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NATURE AND VARIATION OF SOIL PROPERTIES UNDER DIFFERENT LAND MANAGEMENT PRACTICES IN SOUTHERN PART OF KADUNA, KADUNA STATE, NIGERIA

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ABSTRACT
Understanding the nature and variation of soil properties under different land management practices (LMPs) is imperative in determining the types of soil management practices that could be implemented by farmers for improving the soil quality as well as soil productivity. It is also applicable in addressing the issues of agricultural sustainability. This study examined the nature and variability of soil properties under different LMPs. Soil samples were systematically taken at 0-20cm soil depth from three locations on each demarcated hectare cell of the different LMPs in Katugal, Madakiya, Kurmin Sara, Mailafiya and Zankam. This produced a total of 25 composite soil samples. Soil laboratory analysis and Global Positioning System were the instruments employed for data collection. Descriptive statistics and analysis of variance were adopted in the analyses of data. The result of the study showed that about 56% of the soils studied were sandy-loam and 44% loamy in nature. Soil particle sizes, organic matter, total nitrogen, Cation Exchangeable Capacity (CEC), phosphorus, micronutrients and micro biomass carbon were heterogeneous (CV>33%), while bulk density, available water holding capacity, soil pH, electrical conductivity, micro biomass nitrogen and basal respiration were homogenous (CV=15 to 32%). There were significance variations within the level of pH and soil basal respiration at 0.05% among the land management practices. The study recommended the use of animal dung, compost, inorganic fertilizers and crop residue as soil conditioners in addition to the adoption of eco-friendly LMPs to ameliorate soil properties in the low to moderate variability farmlands.

Keywords: Soil properties, Variation, Land Management Practices, Southern Kaduna

INTRODUCTION

Land management practices provide the basis for assessing sustainability and monitoring environmental impacts of various land use practices on soil properties. Sustainable productivity undoubtedly, has been hindered by poor soil fertility and inappropriate land management practices in many regions of the World more importantly in Southern part of Kaduna, which may lead to low crop yield and inefficient agricultural productivity. Therefore, increasing and sustaining agricultural productivity has become a great challenge among developing nations. Furthermore, Ersado et al. (2004), stated that for most Sub–Saharan African Countries, embracing a more effective and productive farming practices and machineries that increase agricultural yield and improve environmental sustainability remains the best option for attaining economic development, food security, and poverty reduction. Effective land management practices and proper farming machineries should be put in place to improve soil nutrient status of farmlands for maximum crop production on a sustainable base which will in turn raise farmers' proceeds. Thus, land management practices as stated by Terr Africa Partnership (TAP, 2006), are land use methods that enable land users to maximize the economic and social benefits from land, while sustaining the environmental support functions of the land resources. Land use and management practices are among the most important factors influencing key properties and ecological functions of soils worldwide (Pacheco et al., 2018). Consequently, the intensive use of land resources should not only be for what the farmers stand to benefit, but should be concern with the sustenance of the fertility status of soils of agricultural lands

Intensive use of land for agricultural purposes by farmers have been observed by Geissen et al. (2009), as causing significant changes and variations in soil physical, chemical and biological characteristics that can affect soil fertility, increase soil erosion and soil compaction. In addition, poor understanding of the soil characteristics and insufficient checking of the soil quality under different land management practices often encourage depreciation of the agricultural lands and sustainable agricultural practices. However, Lal (2015); Ebabu et al., (2018, 2019); and Sultan et al., (2018) stressed that site-specific practices of restoring soil quality and improve crop yield should include among others, conservation agriculture, integrated nutrient management strategies, continuous vegetative cover with residue mulch, planting of cover crops and controlling grazing of animals at appropriate carrying capacity. The type of land management practices adoption in a given agro ecological zone is an important factor in controlling the soil property levels since it affects the amount and quality of litter input, the litter decomposition rates and the processes of organic matter stabilization (Negasa, 2016). These site-specific practices even though they influence the variability of soil properties, they are also very beneficial in restoring soil quality of lands. These benefits cannot be fully achieved without continuous soil monitoring and management of agricultural lands to establish the nature and extent of their variability across agricultural lands.

