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IMPACT OF BUSH BURNING ON MACRONUTRIENTS AND TRACE ELEMENTS IN A FARMLAND AT OKHA, NEAR BENIN CITY, EDO STATE

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ABSTRACT
Bush burning is a practice used to prepare land for cultivation in Nigeria but there is uncertainty about its effect on soil properties. The study assessed the effects of the operation on soil pH, macronutrients and trace elements. Soil samples were collected from a delineated part of a gentle sloping undulating farmland located at Okha, near Benin City before and after bush burning which was subjected to analysis of some macro nutrients and trace elements (Fe, Cg, Zn, Cd and Cr). The result showed that the burning did not significantly ($p \leq 0.05$) affect the soil texture and nutrient parameters (organic C, N, P, K, Ca, Mg, Na, EC, ECEC, and BS) but reduced pH (from 5.6 – 4.7) and increased soil acidity by a nine-fold. Only the concentration (mg/kg) of Zn was significantly reduced in the burnt soil from 7.19 to 0.93. Low intensity burning of farmland can cause the need to apply relatively more liming material and Zn fertilizer to soil so as to enhance comparable nutrient quality of the crop grown on it.

KEYWORDS: *Bush burning, Low-fire intensity, Soil pH, Trace elements, Base cations, Zn micronutrient*

INTRODUCTION

Bush burning is a traditional practice used for clearing land annually in preparation for the planting season. It is the most convenient and easiest means adopted by farmers for the purpose in the humid tropics (Edem *et al*., 2013) which involves intentional setting fire on grasses/crop residues or by slashing them before burning termed 'slash-and-burn'. Although many studies have reported increase in soil fertility due to available nutrient-rich ashes and increase in soil pH (De Rouw, 1994; Maass, 1995; Ubuoh *et al*., 2017) but some have recorded reduced insignificant ($P \leq 0.05$) nutrients with increase in soil pH (Pantami *et al*., 2010), no effect on soil nutrients with significant increase in pH (Ibitoye *et al*., 2019) and significant increase of some nutrients, along with reduced soil pH (Dhungana, 2024).

The effects of bush burning on physical and chemical properties of soil are highly variable and mainly depend on the intensity of fire (Ibitoye *et al*., 2019), usually influenced by vegetation, weather and topography or shape of land (Cary *et al*., 2006), in addition to frequency and severity of the fire (Keeley *et al*., 2009). The intensity of fire is classified as low (<100°C), medium (up to 250°C), or high

(>350°C) based on heat output per burnt area over time (Caon *et al*., 2014). The traditional use of burning for land management can be described as low-intensity fire (Pfeifer, 2013) and soil temperature does not usually exceed 100°C until the soil water is evaporated (Campbell *et al*., 1994). Besides, there is usually limited heat penetration into soil, a poor conductor of heat, from a very intense-flaming fire which consumes most available ground and above-ground fuel, unless the fire is very slow moving or large amounts of ground fuel are consumed (e.g. pile burning) as reported by Busse *et al*. (2014) and Stoof *et al*. (2013).

The effects of bush burning on trace elements/micronutrients in soil have not received much attention, especially in Nigeria and the findings have also varied among authors. Murphy (2020) reported that the effect increases trace elements such as Fe, Al, Zn, Ni, Cd, and Pb while García-Marco and Gonzále-Prieto (2008) mentioned increase in Mn and Zn, decrease in Fe and no effect on Cu. Consequently, there is a lack of consistency about the impact of fire on soil nutrients in the tropics (Patami *et al*., 2010; Ibitoye *et al*., 2019; Ohwoghere-Asuma, 2012) and there is paucity of research on the impact of controlled bush burning on soil properties in southern Nigeria. The objectives of this study are to determine the impact of low-intensity fire on soil texture, pH, macronutrients and trace elements in an ultisol of a farmland Okha, Nigeria.

