranged between 3.24-57.6respectively. This indicate that soil of the study area has a particle size that are within the range that can influence water holding capacity. This result is in line with the findings of Jemie*et al.*, 2013 in ((Musina 2017) Soil moisture values increased with increasing of soil depth. The bulk density distribution is falls in to three in study area that is non sticky 15.13%, slightly sticky 36.80% and severely sticky with 48.07% respectively.

Chemical characteristic of land units

The high exchange cationcapacity make soil fertile for crop production. The mean values of the CEC of the five land units are 5.55 (cmol/kg), 7.03 (cmol/kg), 5, 4.03 (cmol/kg), and 9.02 (cmol/kg). The CV of the CEC values ranged within 3-46.56% (see table 5). The mean values of CEC among the land units shows no significant difference at $p \geq 0.05$. The result of the present research of CEC across the five land units are generally low. However, Zahara, Soltangheiss, Khan, Batool& Ashraf (2018) argue that, with management practice good yield can be obtained. A lowcations indicate low resistance of soil to change in soil chemistry that may cause by land use (Hazelton 2007). The study area was divided into five classes in terms of CEC spatially (refer to figure 4). Very high 9.23%, high 46.80%, moderate 17.73%, low 23.87% and very low 2.37% of the study area respectively.

Table 5 Descriptive statistic of BD, AWC, SD, pH, CEC and OC of the land units

	BD			AWC			SD			pH			CEC			OC (%)		
LU	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
LU 1	1.55 a	0.21	13.55	56.76 c	32.68	57.58	33.33 a	16.07	48.21	6.27 a	0.64	10.21	5.55 ab	0.75	13.5	2.11ab	0.24	13.37
LU 2	1.31 b	0.18	13.74	96.2 a	3.12	3.24	33.33 a	17.56	52.69	6.0 a	0.56	9.33	7.03 ab	1.94	27.6	2.36a	0.09	38.14

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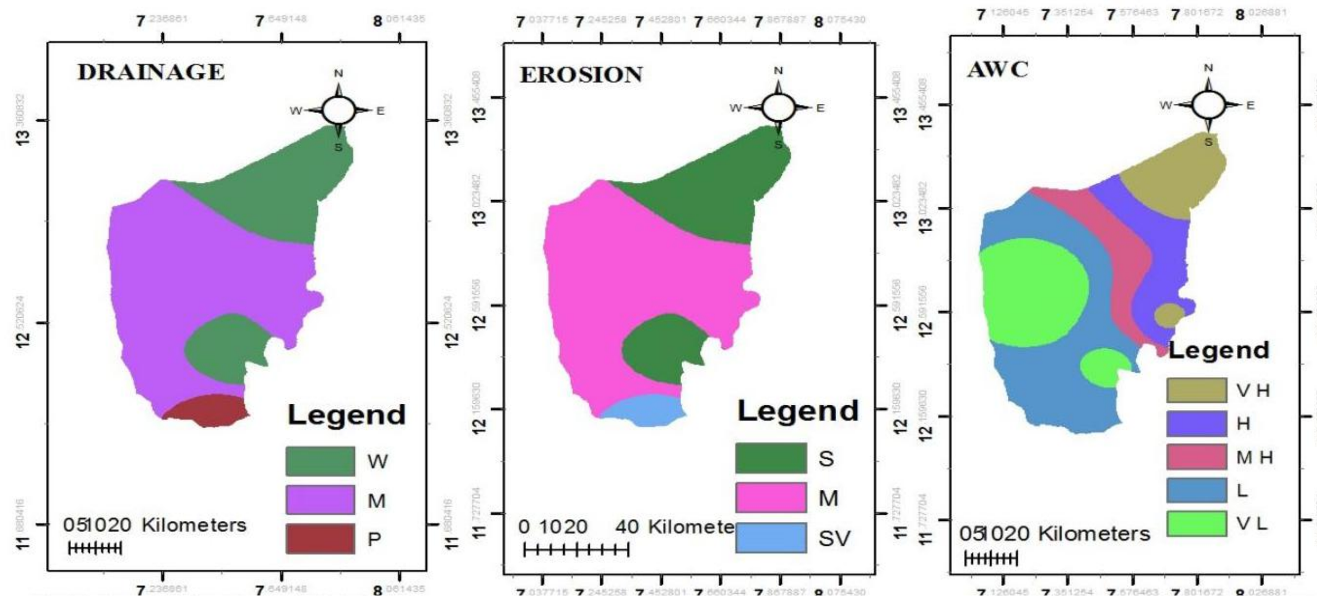
LU 3	1.5ab	0.05	3.33	90.74 ba	12.02	13.25	33.33 a	20.81	62.44	6.63 a	0.98	14.78	5 b	0.15	3	2.05 ab	0.23	11.22
LU 4	1.49ab	0.05	3.36	63.18 bc	12.77	20.21	33.33 a	24.66	73.99	6.76 a	0.7	10.36	4.03 b	0.73	18.1	1.92 b	0.19	9.89
LU 5	1.42ab	0.05	3.52	84.58 abc	7.05	8.34	33.33 a	24.66	73.99	6.46 a	0.35	54.18	9.02 a	4.2	46.6	1.87 b	0.25	13.37
P value	0.217			0.043			1			0.76			0.1			0.04		