Therefore, this study examined the nature and variation of soil properties under different land management practices. This was with a view to establishing the extent of soil property variability under different land management practices in Southern part of Kaduna.

The Study Area

Southern part of Kaduna lies within the Guinea Savanna Agro-ecological Zone of Nigeria, covering approximately 24,536km2 and

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lies between Latitudes 9° 00˙ 00˙˙and 10° 45˙ 00˙˙North of the Equator and Longitudes 7° l0˙ 00˙˙and 8° 45˙ 00˙˙East of the Greenwich Meridian (Oriola and Atiyong). The area shares boundaries with Niger State in the West, Federal Capital Territory (FCT) and Plateau State to the South and South-East. It also shares borders with Bauchi States to the East and Kano to the North (Figure 1and 2). The area is designated as Koppen's Aw climate with two distinct seasons, a wet season in summer and a dry season in winter. Rainfall occurs between the months of April to October with a peak in August, while the dry season extends from ending of October of one calendar year to April of the next (Abaje et al, 2016). The mean annual rainfall is about 1733 mm in Kafanchan-Kagoro areas in the South of the study area (Abaje et al. 2010), due to the influence of the Jos Plateau with its orographic rainfall to about 1203mm in the central part of Kaduna. The mean monthly temperature is 28ºC, while the mean atmospheric relative humidity is about 63% (Abaje et al, 2016). The vegetation of the area is the Guinea Savanna type. The main type of soil is the Ferruginous tropical soil which is related to the climate, vegetation, lithology and the topography of the area (Abaje et al., 2010). The soils are well drained and shallow, with texture consisting of loamy sand to sandy loam top soils (0-20cm) and supports wide variety of annual, perennial and tree crops respectively (Eroarome, 2005). The relief is relatively flat and undulating, and it influences the drainage pattern of the area (Abaje et al., 2009).

