Effect Of Burning On Soil Chemical Properties In The Dry Sub-Humid Savanna Zone Of Nigeria

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Abstract: A study was carried out to assess the effects of burning on the chemical properties of soil on soils obtained from within the dry sub-humid savanna agro-ecological zone of northern Nigeria. Surface (0-15cm) composite soil samples were collected from selected locations comprising Bauchi, Gombe and Kano states from un-burnt, lightly burnt and intensely burnt sites in farmers' farms during land preparation of the 2007/2008 cropping season. The samples were obtained from both upland and lowland areas and analysed in the laboratory to assess the effect of burning on the soil's physical properties. The collected data were analysed using the SAS statistical software to test for significant differences at 5% level of significance. Where significant differences were found, the means were separated using the Least Significant Difference (LSD). Result of the laboratory analyses revealed that burning had no effect on pH, electrical conductivity, exchangeable sodium percentage, effective cation exchange capacity, percent base saturation and amounts of potassium and sodium of the soil. Organic carbon, total nitrogen, available phosphorus, calcium and magnesium of the soil were reduced from 12.29gkg^{-1} to 6. 29gkg^{-1}, 1.40gkg^{-1} to 0.58gkg^{-1}, 43.29mgkg^{-1} to 13.06mgkg^{-1}, 2.76cmol(+)kg^{-1} to 2.36cmol(+)kg^{-1} and 0.62cmol(+)kg^{-1} to 0.38cmol(+)kg^{-1} respectively within the lowland areas; and from 7.62gkg^{-1} to 5.59gkg^{-1}, 1.52gkg^{-1} to 0.58gkg^{-1}, 35.33mgkg^{-1} to 5.37mgkg^{-1}, 2.88cmol(+)kg^{-1} to 1.8676cmol(+)kg^{-1} and 0.69cmol(+)kg^{-1} to 0.47cmol(+)kg^{-1} respectively within the upland areas as a result of zero-burning and intense-burning respectively. Based on this research it is evident that burning causes reduction in the fertility status of the soil within the dry sub-humid savanna region of Nigeria. [Researcher 2010;2(7):78-83].

Keywords: Burning, Chemical properties, Dry-humid Savanna

Introduction

As more land is being cleared and prepared for cropping annually, burning has become the easiest and most convenient method quite often employed. In many areas, the attitude changed to one of total burning (wildfire) and this becomes a major cause of depletion of nutrient status. This necessitates a research of this kind to ascertain the effect of such localized burnings and fires on the soil and its subsequent effect on crop production.

The vast majority of area burnt and cleared annually for cropping, to drive game for hunters, to improve grazing condition for livestock and for migration and land settlement lies within the savanna ecological zone (Isah and Adegeye, 2002). This practice invariably results in heating and drying of the soil. The soil temperature reached during such burnings ranged from 93^{o} to 1004^{o}C as a result of burning different types of materials and the time of exposure to heating (Roberts, 1965; Landelout, 1964; Isaac and Hopkins, 1937).

All fires, regardless of whether they are natural or human-caused, alter the cycling of nutrients and the biotic, physical, moisture, and temperature characteristics of soil (Isaac and Hopkins, 1937). In many cases however, these impacts are either negligible or short-lived and thus have little, if any, impact on the overall ecosystem. In some cases however, the impact of fire on soil conditions can be moderate to severe. The overall degree and longevity of this impact is determined by numerous factors including fire severity, temperature, fire frequency, soil type and moisture, vegetation type and amount, topography, season of burning, and pre- and post-fire weather conditions. Studies by Smith (1968) and Kershaw and Rouse (1976) pointed out that relatively large-scale loss of nutrients and an alteration of soil physical conditions occur after a fire.

Past researchers have identified many fire-related impacts on soil conditions. They have divided them into the following categories: Physical and Chemical Properties, Nutrient Properties, Soil Temperature, Soil Moisture, and Soil Biota. In general, when compared to the impacts felt by other ecosystem components, fire effects on soil are typically minor, are often short-lived and can be either positive or negative, with degree of impact increasing with increased fire severity (Haase *et al*. 1988).

Annual bush burning and slash and burn practices have become a pre-occupation in the savannah ecological zone of West Africa (Oguntala, 1980). Each year millions of hectares are burnt without regard to the persistent questions like: what is the precise nature and extent of the effects of burning on the fertility of such soils, what are the long-term effect, what benefits, if any does fire confer on the soil and what is the beneficial effect or disadvantage of 'prescribed burning' on the soil?