Means with the same letter within same column are not significantly different at P> 0.05 using LSD.

Generally accepted, pH is a major driver of soil fertility. As it has been computed ninety-five percent of the sampled soils have acidic pH. The mean values of pH of study area are 6.27, 6.0, 6.63, 6.76, and 6.46 respectively (table 5). This shows that, soil ph increase with increase of elevation. Meanwhile the mean separation of land units falls within the same class i.e a with *p* value of 0.76 which shows no significant difference between the land units in terms of pH content at $p \geq 0.05$. The CV of the soil ph showed more variability among the land units as it ranges 9.33-54.18, this large variation may be due to variability of elevation.This result is signpost the finding of Kebede (2019) who discovered Soil Fertility Status and Numass Fertilizer Recommendation ofTypicHapluusterts in the Northern Highlands of Ethiopia. The study area was divided into five classes spatially in terms of pH content (refer to figure 4). Moderate alkaline 25.78%, Mildly alkaline 22.90%, Neutral 20.36%, Slightly acidic 13.00%, and moderately acidic 17.96%. The amount of TOC in soil affects color, nutrient capacity, cation exchange capacity, water holding capacity, aeration, tillage as well as plant growth health. Microorganism directly or indirectly depend on soil organic carbon. The Mean values of OC of the five land units are 2.11%, 2.36%, 2.05%,1.92% and 1.87% respectively (table 5). The mean values of whole land units show a significantly difference as the computed *P* value is 0.07 (table 5). The land unit 2 has the highest coefficient of OC across the land units and land unit 4 with lowest value of CV. The result of OC distribution in five land units shows that the OC decrease with increase in soil depth (table 4.13). The OC of the five land units shows significant difference between the land units at $p \leq 0.05$ level of percent. The level of organic matter in the study area is distributed in to five classes, area with very high covered 17.45%, high 23.75%, moderate 34.495, low 13.78% and very low with 10.535 respectively.