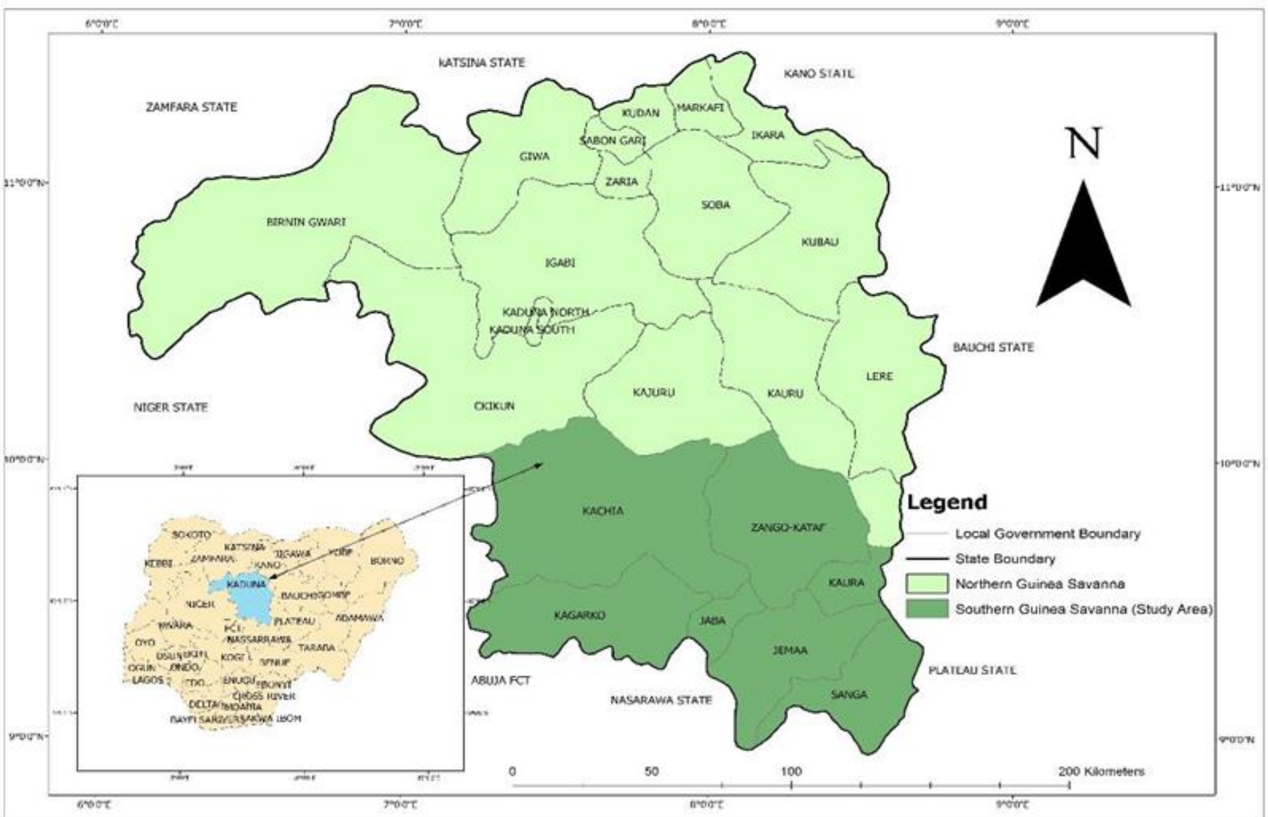

Figure 1: Geographical Location of Kaduna State and the Study Area
Source: Ministry of Land and Survey Kaduna, (2017)

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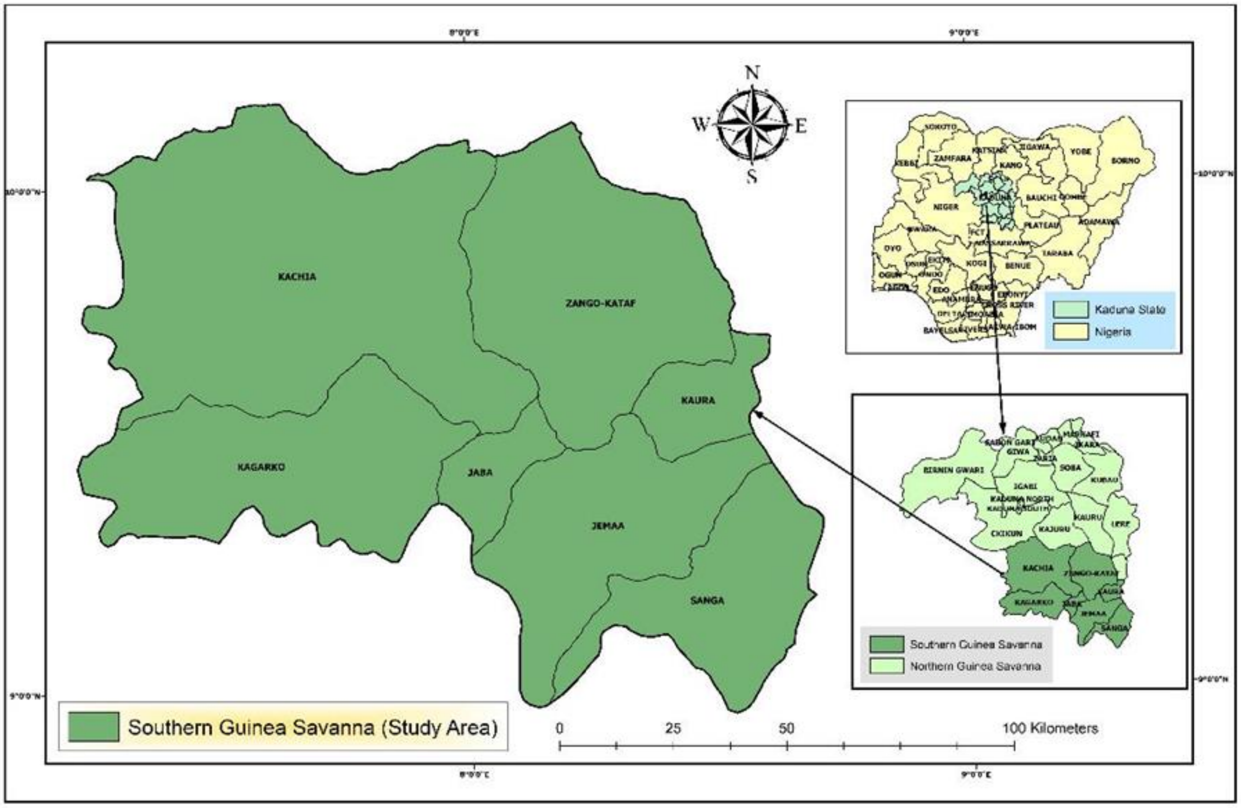

