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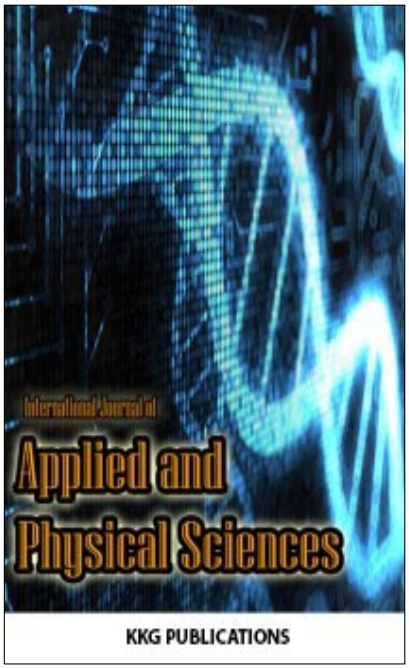

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Variation in Soil Physiochemical Properties at Different Land Use Sites in Northeastern Nigeria

MOHAMMED BAKOJI YUSUF [1], BEGHAM MUSTAFA FIRUZA [2], OSMAN SALLEH KHAIRULMAINI [3]

[1, 2, 3] University of Malaya, Kuala Lumpur, Malaysia

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VARIATION IN SOIL PHYSIOCHEMICAL PROPERTIES AT DIFFERENT LAND USE SITES IN NORTHEASTERN NIGERIA

MOHAMMED BAKOJI YUSUF [1]*, BEGHAM MUSTAFA FIRUZA [2], OSMAN SALLEH KHAIRULMAINI [3]

[1, 2, 3] University of Malaya, Kuala Lumpur, Malaysia

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Abstract. The variability of some soil physicochemical properties related to land-use sites in the northern part of Taraba State, North-Eastern Nigeria, was studied to determine the extent of variation in soil properties between land-use sites. This study's main purpose was to understand farmers' reasons for cultivating hillslopes when there are flatland areas. Six surveyed plots were randomly selected with eight surveyed positions; one composite sample was collected from each position over three successive measurement intervals for soil laboratory analysis. Thirteen soil properties were analyzed using the GLM procedure and the analysis of variance in SPSS release version 22. The results obtained showed a statistically insignificant difference for most soil physical properties; sand and silt, chemical properties, soil pH, TN, and Base cations (Na and Ca), suggesting the absence of effects directly associated with the sites. Hence, the farmers' reasons for cultivating hillslope when there are flatlands. However, differences in soil clay-fraction, OC, P, and Na differences between the two sites were significantly different. These significant differences suggest two important policy implications. 1. Any intervention in soil management should be location-specific, and the blanket recommendations for fertilizer application and soil and water conservation, which is now the norm in Nigeria, should be changed. 2. The severity of soil degradation varies with the site; hence, a local-level investigation is essential to design local-specific and appropriate management interventions. Hence, the study recommends that - the best practices of farmers from time immemorial, such as contour-plowing, intercropping, use of cover crops, and mulch, should be enhanced and encouraged, especially for hillslope farmers. The expectations and perceptions of farmers should be integrated into future studies to provide empirical evidence of farmers' preference for cultivating hillslope sites when there are flatlands.

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INTRODUCTION

It is widely acknowledged that land use sites influence soil physiochemical properties differently [1], [2], [3]. However, the extent to which land use sites influence soil physiochemical properties needs to be studied in greater detail. This is because soil physiochemical properties vary with land use sites laterally and vertically even under a similar geological substratum [4], [5], [6], [7], [8], [9]. A better understanding of the spatial variability of soil physiochemical properties associated with land use sites is an important aspect of soil fertility decline studies [10], [11], [12], [13], in addition to providing essential information for better plant growth and management of soil resources, which is a prerequisite for sound land-use planning.

The conversion and intensification of agricultural activities in sites such as mountainous regions and sloppy lands accelerate soil erosion which in turn threatens valuable soil nutrients and creates serious soil management problems [14], [15], [16].