It is therefore obvious that changes do occur after soil heating most especially after a fire, but to what extent do these changes affect the soil and the ultimate goal of food production?

Soil temperature is one of the more important factors that control micro-biological activity and the processes involved in the production of plants (Bottomley, 1998). It is a well established fact that the rate of organic-matter decomposition and the mineralization of organic forms of nitrogen increase with temperature, but intense temperatures may be detrimental to the soil.

It has been shown that the highest soil and nutrient losses were produced in the period immediately after a fire. However, fire intensity is the factor that determines the soil status with respect to its response to nutrient losses (Andreu *et al.*, 2004). Fire increases or decreases soil nutrient amounts, depending on the intensity and duration of the burn. Two obvious direct effects are volatilization of certain elements and modification of soil particles due to heat. Volatilization sends carbon, hydrogen, and oxygen, (C, H, and 0) into the atmosphere, along with varying amounts of sulphur (S), and phosphorus (P) depending on the composition of the organic matter burned and the degree of combustion (Raison, 1979). Nutrients in mineral form are affected by the changing physical properties of soil particles due to heating and subsequent cooling. When micaceous minerals and clays dehydrate or fracture, the solubility of elements such as P and potassium (K) can increase or decrease (White *et al.*, 1973).

Materials and Methods

Location

Three locations were selected within the dry sub-humid savanna agro-ecological zone of Nigeria (latitudes $8^o52'$-14 $^o23'$N and longitudes 4 $^o12'$ - $12^o37'$) (FAO/NSPFS, 2005) representing both the high and low plains. Soil samples were collected from the dry sub-humid Kauran Namoda-Kano-Bauchi high plain and the dry sub-humid Azare-Gombe-Yola plain. The area were the samples were collected is bordered by the dry sub-humid Gumel-Nguru-Maiduguri plain at the northeast, the dry sub-humid Chibok-Biu-Mubi-Song high plain at the east, the dry sub-humid Ilela-Sokoto-Yelwa plain at the west, the sub-humid Jalingo-Donga-Ganye high plain at the southeast, the sub-humid central Niger-Benue trought and the sub-humid Minna-Kaduna-Kafanchan high plain both to the south (FAO/NSPFS, 2005). The altitude of the entire area exceeds 500m above sea level (Kowal and Knabe, 1972).

Climate

The study area has a tropical climate which is characterised by two distinct seasons, that is the wet and dry seasons. The wet season start from April to October while the dry season commence from November and ends in March, with the rains starting from the southern part and the dry season starting from the northern part. The average rainfall ranged from 600mm per annum in the northern part of the zone to as high as1200mm per annum in the southern part of the zone. Mean annual temperature range from 26^oC - 32^oC, while the diurnal temperature ranges from an average daily maximum of 31.6 ^oC to an average daily minimum of 13.1^oC and relative humidity of 17%-90% (BSADP,1982; KNARDA, 2001; Kowal and Knabe, 1972). The soil temperature regime is iso-hyperthermic which suggests less than 5^oC difference between mean summer and mean winter soil temperature (Soil Suvey Staff, 1999; Mustapha, 2003). The soil moisture regime is dominantly Ustic in the uplands and Aquic in the lowlands (fadama). The arable lands are mostly uplands with some few scattered fadama. The soil orders are mostly Ultisol, Alfisol, Inceptisol and Entisol which have developed mainly from basement complex rock parent material.

The soils in Bauchi and Gombe states are mostly weakly leached ferruginous tropical soil in the eastern plain. However leached ferruginous tropical soil exists on the sandstone plains to the west. Uthormorphic vertisol is also found in the region (BSADP, 1982). Latosols are the dominant soils in the wind drift of Kano state. They are well-drained and brownish to reddish in colour. They are also deep except where iron pans are exposed or occur near the surface (Olofin, 1985). Hydromorphic soils tend to occur throughout the state where annual flooding occurs (fadama). These hydromorphic soils are dark-greyish in colour and have a high content of clay.

Reconnaissance Survey

A reconnaissance survey was carried out in June, 2007 to select appropriate sites for the study. Information collected during the survey includes farm sizes, land tenure system, cropping type and history, and method of land clearance.

Selection of Sampling Sites and Sample Collection

Following the survey, some farms were selected at different locations within the study area. Six locations were selected based on history of method of land clearance. Soil samples were collected from two sites each of Kano, Bauchi and Gombe states. The sites for sample collection were randomly selected from among the lowland and upland areas in the chosen states. The selected locations were; Bauchi 1 (Fadama), Bauchi 2 (Upland), Gombe 1 (Fadama), Gombe 2 (Upland), Kano 1 (Fadama), Kano 2 (Upland).