Figure 2: Geographical Location of Kaduna State and the Study Area
Source: Ministry of Land and Survey Kaduna, (2017)

Methods of Data Collection and Analysis
Global Positioning System (GPS) was used for accurate location of the soil sampling points and subsequent collection of the soil samples. Soil samples were taken from five plots of different land management practices in five selected settlements (Katugal, Madakiya, Zankam, Mailafiya and Kurmin Sara), and crops identified on the basis of their cultivation history. The categories of land management practices include intermittent short fallow, minimum tillage /mulching, organic fertilizers, mixed cropping and surface irrigation practice in the five study settlements. In each land management practice, the farm land was demarcated into grids of one hectare cell (quadrat) measuring 100m by 100m. Samples were taken at 0-20cm soil depth as recommended by Richard et al. (1999), to be the plowing depth in most agricultural soils including the majority of root biomass. The samples were taken from three locations (upper, middle, and lower) in a stratified systematic unaligned grid sampling approach using GPS for accurate location of sample points on each hectare to produce a composite soil sample at each management practice to make a total of 25 samples. The soil samples collected were taken to the soil laboratory for analysis and the soil data obtained. The soil analysis focuses on the physical, chemical and microbiological parameters that are key to soil fertility and crop yield.
Each soil sample was air-dried, crushed and sieved through a 2mm sieve and used for the assessment of selected soil physico-chemical and biological properties. Soil bulk density was determined by the undisturbed core sampling method after drying the soil samples in an oven at 105°C to constant weights (Blake, 1965). Soil particle size distribution was determined by the Boycouos hydrometric method (Bouyoucos, 1962), after removing organic matter using hydrogen peroxide (H2O2) and dispersing the soils with sodium hexametaphosphate (NaPO3) solution. In order to determine the available water holding capacity (AWHC) of the soil, the field capacity (FC) and permanent wilting point (PWP) was measured at -1/3 and -15 bars soil water potential, respectively, using the pressure plate apparatus (Klute, 1965).
The pH of the soils was measured in water and potassium chloride (1M KCl) suspension in a 1:2.5 (soil: liquid ratio) potentiometrically using a glass-calomel combination electrode (Van Reeuwijk, 2002). Exchangeable acidity was determined after extracting with 1N KCl and titrating with NaOH. Organic matter was obtained by multiplying percent soil Organic Carbon by a factor of 1.724 following the assumptions that Organic matter is composed of 58% carbon. Nitrogen was obtained by the semi-micro kjeidahl Digestion and Distillation method (Bremner & Mulvaney, 1982). Cation exchange capacities were thereafter estimated titrimetrically by distillation of ammonium that was displaced by sodium from NaCl solution (Chapman, 1965). Available soil Phosphorus was analyzed according to the standard procedure of Olsen et al. (1954) extraction method. Micronutrients were extracted with Diethylenetriaminepentaacetic acid (DTPA) (Lindsay & Norvell, 1978) and measured by atomic absorption and emission spectrophotometry. Microbial biomass C & N was determined by Chloroform Fumigation and extraction procedure (MBC, MBN)

(Vance et al., 1987). Similarly, soil basal respiration (RESP) was measured using a multiple sensor respirometer (Micro-Oxymax, Columbus, OH, USA). Descriptive statistics in the form of proportional percentages mean and coefficient of variation, and analysis of variance were used to analyzed the data.