In Nigeria, most particularly in the study region, unlike in other areas in humid tropic and subtropical regions; where the human impact of agricultural practice on hillslope areas has increased because of the twin problems of population explosion and shortage of arable land [3], the study region is sparsely populated. With a total population of 778,131 people in 2013, the projected annual growth rate was 3.1% and a population density of 54 people per SQ km [17]. At the same time, the high amount and the intensity of rainfall together with the physiographic characteristics of the area exacerbate soil degradation through soil erosion by water [18]. In addition, the increase in diminishing gazetted grazing fields in the mountainous areas often results in clashes between farmers and grazers, either because animals have strayed into farms or farmers have extended their cultivation onto animal tracks. Yet, agricultural activities on hillslope areas have increased in recent times, even though there are flatland areas. This increased conversion and intensification of agricultural activities on hillslopes, disregarding the flat land provided by nature, make research on them urgent [19].

Despite several studies on the influence of sites on soil variability in other parts of the world, in Nigeria, very little

*Corresponding author: Mohammed Bakoji Yusuf
†Email: mbyusuf36@yahoo.com

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information exists, and what there is now is more focused on the southwestern and eastern parts of the country, which have different geographical settings from the study region [20], [3], [21], [22]. Moreover, these studies were conducted at sole land use sites (hill terrain), either before cultivation or after crop harvest. Therefore, in this research report, we investigated the variability in soil physiochemical properties according to sites, using two contrasting land use sites, hillslope and flatland. To provide for variations, different land use types were selected, and measurements were taken over three successive measurement intervals (before, during and after the peak of rainfall). This is a relatively new concept and should have helped to overcome the constraints outlined previously.

It was, therefore, the prime objective of this research to analyze and compare certain physiochemical properties of soils associated with differences in land use sites, over three successive measurement intervals. The goal was to identify the existing variation in the types and level of soil physiochemical properties. The objective was to gain a better understanding of farmers' reasons for cultivating hill slopes, while, there were flat land areas in the study region. The present study provides useful information on the physiochemical properties of the soils that will guide the use to which the sites can be put and provide baseline data for future similar studies.

MATERIALS AND METHOD

Site Description

The study region, the Northern part of Taraba State, ($6^0 30^1$ and $9^0 36^1$N; $9^0 10^1$ and $11^0 50^1$E) is located in North-Eastern Nigeria, along the Nigerian-Cameroun border (Fig.1). In terms of relief configuration, it is categorized into two zones Highland/ mountain range and lowlands [23]. The highlands are characterized by interlocking spurs and steep slopes, with an elevation ranging from an average of 1,800 -2,400 meters above sea level, constituting 30% of the region's total land area. In contrast, the lowland is gentler and flat, occasionally interrupted by hilly and rocky outcrops and makes up 70% of the region's total land area. The study region records higher rainfall than the surrounding regions, because of the relief [24]. The ITD is very influential in determination of the time of inception and cessation of rainfall. Intensive rain occurs from May to September, and the wettest months are July/August. The mean annual precipitation and temperature are 1300 mm and 24°C, respectively. The relative humidity is (65-90%), earth temperature at a depth of 0-30cm soil (25-30°C), evaporation rate (2-5 cm/day) and sunshine hours (6-7) per day.

Tropical ferruginous and lithosol soil derived from basement complex formations and deposits of tertiary rocks are the major soil types [23]. Characterized by a sandy surface horizon, with clay subsoil, deep loamy soil is found in between rocks on the hilly terrain. The soils are naturally fertile for agricultural productivity and susceptible to erosion, more especially on the hill slope where the farming techniques used in raising crops are inappropriate for the soil type.

Farming is the primary traditional occupation of the people of the area [25]. The farming system practiced includes: mixed cropping, crop rotation, and single cropping. Farm sizes vary according to villages reflecting population density, accessibility to the farm and the personal preferences of the occupants. Sorghum, yam, maize, millet and vegetables are the chief crops widely cultivated in the study area. The farming operations are laborintensive, and a reflection of traditional methods using drudgery-enhancing primitive tools such as hoes, cutlasses, matches, and axes, which have been passed from generation to generation [25]. The research area has a large number of livestock especially cattle, goats, sheep, pigs and poultry. The growth of these crops and the rearing of these animals have threatened the natural resilience of the vegetation and soils of the region and, hence, have produced erosion.