Treatments and Experimental Design

The treatments consisted of soil samples which had been subjected to three different burning regimes by the local farmers as part of their land preparation for farming. They consisted of soil samples from un-burnt areas as well as soil samples which had been subjected to Light-burning and Intense-burning from the three aforementioned geographical locations; Kano, Bauchi and Gombe states with two bulk soil samples from two of each location i.e. lowland and upland areas. The experimental design was hierarchical (nested) design in which the burning intensities were nested in the locations and the locations nested within the sites.

Sample Preparation

Sub-samples from the bulk soil samples were collected air-dried in the laboratory for several days. The sub-samples were gently crushed with porcelain pestle and mortar and passed through a 2mm sieve to remove debris and coarse fragments. The fine earth separates (<2mm soil portion) were labeled and stored in polythene bags for laboratory analyses. Weighing of the soil samples for laboratory analyses was done using an electric weighing balance, Model ADP 3100L.

Laboratory Analyses

The soil pH was determined both in water and 0.01M $CaCl_2$ solution, using a 1:1 for soil:water ratio and 1:2 for soil:$CaCl_2$ ratio (IITA, 1979) on two-way equilibration with buffer solution at pH 4.01 and 7.01, pH was read with a glass electrode on a Cyberscan 20 pH meter. The temperature was calibrated before the pH was taken. Electrical conductivity of the saturated paste extract of 1:2 soil to water ratio was determined using a conductivity meter, at 25^oC (Bower and Wilcox, 1965). Exchangeable Ca, Mg, Na and K were extracted with 1M ammonium acetate (1M NH_4OAc) solution buffered at pH 7.0 as described by Anderson and Ingram, (1998). Potassium and sodium in the extract were read on a Gallenkamp Flame Analyser. The extracts were diluted two times with the addition of 2 ml of 6.5% lanthanum chloride to prevent ionic interference before Ca and Mg were read. The Ca and Mg were read on a Buck Scientific atomic absorption spectrophotometer (AAS) model 210 at 423 and 285 nm wavelength respectively. The sum of Ca, Mg, Na and K gave total exchangeable bases. Exchange acidity (Al + H) in the 1M KCl extract was determined by titrating with 0.1M sodium hydroxide (1M NaOH) solution as described by Andesrson and Ingram, (1998). Effective CEC was calculated from the summation of exchangeable bases determined by 1M NH_4OAc extraction and the exchange acidity by 1MKCl extraction as described by Anderson and Ingram (1998). Percentage base saturation was calculated by dividing the total exchangeable cations (Ca, Mg, K and Na) by the effective cation exchange capacity (ECEC) obtained by the 1M NH_4OAc (pH 7.0) method. The exchangeable sodium percentage (ESP) was calculated as the proportion of the ECEC occupied by exchangeable sodium. The organic carbon content was determined by the wet oxidation method of Walkley and Black (1934) as described by Nelson and Summers (1982). The reaction was activated with the addition of concentrated sulphuric acid as a catalyst. The total nitrogen content was determined using the Macro-Kjeldahl technique as described by Bremner (1982). Free ammonia liberated from the solution by steam distillation in the presence of 10M NaOH was collected. The distillate was then titrated with 0.1M H_2SO_4. Available phosphorus was extracted using the Bray No. 1 method (Bray and Kurtz, 1945). Phosphorus in the extract was determined colourimetrically by the molybdo - phosphoric – blue method using ascorbic acid as a reducing agent (Murphy and Riley, 1962).

Data Analysis

The data collected were analyzed using Analysis of Variance (ANOVA) using SAS Computer Statistical Software to test for significance (F* Test). Where the tests show there are Significant Differences, the Means were compared using Least Significant Difference (LSD).

RESULTS

The results presented in tables 1 and 2 shows the effect of burning on soil pH, electrical conductivity, exchangeable sodium percentage, organic carbon, total nitrogen and available phosphorus. Soils within the study area were found to be slightly acidic to moderately acidic in nature

(5.97-6.13). In table 1 the soil pH_w was found to increase non-significantly ($P \leq 0.05$) as a result of burning within both the lowland and upland areas. The increase was from a mean value of 5.97 in sites with no burning to a mean value of 6.15 in intensely burnt sites within the lowland areas, while the increase was from a mean value of 6.13 in un-burnt sites to a mean value of 6.42 in intensely burnt sites within the upland areas (Table 1). This increase may be as a result of ash accretion due to burning. The rise depends on the amount of ash deposited and the buffering capacity of the soil and as intense burning is likely to deposit more ash we would expect higher rise in pH from the intensely burnt sites. This finding is in accordance of with the findings of Humprey *et al.* (1969), Wright and Bailey (1982), Marion *et al.* (1991) and Chorover (1994). There was also no significant difference in the effect of burning on soil pH_w between the lowland and upland areas.