Results and Discussion

The results of the soil physical properties distribution for the various land management practices under consideration is presented in Table 1. In all the land management practices, the mean values of sand contents are highest in organic fertilizer (49.20%) category, the mean values of silt contents were fairly similar with the highest found in surface irrigation practice 46.80%, while the mean values of clay content were highest (16.00%) under minimum tillage/mulching. Generally, the textural class of the soil is more of sandy loam and loamy soil in nature. The values of the coefficient of variability ranged between 7.15% under surface irrigation practice and 72.21% under minimum tillage/mulching sites, indicating relatively heterogeneous soil particle size distribution within the respective management practices. This result of particle size distribution is in consonant with Chude (1998), assertion that soils in Northern Nigeria range generally from sandy to loamy texture at the plough layer, moderate to well drain with a low water retentive capacity and a poor structural development. In addition to, the general feature of soils could be a reflection, at least partly, of the granitic nature of soil parent material over the study area (Brady, 1990).

The mean bulk density of the soil is fairly similar 1.40g/ cm3 in all the soil management practices, except that of surface irrigation which is 1.33g/cm3. The coefficient of variation ranged between 6.88% in minimum tillage/mulching and 12.89% in surface irrigation. This implies a relative homogeneity within each land management practices. Similarly, the mean values for the available water holding capacity under organic fertilizer is 29.90mm/m, minimum tillage/mulching 28.10mm/m, intermittent fallow 27.04mm/m, mixed cropping 26.76mm/m and the lowest value (25.17mm/m) is recorded under surface irrigation. The coefficient of variation is highest 16.53% under surface irrigation practice and lowest (10.87%) in minimum tillage/mulching system indicating a slight variability but relative homogeneity in the AHWC of soils amongst the practices which is expected.

Generally, the coefficient of variation of clay content in the soil is highly variable (>33%), lowest value is 33.50% in organic fertilizer farming system and a highest value of 72.21% in minimum tillage/mulching. Variability of sand, silt, BD, and AWHC ranges from ≤15% low to moderate variability (≤15-32%). The high variability nutrient status of these soils may be attributed to differences in land management practices adoption and cultural practices occurring within the study area. However, the results reveal that there is no significant variation in the mean values of all the physical properties of the various land management practices. This reflects the managements of the soil parent material vis-à-vis the soil textural class.

The results of the soil chemical properties distribution for the various land management practices under consideration is presented in Table 2. The soil pH in H2O shows a decrease from a mean of 5.78% in fallow sites through 5.74% and 5.68% in minimum tillage/mulching and mixed cropping respectively. While the lowest mean value (5.12%) was recorded under surface irrigation practice. This indicates that the soils are generally acidic in nature. The important causes of acidity on agricultural land, according to Goulding (2016), are the application of ammonium-based fertilizers and urea, elemental Sulfur fertilizer and the growth of legumes. Furthermore, there is a low variation (CV ≤ 15%) in the soil pH values of the land management practices. The result of the soil electrical conductivity decreases consistently from 25.40ds/cm (0.254ds/m) in surface irrigation practice to 19.60ds/cm (0.196ds/m) in intermittent short fallow. Soil contents having EC values of 0 to 2ds/m, are considered non-saline soil and the saline effect is negligible and values from more than 2 to 4ds/m are slightly saline and yield of sensitive crops may be restricted. This implies that intermittent short fallow and mixed cropping farms are not saline whereas minimum tillage/mulching, organic farming and surface irrigation farmlands are slightly saline. However, the coefficient of variation revealed a moderate variability of EC (15–32%) among the management practices. This implies a general homogeneity in the EC of the soil.