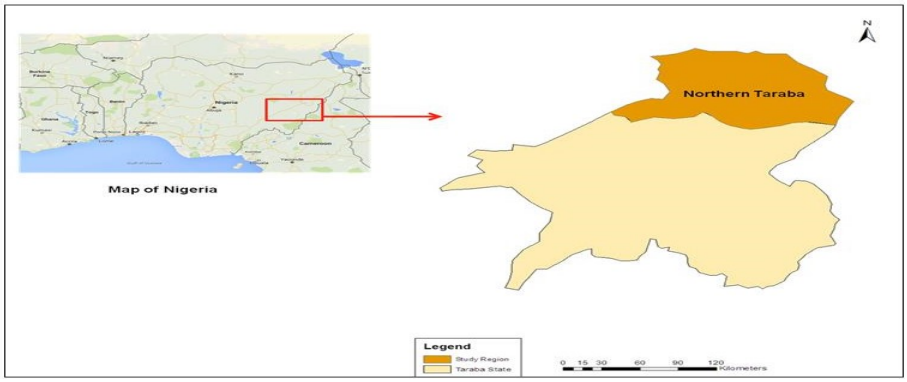

Fig. 1. Simple linear Regressions-The impact of ER on CI

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Method

From the total of sixty-two districts, each having a range of 21 to 47 major villages, that made up the study region, one village was purposively selected for soil sample collection. The most important considerations, in choosing the village were; the seriousness of the soil erosion problem, accessibility and representativeness of the study area, the need to have two comparable slope and flatland farms representative of the study region, and selection that considered land use types, rather than soil types.

Subsequently, six surveyed plots made up of farmland under continuous cultivation for more than ten years in both the hillslope and flatland areas, with a slope angle range of 0-4% and 5-22%, respectively, a fallow plot (7-10 years) and a forest field, that had been intact as long as the local people could remember were randomly selected. The forest soils were used as the control against which changes in soil properties resulting from the establishment of other land use were assessed. Vitellaria paradoxa, Tamarindys indica, Parkia species, Aegyptiaca and Balantie species were the dominant tree species in the forest areas. Shrubs, with little useful wood mixed with some grasses, were the dominant plant species in the fallow fields, (Myparrhemia violescens spp, Penisetum pedicellatum, Schizachyrium exile, Typha, wind sorghum, Calotropis proceras, and Ipomeas spp). Guinea corn, millet, yam, cassava were the principal crops grown at both sites.

From the six surveyed plots, eight surveyed positions (five on the hillslope and three on the flat-land) were randomly designated for soil sample collection. The five surveyed positions on the hillslope sites comparised one each on the upslope, midslope and downslope of the continuously cultivated farmlands, and one each on the fallow and forest fields, and on the flat land, the positions were one each on the farmlands under continuous cultivation, the fallow field, and the forest plot.

Grids, which were 50m x 50m were imposed over each surveyed position, and these were later divided into one-meter square grids [26], [27], [28]. Ten of these one-meter square grids was selected using a table of random numbers. One composite sample was collected after carefully mixing twenty-five soil samples taken from each of the selected grids from a depth of 0-20cm at each surveyed position. The samples were obtained at three successive intervals, before, during, and after the peak of rainfall in the study area. Soil sampling was restricted to the uppermost soil profile, because most significant changes in soil physiochemical properties, especially in a tropical environment, are limited to the topmost ploughable layer, 0-20 cm of the soil profile [29], [30], [31], [16]. A total of six hundred soil samples (24 composite samples) were obtained with the aid of the soil auger. Each composite sample was put in a new well-labeled polythene bag. The soil samples were then air-dried at a room temperature of 280C, lightly ground and sieved using 2mm mesh sieve, and analyzed using standard laboratory procedures, taking utmost care to avoid differential loss of fine dust.