There no significant change ($P \leq 0.05$) in the electrical conductivity of the soil in both the lowland and upland areas as a result of burning, though there was a slight non-significant ($P \leq 0.05$) decrease in the electrical conductivity of the soil from 17.00mmhoscm^{-1}in un-burnt sites to 12.33mmhoscm^{-1} in lightly burnt sites which was seen to increase non-significantly to 14.67mmhoscm^{-1} in intensely burnt sites. The exchangeable sodium percentage of the soil was seen to be unaffected significantly as a result of burning in both lowland and upland areas. The initial decrease may be because of the loss of salt as a result of burning as put forward by the findings of Raison *et al.* (1985) and Macadam (1989) who argued that salts are normally carried aloft in the form of smoke. No difference was observed between the burning effect on the electrical conductivity of the soil between the lowland and upland areas.

The organic carbon content of the soil was seen not to be significantly affected as a result of burning within the lowland areas, but it was found to be significantly reduced within the upland areas. The reduction was from a mean organic carbon content value of 7.62gkg^{-1} in un-burnt sites to a mean organic content value of 5.59gkg^{-1} in intensely burnt sites. The total nitrogen content was found to be significantly reduced as a result of burning within both the lowland and upland areas. The total nitrogen content reduced from a mean value of 1.40gkg^{-1} in un-burnt sites within the lowland areas to a mean value of 0.58gkg^{-1} in intensely burnt sites; while the decrease was found to be from a mean value of 1.52gkg^{-1} to a mean value of 0.58gkg^{-1} in intensely burnt sites within the upland areas. The organic carbon content of the soil in the study area which is an indicator of the organic matter content of the soil was found to be low within the upland areas and moderate within the lowland areas. This should be expected as the lowlands are annually replenished of the plant nutrients by flood waters and is in agreement with the reports of Ahn (1970), Jones and Wild (1975) and Esu (1983, 1989) who found out that organic matter the soil organic matter levels are generally low except within the lowland areas which my be due to the rapid mineralization, sparse vegetation and cultural practice of crop residue removal, thus preventing accumulation and any appreciable level of humification. The initial organic matter content before burning was observed to be higher within the lowland areas which may explain why the effect of burning on the organic carbon content within the lowland areas was not significant. The decrease in the organic carbon content as a result of burning is in agreement with the findings of Hoskings (1938), Humprey *et al.* (1969), Rundel (1981), Hart (1999) and Iwuafor *et al.* (2000). The reduction may be attributed to oxidation of organic carbon as most organic colloids are altered by soil heating from 100-250^{o}C.

Significant reductions in the amount of the soil total N was observed as a result of burning. Reductions of 58.57% and 61.84% were recorded as a result of burning within the lowland and upland areas respectively. The decrease in the total soil N with increasing burning temperature may be related to the decrease in organic N contained in organic matter (Knight, 1966) and direct volatilization (DeBell and Ralston, 1970; Sharrow and Wright, 1977). This result coincides with the findings of White *et al.* (1973), Sharrow and Wright, (1977a & b), Hugh (1981), Raison *et al.* (1985), McNabb and Cromack (1990), Neary *et al.* (1999) and Wan *et al.* (2005). The effect was found to be similar both within the lowland and upland areas.

Significant reduction in the amount of soil available P was also recorded as a result of burning within both the lowland and upland areas. Within the lowland areas the reduction was observed to be from a mean value of 43.29mgkg^{-1} in un-burnt sites which is statistically different to a mean value of 24.27mgkg^{-1} recorded for the lightly burnt sites and finally to a mean value of 8.04mgkg^{-1} recorded in intensely burnt sites which was also significantly different. A similar trend was observed within the upland areas, but here the reductions were from 35.33mgkg^{-1} to 20.46mgkg^{-1} and finally to 5.37mgkg^{-1} in similar sites respectively. This may be as a result of direct volatilization and oxidation (Raison *et al.,* 1985) and nutrient loss as particulates in smoke (Macadam, 1989). The effect was similar in both the lowland and upland areas and is agreement with the findings of Phillips (1974), Mott and Popence (1977) and Iwuafor *et al.* (2000) but was found to be in contrast to the findings of other workers (Smith, 1970; White and Gartner, 1975) who found the amount of the soil P to actually increase after burning. Vance (1984) found the availability of P as a result of burning to vary by site.