Table 1: Mean Values of Soil Physical Properties According to Land Management Practices

Soil properties	Intermittent Short Fallow			Minimum Tillage			Mixed Cropping			Organic fertilizer			Surface Irrigation			f
	X	SD	CV %	X	SD	CV %	X	SD	CV %	X	SD	CV %	X	SD	CV %	
Clay %	13.60	8.68	63.81*	16.00	11.55	72.21*	8.80	3.96	45.03*	7.00	2.35	33.50*	10.20	4.66	45.67*	1.32
Sand %	42.40	3.78	8.92	44.00	10.12	23.01	48.40	9.15	18.91	49.20	5.93	12.06	43.00	7.21	16.77	0.87
Silt %	44.00	10.07	22.90	40.40	8.65	21.41	42.80	5.26	12.30	43.80	4.60	10.51	46.80	3.35	7.15	0.56
Textural class		L			SL			SL			SL			L		
BD (g/cm^3)	1.44	0.12	8.54	1.45	0.10	6.88	1.45	0.14	9.53	1.43	0.14	9.76	1.33	0.17	12.89	0.73
AWHC (mm/m)	27.04	4.13	15.29	28.10	3.06	10.87	26.76	3.02	11.27	29.90	3.91	13.06	25.17	4.16	16.53	1.13

Source: Field Survey, 2019, X= mean, SD = Standard Deviation, CV = Coefficient of Variation, *CV>33% = Significant

Table 2: Mean Values of Soil Chemical Properties According to Land Management Practices

Soil properties	Intermittent Short Fallow			Minimum Tillage			Mixed Cropping			Organic fertilizer			Surface Irrigation			f
	X	SD	CV	X	SD	CV	X	SD	CV	X	SD	CV	X	SD	CV	
pH (H_2O) %	5.78	0.31	5.39	5.74	0.42	7.25	5.68	0.20	3.61	5.40	0.37	6.80	5.12	0.37	7.23	3.35***
EC (ds/cm)	19.60	6.15	31.37	21.40	6.95	32.48	20.00	5.79	28.94	22.40	6.02	26.90	25.40	6.43	25.30	0.68
TN (kg./ha)	0.15	0.05	32.85	0.19	0.11	56.45*	0.16	0.04	25.21	0.19	0.09	47.95*	0.18	0.06	33.92*	0.32
OM (%)	2.10	0.69	32.76	2.58	1.46	56.31*	2.14	0.56	26.06	2.67	1.28	48.08*	2.46	0.83	33.97*	0.32
P (mg/kg)	12.81	8.57	66.88*	9.21	4.14	44.93*	14.32	7.21	50.37*	17.82	8.01	44.94*	7.32	1.55	21.22	2.07
CEC (cmol/kg)	6.70	2.47	36.81*	5.01	1.85	36.87*	5.22	0.71	13.64	9.84	6.01	61.09*	5.08	1.88	37.04*	2.14
Fe (kg/ha)	56.26	22.90	40.71*	49.17	30.70	62.43*	40.14	28.68	71.46*	26.72	16.28	60.92*	40.74	33.85	83.08*	0.83
Cu (kg/ha)	13.58	9.77	71.94*	22.00	13.53	61.49*	9.40	7.80	82.95*	26.00	20.60	79.24*	9.40	6.73	71.60*	1.77
Zn (kg/ha)	26.36	14.84	56.30*	37.58	34.85	92.73*	54.80	13.35	24.36	55.80	28.02	50.22*	35.24	22.35	63.43*	1.43
Mn (kg/ha)	55.90	34.45	61.64*	21.60	11.40	52.78*	28.78	11.88	41.27*	26.76	28.07	104.91*	44.52	29.39	66.01*	1.63
			60%			80%			40%			80%			70%	

Source: Computed from Field Survey Data, 2019, X= mean, S.D = Standard Deviation, C.V = Co-efficient of variation, Analysis of variance at (***significant p<0.05%), *CV>33% = Significant