The particle size distribution was obtained using the Bouyocous hydrometer method [32]. In sequence, the textural class of the soils was determined by subjecting the obtained particle size distribution to Marshall's textural triangle. The gravimetric water content of a given quantity of soil determined the water holding capacity fully saturated with water, while, the bulk density was determined by the clod method. The soil pH was measured in a 1:2.5 soil: water suspension ratio with the use of a glass electrode pH meter. The Electrical Conductivity (EC) of the saturation extracted was determined, in sequence, alongside the pH in the same suspension using an EC meter. The Organic Carbon (OC) was determined using Walkley & Black's potassium dichromate wet oxidation method, in which the soil organic matter content is obtained by multiplying organic carbon content by a conversion factor of 1,724 [33]. Similarly, Total Nitrogen (TN), available phosphorus (P), available potassium (K) and sodium (Na) were determined by the Kjeldahl method [34], the Bray extraction method, [35] and flame photometry [36], respectively. Exchangeable calcium (Ca) was determined by the titrimetric method, while; Cation Exchange Capacity (CEC) was computed from the analyzed results of the soil bases. The soil properties of the forestland, on one hand and of land under other types of use, on the other, to show the extent to which soil physiochemical variability is related to land use.

The values of the three composite soil samples collected from the farm under continuous cultivation on the hill site (upper, mid and lower slope positions) for each successive measurement, were condensed into one composite value for statistical analysis. Statistical mean analysis was undertaken using the GLM procedure of the SPSS release 22 version. Moreover, the analysis of variance was used to compare the soil properties of the different land use sites to determine whether the differences in these soil properties were significant.

RESULTS AND DISCUSSION

Soil Physical Properties

The soils from all the sites had higher sand content than silt and clay content (table 1). The mean sand and silt contents were relatively higher for most measurement intervals of land use type on the hillslope site, compared to those on the flatland site. However, the mean clay content showed the opposite trend to sand and silt. The sites on the flatland had significantly higher mean clay content than the hill sites for most measurement intervals.

The reasons for the slightly greater sand and concomitant smaller clay content of the soils under land use on the hillslope site for most measurement intervals, compared to those on the flatland site were, however, not clear. Some possible causes might be the loss of clay through surface washing and leaching. Alternatively, more clay is deposited in flatland sites through the process of weathering from the adjacent hilly areas. In addition, the silt content found in all soils at both sites during each measurement interval was much greater than that found in other soils in the neighboring North Central and North Western regions of Nigeria [37], [38], [45]. The textural class of soils class varied between sand loamy to sandy, loamy clay.

Although, noticeably higher sand, and silt mean contents were recorded for land use types on the hillslopes compared to those on the flatlands, for most measurement intervals, the f test results in table 2 show insignificant differences between and within sites in terms of soil texture, sand and silt for the three measurement intervals. This indicates that textural properties are hardly affected by the site. The result contradicts earlier findings reported by [2-3], that, slope and relief determine the spatial pattern of soil textural properties in land under agricultural use. Hence, the farmers reason for cultivating the hilly slopes in the study region while there is flatland. However, clay was found to be significant for all successive measurements interval between and within land use sites, implying, also, that site had a significant effect on the textural properties of soils.

TABLE 1
MEAN VALUE OF SOIL PHYSIOCHEMICAL PROPERTIES (BEFORE, DURING AND AFTER THE PEAK OF RAINFALL) FOR DIFFERENT LAND USE SITES