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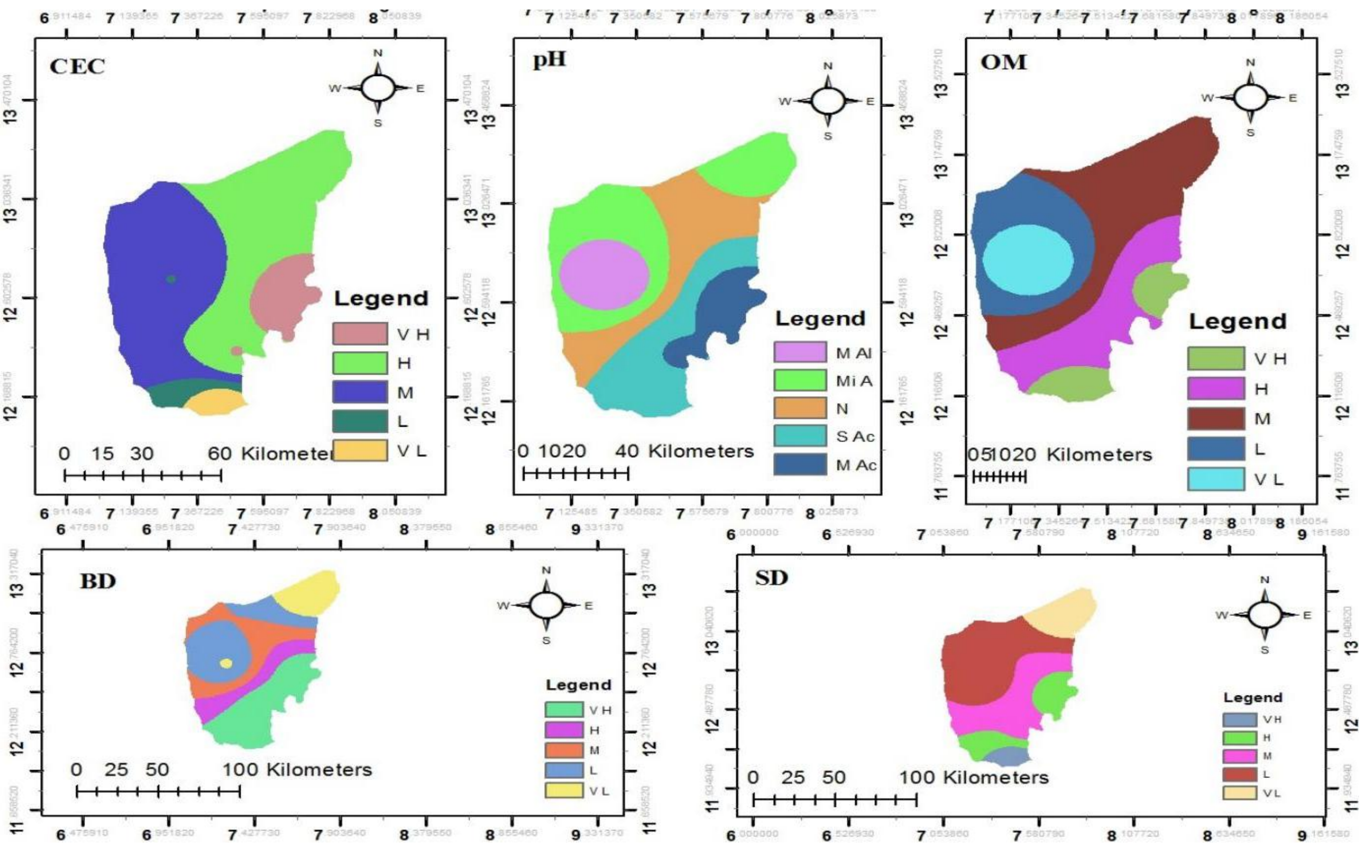

Figure 4 Soil thematic maps for drainage, erosion, AWC, CEC, pH, SD, BD and OM.

Where W=well drained, M=moderately drained, P=poorly drained, S= slight erosion,SV= severely erosion, VH=very high, H=high, M=moderate, L=low, VL=very low, M Al=mildly alkaline, M A= moderately alkaline, N=neutral, S Ac= slightly acidic, and M Ac=moderately acidic.

Table 6 Pearson correlation coefficient (r) between soil characteristics of all Land units

	CEC	pH	OC	SAND	CLAY	SILT	SD	BD	AWC	DRAIN.	EROS
CEC	1										
pH	-0.168	1									
OC	0.278	-0.303	1								
SAND	-0.129	0.047	-0.026	1							
CLAY	0.170	-0.040	0.040	***-0.960	1						
SILT	-0.085	0.030	-0.058	-0.321	0.051	1					
SD	0.267	-0.256	0.378	-0.057	-0.011	0.225	1				
BD	-0.316	0.465	-0.300	0.488	-0.470	-0.211	-0.333	1			
AWC	0.405	-0.223	0.381	-0.580	**0.649	-0.139	0.112	-0.528	1		
DRAI.	0.501	-0.003	-0.276	-0.250	0.348	-0.220	0	-0.354	0.197	1	
EROS.	0.501	-0.003	-0.276	-0.250	0.348	-0.220	0.000	-0.354	0.197	**1	1.