DISCUSSION

The total nitrogen contents of soils range from 0.15% in intermittent short fallow to 0.19% in minimum tillage/mulching land management practices. The coefficient of variation is moderately high (15–32%) to high (CV>33%) in all the land management practices. This implies a relative heterogeneity in the total nitrogen contents among the land management practices. Soil organic matter presented in Table 4.2 shows a minimal content (2.10%) under intermittent short fallow and the highest (2.67%) under organic fertilizer. The relatively low organic matter in mixed cropping system may be attributed to their lost through extensive cultivation and multi cropping (Oriola & Bamidele, 2014). Coefficient of variation is moderately high (CV=15–32%) to high (CV >33%) in all the land management practices. This implies a relative heterogeneity in the SOM contents in all the land management practices. The relative moderate variability exhibited in OM was found not to be significant in the different land management practices at p≤0.05.

In the same vein, the content of available phosphorus ranges from 17.82mg/kg in organic fertilizer to 7.32mg/kg under surface irrigation practice. The coefficient of variation is high (CV>33%) in all the land management practice except in surface irrigation with CV=15-32%. The level of variation implies heterogeneity in the available phosphorus contents. Also, relatively high CEC mean values were observed under organic fertilizer (9.84cmol//kg) followed by intermittent short fallow (6.70cmol/kg) and mixed cropping (5.22cmol/kg), when compared with the values observed under minimum tillage/mulching (5.08cmol/kg) and surface irrigation (5.01cmol//kg). This may be attributed to the fact that organic matter and clay are the principal soil colloids materials upon which the phenomenal of CEC processes rests (Fitzpatrick, 1980, cited in Oriola & Bamidele, 2014). The values indicate that the soils have low CEC being generally, less than 10cmol/kg (Essoka & Essoka, 2014). Coefficient of variation is high (CV<33%), indicating heterogeneity in the CEC among the land management practices except in mixed cropping where the CEC has CV <15%.

On the micronutrient properties, Chude et al. (2013), reiterated that there was no study carried out on micronutrient in the Savanna Zone prior to the work of Heathcote (1970), on “the role of organic manures on soil productivity under continuous cultivation in Northern Nigeria”. He attributed these to the non-intensive farming practices prevailing then, of which the trace element deficiencies were not expected but today the situation has changed because of the inevitable shift from the traditional land rotation or shifting cultivation to intensive and continuous cultivation, that have placed considerable pressure on the micronutrient reserves of these soils. The results shows that the highest mean value of iron (Fe) was found in intermittent short fallow (56.26 mg/kg) and the lowest value of 26.72mg/kg in organic farming practice. The coefficient of variation shows high variability (CV<33%) in all the land management practices indicating heterogeneity in Fe2+ content. In spite of the significant variation observed, available Fe2+ was in a sufficient level for plant growth under all land use systems based on the Fe rating established by Havlin et al. (1999). Available copper (Cu) content has the highest mean value (26.00mg/kg) under organic fertilizer and the lowest value is found in mixed farming and surface irrigation practice which is 9.40mg/kg respectively. Coefficient of variation revealed high CV>33%. This implies that Cu content is highly varied in all the land management practices.

Highest concentration of available zinc (Zn) was found under organic fertilizer (55.80mg/kg) and lowest value which is 26.36mg/kg in intermittent short fallow. Coefficient of variation indicates considerable variation in the Zn contents among the management practices except in mixed cropping CV=15-32%), all others land management practices have CV>33%. In spite of the significant variation, the concentrations of available Zn in all land use systems were within the adequate level as indicated by Havlin et al., (1999) soil fertility rating.