Sample Location	Period	% Sand	% Silt	% Clay	Tex-ture	PH (H2O) (1.2.5)	EC (dSm-1)	OC (g kg-1)	TN (g kg-1)	P (mg/kg-1)	K Cmol(+) kg-1	Na Cmol(+) kg-1	Ca Cmol(+) kg-1	CEC Cmol(+) kg-1	% BS
Hillslope Site															
Continuously	BPR	72.0	18.0	9.8	SL	4.6	.06	8.2	.033	10.4	.08	.05	2.2	4.5	36.1
Cultivated	DPR	71.7	19.0	9.3	SL	4.3	.07	8.3	.043	11.1	.09	.04	1.6	4.3	37.1
farm	APR	71.0	17.7	11.3	SL	4.9	.08	8.2	.043	11.4	.08	.06	1.5	4.2	36.7
Fallow Plot	BPR	66.0	20.0	14.0	SL	5.6	.10	8.9	.060	9.4	.12	.06	2.6	5.3	35.2
	DPR	62.0	20.0	18.0	SCL	5.4	.12	9.2	.056	10.2	.11	.06	2.4	5.0	33.2
	APR	62.0	23.0	15.0	SL	5.3	.11	8.9	.063	10.2	.11	.06	2.0	5.0	30.6
Forest Field	BPR	56.0	24.0	20.0	SCL	6.0	.13	9.6	.070	8.7	.12	.07	2.7	7.4	35.2
	DPR	58.0	22.0	20.0	SCL	5.5	.12	9.1	.062	10.4	.11	.08	2.4	5.7	30.4
	APR	58.0	22.0	20.0	SCL	5.3	.15	9.4	.066	10.1	.12	.07	2.2	5.8	30.4
Flatland Site															
Continuously	BPR	69.0	17.0	14.0	SL	5.2	.13	8.7	.068	10.1	.12	.10	2.8	6.1	41.2
Cultivated	DPR	72.0	19.0	10.0	SL	5.4	.14	8.7	.061	10.6	.10	.08	2.3	5.6	42.3
farm	APR	73.0	19.0	8.0	SL	5.1	.13	8.2	.065	10.8	.11	.08	2.3	5.8	43.7
Fallow Plot	BPR	60.0	20.0	20.0	SCL	6.5	.16	14.4	.082	8.4	.14	.14	3.4	7.5	40.6
	DPR	62.0	18.0	22.0	SCL	6.3	.14	12.2	.071	10.2	.12	.13	2.9	7.4	40.1
	APR	64.0	18.0	18.0	SCL	6.8	.16	10.9	.077	9.8	.14	.12	3.6	7.9	40.2
Forest	BPR	51.0	23.0	26.0	SCL	7.6	.17	22.5	.084	6.9	.15	.17	3.6	10.4	31.3
Field	DPR	53.0	21.0	27.0	SC	7.2	.19	20.0	.080	8.2	.13	.16	3.5	12.20	33.4
	APR	52.0	21.0	27.0	SC	7.5	.18	18.2	.085	8.1	.14	.17	3.8	11.8	35.6

BPR = Before Peak of Rainfall; DPR = During Peak of Rainfall; APR = After Peak of Rainfall, SL = Sandy Loam; SC = Sandy Clay; SCL = Sand Clay Loam.

Soil Chemical Characteristics

The mean pH values of the soils between and within the land use sites were significantly different at successive measurement intervals (table 1), with the mean pH values for farms under continuous cultivation and fallow plots on the hillslope site being lower (4.3 and 5.6) compared to those (5.1 and 6.8) for farms under continuous cultivation and fallow plots, respectively, on the flatlands. However, the mean pH values for land use types on either site were lower compared to the mean values for the forest fields. The soils were categorized as acidic. The acidic nature of these soils might be either due to the character of the parent rock that is acidic or the intensive erosion and leaching process or a combination of both. The lower pH values across the study sites corresponded to the smaller amounts of organic carbon in the soil (table 1). Soil pH influences plant growth directly, via the effect of hydrogen ions,

and indirectly, via the effects of nutrient availability; the latter is more important [39]. However, the f test results in table. 2 show that there were no significant differences in pH values between and within land use sites for the three successive measurement intervals. This indicates the reason farmers in the study region cultivate hillslope areas while there are flatlands.

In comparison with the farms under continuous cultivation and the fallow plots on the hillslope site, the plots under continuous cultivation and the fallow plots on the flatland site had a higher mean soil OC content for three successive measurement intervals, but it was lower than for forest fields (table 1). As a whole, the plots under continuous cultivation and the fallow plots on either site could be regarded as having low OC content. Mean values ranged from 8.2 g Kg^{-1} to 14.4 g Kg^{-1} compared to 30.00 g Kg^{-1}, regarded as the threshold values required for optimum crop production in the region [40], [41], [42].

However, comparably lower mean values of 7 g Kg-1 to 13 g Kg^{-1} were reported for an upland farming area in northern Nigeria [43]. Hence, this could presumably be one of the farmers' reasons for cultivating hillslopes while there are flatlands. However, the ANOVA results in table 2, show a statistically significant variation in OC between the two sites, suggesting the existence of the effects of sites that can be a link to organic matter variability in the study region.

The pattern of TN content is similar to that of OC content between and within the land use sites for the successive measurement intervals (table 1), except that all the mean values for both sites can be rated as being very low when compared with the ecological region's minimum range of 1.00 to 4.50g Kg^{-1} [40], [41], [42], [44]. Similarly, no significant differences were recorded in terms of TN content between and within the two sites (table 2). Hence, this could be one of the reasons farmers in the study region cultivate hillslopes while there are flatlands.