The amounts of exchangeable bases (Ca, Mg, K and Na) in the soil under study varied differently as a result of burning within the lowland and upland areas (Tables 3 and 4). The Ca content of the soils varied significantly ($P \leq 0.05$) between the un-burnt sites and the intensely burnt sites but there was no significant difference between the un-burnt sites and lightly burnt sites. The Ca content of the soil was seen to decrease from a mean value of 2.76cmol(+)kg^{-1} recorded in the un-burnt sites to a mean value of 2.36cmol(+)kg^{-1} recorded for the intensely burnt sites within the lowland areas; and from a mean value of 2.88cmol(+)kg^{-1} to a mean value of 1.86cmol(+)kg^{-1} in the un-burnt sites and the intensely burnt sites, respectively within the upland areas. There was also a similar reduction in the amount of soil Mg content, where the reduction was from a mean value of 0.62cmol(+)kg^{-1} in un-burnt sites to a mean value of 0.38cmol(+)kg^{-1} in intensely burnt sites within the lowland areas; and a reduction from a mean value of 0.69cmol(+)kg^{-1} to a mean value of 0.47cmol(+)kg^{-1} in the un-burnt and intensely burnt sites, respectively. No significant difference was observed as a result of burning in the contents of the soil K and Na in both the lowland and upland areas (Table 3). In a like manner, the exchangeable acidity, effective cation exchange capacity as well as the base saturation of the soils under study were not seen to be significantly affected as a result of burning (Table 3) in both the lowland and upland areas. No significant difference ($P \leq 0.05$) was found between the burning effects in the lowland and upland areas (Table 4). The result of the analysis showed variability in the amount s of exchangeable bases of the soils in the area under study as a result of burning. The Ca and Mg contents of the soil were shown to significantly decrease as a result of burning while the contents of the soil K and Na remain unaffected by burning. However, the effect was only observed as a result of intense burning. There was no difference in the burning effect between the lowland and upland areas. The decrease may as a result of ash transport, leaching and erosion (Macadam, 1989; Raison *et al.* 1985). This finding coincides with that of McKee (1982), Raison *et al.* (1985), Neary (1999), Giardiana *et al.* (2000) and Iwuafor *et al.* (2000). Other researchers found the amount of soil Ca and Mg to either be increased or remain unaffected as a result of burning (Campbell *et al.,* 1977; DeBano *et al.* 1998). The amounts of soil K and Na presented in table 3 were found to be significantly unaffected as a result of burning. This is supported by the findings Hough (1981) and Wan *et al.* (2001) but contrast to the findings of White *et al.* (1973), Tiedman and Anderson (1980) and Raison *et al.* (1985). The result also indicated no significant difference in the amount of soil K and Na between the lowland and upland areas.

Exchangeable acidity was found not to be affected significantly as a result of burning, in which the effect is similar for both the lowland and upland areas. The soil effective cation exchange capacity as well as the percent base saturation were also not found to be significantly affected as a result of burning. This contrasts the finding of Campbell *et al.* (1977) who reported a decrease in the soil cation exchange capacity as a result of soil heating.

Conclusion

The results of the laboratory analysis revealed that burning has no significant effect on the pH, electrical conductivity, exchangeable sodium percentage, exchangeable sodium percentage, effective cation exchange capacity, percent base saturation and the amounts of potassium and sodium of the soil while the amounts of organic carbon, total nitrogen and available phosphorus of the soil were seen to be significantly affected as a result of burning. The amounts of organic carbon, total nitrogen, available phosphorus, calcium and magnesium contents of the soil were seen to decrease as a result of burning.