The correlation analysis of 11 soil physio-chemical properties of all the five land units was computed in (table 6). This shows that the parameters of the land units are not independent. The indications in this results is that some soil parameters of the land units are significantly correlated. The result presented the highly positive correlation between, OC and CEC, AWC and CEC, Erosion and CEC, as well as Drainage and CEC with r values of 0.278, 0.267, 0.405, 0.501, and 0.501 respectively. The positive correlation of OC and CEC (r = 0.278) demonstrate the controlling role of OM on CEC, the result is similar to (Kane &Packee, 2010) who discussed carbon stores and biogeochemical properties of soil under black spruce forest, Alaska. The moderate correlation of AWC and CEC (r= 0.405) show the level of CEC as a determining factor of wilting point. This is consistence with Nourbakhsh, Afyuni, Abbaspour, &Schulin (2014) who investigated on estimation of field capacity and wilting point from basic soil with reference to physical and chemical characteristics. The weak correlations exist between Clay and CEC (r = 0.172), this weak relationship is as a result of high percentage of sand in the study area, as sand rely heavily on the high CEC of organic matter for the retention of nutrients in the top soil. However, result is contrary to (Ross, Bartlett, &Magdoff, 1991). AWC and SD, as well as AWC and Drainage on regression values of 0.170, 0.112 and 0.197. However important negative correlation among the soil characteristics was also found in the study area among BD and OC, CEC and pH, OC and pH, Sand and CEC, Sand and Clay as well as Sand and AWC with r values of -0.300, -0.168, -0.303, -0.129, -0.960, and -0.580 (table 6). These results confirmed the low, negative correlation between OC and BD (r = -0.3.00). The findings are in line with Gol (2009) who dicusses decrease of soil organic matter through the conversion of the forestland in to crop land use caused the high bulk density in the cultivated area. Similarly, Hajabbasi et al (1997) depicted that deforestation and constant tillage practices resulted nearly 20% increase in bulk density and 50% decrease of OC for a depth of 0-30cm in central Zagros. The slight negative relationship between of CEC and pH (r = -0.168) discovered in this research concur with (Ross, Bartlett, &Magdoff, 1991) who discussed Exchangeable cations and the pH-independent distribution of cationexchange capacities in Spodosols of a forested watershed. The results obtained between Sand and CEC are weak negative correlation (r = -0.129) this finding is in line with Roslan, Shamshuddin, Fauziah, &Anuar (2011) who discovered the low CEC due to the high percentage of sand in the soil. The CEC and sand are also negatively correlated (-0.129) this relationship is as a result of high percentage of sand in the study area. The result is similar to work of Musina (2017) who conducted a research on cation exchange capacity of agricultural soils.

IV. CONCLUSION

The study analyzed the climate, physical and chemical characteristics of soil with similar micro ecological condition under different land units (flood plain, valley land, plain land, undulating lowland and hilly land) in North west zone of Nigeria. The OC results showed decrease in content with increase of elevation (OM is higher at lowland). The soil pH of the study area decreases with increase of altitude. The AWC results revealed increase with increase of clay and CEC content of the soil. In fact, all the land units characterized with low OC, this may be due to the disturbed of natural forest as a result of deforestation. Measuring and monitoring the spatial variability of climate, and physio – chemical characteristics of soil is very important for sustainable land use, checking soil degradation and other related land use activities. The production of soil thematic maps in modern agriculture has become very important as it helps in determining the spatial distribution of soil limitations and the ways of controlling it. It would also help in reducing the amount of farm inputs been added to the soil.

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