The mean values of P content were relatively higher in farms under continuous cultivation and fallow plots on the hill site; with a mean value varying from 8.70 to 11.40 compared to 8.40 to 10.40 for a comparable flatland site, and 6.90 to 8.20 for forest fields (table 1).

Despite, the higher OC content of the forest soils, the P content level for the soils was comparatively lower than that for other land use types. However, regardless of land use type and site, the mean P content of the soils in the study region was at a deficiency level, compared with the ecological region's threshold values of 15mg Kg^{-1} , with regard to optimum soil productivity [40], [41], [42].

There was also a statistically significant variation in P content in the soils at the different sites (table 2), implying that site has a significant influence on the amount of soil P content in the study region. The variation can probably be attributed to the differences in the soils' OC content and the pH values of the soils, the severity of erosion and leaching, and land use type and intensity of cultivation.

There was a mean variation in exchangeable Ca, K, & Na, values between and within the land use sites, for the three successive measurement intervals table 1. Farms under continuous cultivation and fallow plots on the flatland site had higher mean values (values ranged from 0.08 to 3.6), than those on the hillslope site, (mean values ranged from 0.04 to 2.6). Similarly, the mean value for forest fields on flatland (0.12 to 3.8) was comparatively higher than the 0.7 to 2.7 ranges for the hillslope forest field. As a whole, these values were lower than the threshold values of 1.5. to 3.5, for individual basic cations needed for optimum crop production in the ecological region [40], [41], [42].

High rains and the rough texture of the soils in the study probably favored the intensive leaching of the base cations. However, the mean K and Ca contents of the soils showed statistically insignificant differences between and within the land use sites at successive measurement intervals (table 2). This suggests the absence of any effect that can be linked to the sites in the study area. Hence, this is one of the reasons farmers have for cultivating hillslopes while there are flat lands.

The mean CEC shows similar trends to soil organic carbon and clay contents (table 1). The CEC values of the soils in continuously cultivated farms and fallow plots on the flatland site, were relatively higher (values ranging from 5.6 to 7.9); than those on the hill slope site (values ranging from 4.3 to 7.4). The higher CEC content in the soils of the flatland might be due to soil texture, the amount of OC in the soil, clay mineralogical composition and degree of erosion. CEC is crucial for soil fertility for two fundamental reasons: firstly, the total quality of nutrients available to plants as exchangeable cations depends on it, and secondly, it influences the degree to which hydrogen and aluminum ions occupy the exchange complex, thus affecting the pH of soils [40], [41], [42].

As a whole, the CEC values were within the region's threshold values for crop production. The difference among the land use sites was found to be significant before and after peak rainfall. However, insignificant differences were recorded during peak rainfall, as shown by the f-test results, table 2. Hence, this could also be one of the reasons for farmers cultivating hill slopes while there are flat lands.

The mean base saturation ranged from 30.40 to 37.10 in farms on the hill site to 40.10 to 43.70 in farms on the flatland site, table 1. The variation in base saturation range reflects the leaching intensity of bases and the soil erosion in the

study region. There was no significant mean base saturation difference between the two sites table 2, implying an absence of the effect of site on base saturation, and, therefore, a reason for farmers cultivating hill slopes while there is flatland.