The mean value of available manganese (Mn) concentrations was highest in intermittent short fallow (55.90mg/kg) and the lowest mean value 21.60mg/kg under minimum tillage/mulching system. According to the nutrient toxicity level suggested by Lindsay and Norvell (1978), the concentration of Mn was in the toxic level in all land management practices, as the concentrations were greater than 21.60mg/kg compared to the critical level of 5mg/kg. This higher content of Mn could be due to acidic nature of the soil pH where manganese becomes more available in acidic soils. The coefficient of variation is high (CV>33%) in all the land management practices. This implies heterogeneity in Mn soil contents. The highly variable micronutrient status of the soils may be attributed to differences in land management practices and cultural practices occurring within the study area couple with the socio-economic status of the farmers as it contributes to different inputs (soil conditioners) application in their farm.

More than 60% of the soil chemical properties have significant variation with the land management practices but not among the different land management practices except for soil pH which happens to be internally homogenous. Whereas in mixed cropping, only 40% of soil is more varied. The result also reveals that there is no significant difference in the mean values of all the soil chemical properties of the various land management properties except the soil pH. This reflects the homogeneity of the soil parent material vis-à-vis the soil textural class.

Table 3 presents the results of micro biomass. The mean values for microbial biomass C (MBC) were 0.01% (100µgCg-1) under all the land management practices. Similarly, the highest mean microbial biomass N values under the intermittent short fallow, mixed cropping and surface irrigation practice was 0.002% (200µgNg-1) while the lowest mean value of microbial biomass N under minimum tillage and organic fertilizer was 0.001% (10µgNg-1). This conforms with the result of Oyedele et al. (2014), which shows the mean values for microbial biomass C (MBC) ranged from 0.0013% (129.18µgCg-1) to 0.0200% (200.04µgCg-1) while the mean microbial biomass N (MBN) ranged from 0.0127% (12.74µgN-1) to 0.0198% (19.84µgNg-1).

Relatively dense growth of plants, vis-à-vis greater accumulation of litter and fine roots in the intermittent short fallow, mixed cropping and surface irrigation practice, favour the growth of microbial populations and accumulation of N in the microbial biomass as observed by Oyedele et al., (2015). The result is an indication that land management practices have a significant impact on the soil microbial biomass C and N as it provides the avenue for the growth and sustenance of microorganisms. The highest mean value of soil basal respiration (CO2) was 3.18 mg CO2 g-1 under organic fertilizer and the lowest mean value is 2.20mgCO2g-1 in surface irrigation practice.

The microbiology parameters are generally homogenous CV<33% except Micro biomass C (MBC). This property exhibit high variability in each of the land management practices but there was no significant variation among the land management practices. The ANOVA shows no significant variation in MBC and MBN but a significant variation was established in the soil basal respiration (CO2).

Table 3: Mean Values of Soil Microbiological Parameters According to Land Management Practices

Soil properties	Intermittent Short Fallow			Minimum Tillage			Mixed Cropping			Organic fertilizer			Surface Irrigation			f
	X	SD	CV	X	SD	CV	X	SD	CV	X	SD	CV	X	SD	CV	
MBC %	0.01	0.00	55.90*	0.01	0.01	102.22*	0.01	0.01	94.72*	0.01	0.01	89.15*	0.01	0.01	60.50*	0.33
MBN %	0.002	0.001	5.000	0.001	0.002	5.000	0.002	0.001	5.000	0.001	0.001	5.000	0.002	0.001	5.000	0.27
CO_2 %	2.38	0.18	7.75	2.53	0.16	6.28	2.60	0.18	7.09	3.18	0.25	7.79	2.20	0.35	15.81	12.34***

Source: Computed from Field Survey Data, 2019
*** Significant at P<0.05, *CV>33% = Significant

CONCLUSION

The soil properties generally showed the textural class of the soil to be more of sandy loam and loamy soil in nature. The variability reported for soil properties between moderate and high were a consequence of differences in micro relief and sources of parent materials that gave rise to the entire soil composition. Similarly, the variability may not also be unconnected to the different forms of management practices in place which definitely will influence variability of soils. The study recommends that Soil properties in the low to moderate and high variability status that were considered unfavourable should be adequately managed for better sustainability of crop production. Regular monitoring and evaluation of soil by farmers should be encouraged.

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