Based on this research it is evident that burning causes reduction in the fertility status of the soil; therefore, farmers should be cautious of the use of fire as a means for land clearance as there might be cumulative negative effects as a result of burning which will lead to far greater loss in soil fertility and that can ultimately affect optimum crop production

Table 1: **Effect of burning on pH, Electrical Conductivity (EC), Exchangeable Sodium Percentage (ESP), Organic Carbon, Total Nitrogen and Available Phosphorus on some soils in lowland and upland areas within the dry sub- humid savanna agroeclogical zone of northern Nigeria.**

Location	**pH (in water)**	**pH (in $CaCl_2$)**	**EC ($mmhoscm^{-1}$)**	**ESP (%)**	**Org.C (gkg^{-1})**	**Total N (gkg^{-1})**	**Availalable P ($mgkg^{-1}$)**
Lowland							
Zero-burning	5.97	5.34	16.00	2.86	12.29	1.40	43.29
Light-burning	6.11	5.54	16.00	2.93	11.39	1.17	24.27
Intense-burning	6.15	5.72	16.00	3.23	6.29	0.58	8.04
LSD (0.05)	NS	NS	NS	NS	NS	0.65	13.06
Upland							
Zero-burning	6.13	5.48	17.00	4.42	7.62	1.52	35.33
Light-burning	6.41	5.67	12.33	2.28	6.54	0.93	20.46
Intense-burning	6.42	5.75	14.67	3.54	5.59	0.58	5.37
LSD (0.05)	NS	0.10	NS	NS	1.30	0.42	12.02

Table 2: **Effect of burning intensity on pH, Electrical Conductivity (EC), Exchangeable Sodium Percentage(ESP), Organic Carbon, Total Nitrogen and Available Phosphorus on some soils between lowland and upland areas in the dry sub- humid savanna agroeclogical zone of northern Nigeria.**

Site	**pH (in water)**	**pH (in $CaCl_2$)**	**EC ($mmhoscm^{-1}$)**	**ESP (%)**	**Org.C (gkg^{-1})**	**Total N (gkg^{-1})**	**Availalable P ($mgkg^{-1}$)**
Zero-burning							
Lowland area	5.97	5.34	16.00	2.86	12.29	1.40	43.29
Upland area	6.31	5.48	17.00	4.42	7.62	1.52	35.33
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS
Light-burning							
Lowland area	6.11	5.54	16.00	2.93	11.39	1.17	24.27
Upland area	6.41	5.67	12.33	2.28	6.54	0.93	20.46
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS
Intense-burning							
Lowland area	6.15	5.72	16.00	3.23	6.29	0.58	5.37
Upland area	6.42	5.75	14.67	3.54	5.59	0.58	8.04
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS

Table 3: **Effect of burning on Exchangeable Bases (Ca, Mg, K and Na), Exchangeable Acicidity (EA), Effective Cation Exchange Capacity (ECEC) and Base Saturation Percentage (BS) on some soils in lowland and upland areas within the dry sub- humid savanna agroeclogical zone of northern Nigeria.**

Location	**Ca**	**Mg**	**K**	**Na** (cmol(+)Kg)	**EA**	**ECEC**	**BS (%)**
Lowland							
Zero-burning	2.76	0.62	0.36	0.13	1.16	4.68	75.59
Light-burning	2.68	0.50	0.24	0.12	0.83	4.39	80.43
Intense-burning	2.36	0.38	0.30	0.12	0.47	3.96	87.38
LSD (0.05)	0.32	0.17	NS	NS	NS	NS	NS
Upland							
Zero-burning	2.88	0.69	0.26	0.15	0.47	3.49	80.44
Light-burning	2.46	0.58	0.33	0.13	1.00	4.84	85.93
Intense-burning	1.86	0.47	0.36	0.10	0.47	3.88	87.72
LSD (0.05)	0.68	0.14	NS	NS	NS	NS	NS

Table 4: **Effect of burning on soil Exchangeable Bases (Ca, Mg, K and Na), Exchangeable Acidity (EA), Effective Cation Exchange Capacity (ECEC) and Base Saturation Percentage (BS) between lowland and upland areas in the dry sub- humid savanna agroeclogical zone of northern Nigeria.**

Site	**Ca**	**Mg**	**K** (cmol(+)Kg)	**Na**	**EA**	**ECEC**	**BS (%)**
Zero-burning							
Lowland area	2.88	0.62	0.36	0.13	1.16	4.68	75.59
Upland area	2.76	0.69	0.26	0.15	0.47	3.49	85.93
LSD (0.05)	NS	NS	NS	NS	NS	0.42	NS
Light-burning							
Lowland area	2.68	0.50	0.24	0.12	0.83	4.39	80.43
Upland area	2.46	0.58	0.33	0.10	1.00	4.84	80.44
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS
Intense-burning							
Lowland area	2.36	0.38	0.30	0.13	0.47	3.96	87.38
Upland area	1.86	0.47	0.36	0.12	0.47	3.88	87.72
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS

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