TABLE 2
ANALYSIS OF VARIANCE OF THE SOIL PROPERTIES

Soil Properties	Before Peak of Rainfall				During Peak of Rainfall				After Peak of Rainfall			
	Mean Square	Error	F	Sig.	Mean Square	Error	F	Sig.	Mean Square	Error	F	Sig.
Sand%	93.100	21.000	4.433	NS	78.567	24.333	3.229	NS	79.900	9.00	8.88	NS
Silt%	9.100	21.000	.433	NS	2.375	21.000	.113	NS	6.667	6.33	1.05	NS
Clay%	50.310	.083	603.725	**	69.042	1.333	51.781	**	53.367	.33	160.10	***
PH(H2O)(1.2.5)	1.626	.190	8.557	NS	1.532	.010	153.175	NS	1.336	.17	7.71	NS
EC (dSm-1)	.003	.000	9.781	NS	.003	3.333E-5	83.525	**	.002	.00	15.43	NS
OC (g kg-1)	35.671	.093	382.186	**	22.910	.010	2290.975	***	16.588	.09	177.73	**
TN (g kg-1)	.001	.001	1.050	NS	.000	3.333E-5	7.952	NS	.000	.00	2.72	NS
P (mg/kg-1)	2.198	.053	41.206	**	1.314	.043	30.315	**	1.748	.06	27.61	**
K Cmol(+)kg-1	.001	.002	.437	NS	.000	.004	.086	NS	.001	.00	.86	NS
Na Cmol(+)kg-1	.003	3.333E-5	80.000	**	.003	3.333E-5	80.000	**	.002	.00	69.78	**
Ca Cmol(+)kg-1	.397	.043	9.151	NS	.658	.390	1.687	NS	1.160	.25	4.58	NS
CEC Cmol(+)kg-1	6.043	.090	67.144	**	9.967	.063	157.367	NS	9.514	.02	407.73	***
BS%	13.959	16.000	.872	NS	21.036	8.710	2.415	NS	27.647	1.81	15.28	NS

** = $p < 0.05$ * ** = $p < 0.01$;

IMPLICATIONS OF THE STUDY

The results of this study showed that topographical variation associated leaching, soil erosion, and deposition affected the physiochemical properties of the studied soils to a greater extent. The study showed a statistically insignificant difference in soil physical properties; sand and silt, and in chemical properties; soil pH, TN, base cations (Na, and Ca), and base saturation between and within land use sites for the three successive measurement intervals. This suggests the absence of any considerable effects that could be directly associated with sites, and therefore reasons for farmers cultivating hill slopes while there are flatlands. In addition, variation among soil EC and CEC was found to be statistically significant during one or two of the three successive measurement intervals, suggesting that the effect of site on soil properties can be influenced by rainfall. However, differences in the distribution of soil clay fraction, OC, P and Na between the two sites over the three successive measurement intervals were found to be significant, suggesting sites significantly influenced the properties according to land use. Our findings of significant differences in soil properties between the two surveyed sites over successive measurement intervals have two important policy implications. 1. Any intervention in soil management should be location-specific and the blanket recommendations for fertilizer application and soil and water conservation, which are now the norm in Nigeria should be changed. 2. The severity of soil degradation varies with land use; hence, local level investigation is essential to design local-specific and appropriate management interventions.

CONCLUSION

In this study, variations in important soil properties emanating from two contrasting land use sites (hillslope and flatland areas) were investigated for three successive measurement intervals. Using 24 composite samples randomly selected from six surveyed plots, with eight surveyed positions from the two contrasting areas for soil laboratory analysis, thirteen soil properties were analysed using the GLM procedure and the analysis of variance in SPSS version 22, to gain an understanding of farmers' reasons for cultivating hillslope areas while there are flatlands. The obtained results showed statistically insignificant differences in most soil physical properties; sand and silt, chemical properties; soil pH, TN, base cations (Na, and Ca), and base saturation. However, the differences in the distribution of soil clay fraction, OC, P and Na among the two sites were significantly different. The obtained results would provide useful information on the physiochemical properties of these soils that will guide the uses to which these sites can be put and provide baseline data for future similar studies in the study region.

RECOMMENDATIONS

To improve the soil physiochemical properties at both sites, it is recommended that the best practices of the farmers from time immemorial, such as contour ploughing, intercropping, use of cover crops and mulch, should be enhanced and encouraged especially for hillslope farmers.

Studies that may result in a higher amount of organic matter, reduced erosion and increased water-holding capacity of the soils under investigation should be undertaken, and this is what is also advocated for areas constrained by similar response mechanisms.

The expectations and perceptions of farmers should be integrated into future studies to provide empirical evidence of farmers preference for cultivating hillslope site while there are flatlands. To provide an answer to the possible root cause of the aged old conflict between farmers and pastoralists is a thrust for further studies.

LIMITATIONS

A major factor that may constrain the generalizability of the present study is that the sample size for each land use is small. A larger size would have been more reliable. However, despite the small sub-sample sizes, the fact is that the study is the first of its kind examining the influence of sites on soil physiochemical property variability over three successive measurement intervals. It is hoped that future researchers will contribute by using a larger sample size.

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