MATERIAL AND METHODS

Study Area

The study was carried out in January, 2023 at the Teaching and Research Farm (06º 11'48" to 06º 11'44" N latitude and 05º 39'13" to 05º 39'17 E longitude) of the Faculty of Agriculture and Agricultural Technology, Benson Idahosa University, Okha near Benin City. The delineated farm which covers about 1.08 ha (Figure 1) lies on an undulating landscape with gentle slopes, dominated mainly by Guinea grass. The soils are underlain by sands, clayey sands and discontinuous clay sequences of the Benin Formation of the Niger Delta Basin classified as ultisols. The humid tropical climate of the area consists of the rainy season which spans from April to October with a two-week break in August and a dry season from November to February; with a cold, humid and dusty harmattan period between December and January. The driest month is usually January, with about 9 mm of rainfall while most precipitation falls in September, with an average of 338 mm. Generally, about 2025 mm of precipitation falls annually. The temperature ranges between 25ºC in the rainy season and 28ºC in the dry season.

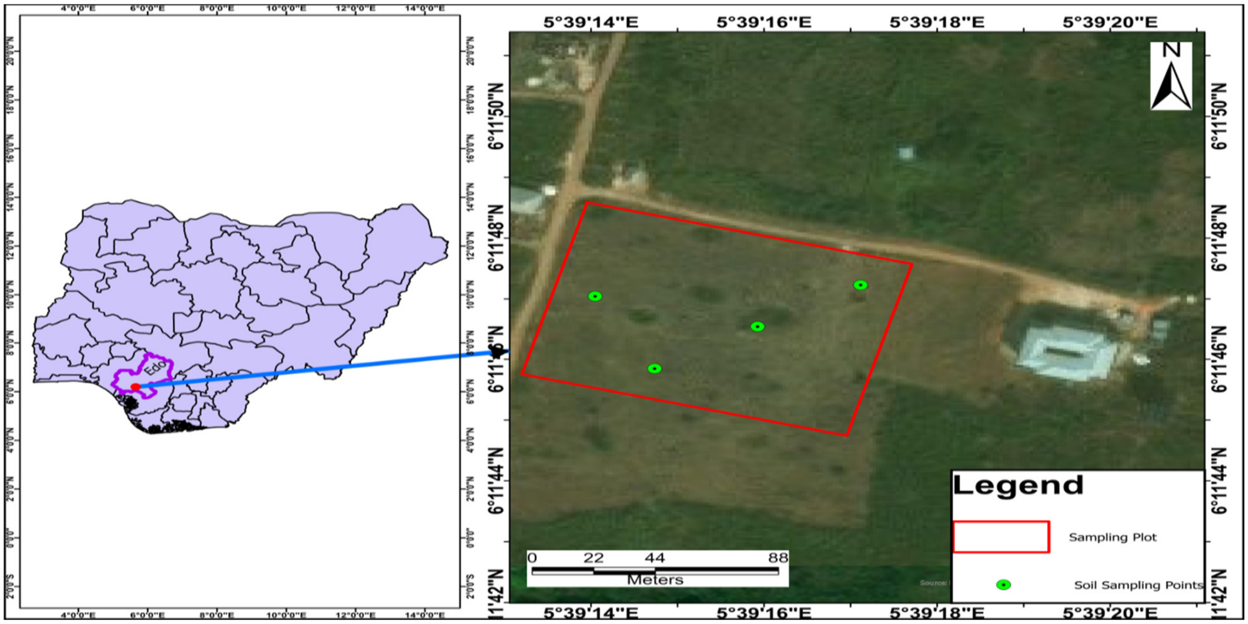

Fig. 1: Delineated site showing sampling points at Okha

Soil Sampling and Preparation

A total of six soil samples were collected with auger randomly at a depth of 0-20cm from the delineated part of the farm. Firstly, three samples were collected from the bushy site which was later set on fire before another three soil samples were collected after three days from the burnt site in a similar manner. All foreign materials were removed while putting the samples in a polythene bag which were labelled appropriately for easy identification before taken to the laboratory. Thereafter, the samples were air dried, crushed with a wooden mallet and passed through a 2mm sieve in preparation for analysis

Soil Analysis

Particle size distribution was carried out by the hydrometer method of Bouyoucos as modified by Day (1965). The soil pH was determined in a 1:2 soil/water ratio with a pH meter before the suspension was used to measure the EC with an EC meter. Soil organic carbon was measured using the Walkley and Black method as outlined by Nelson and Sommers (1996). Total N content by the Kjeldahl procedure (McGill and Figueiredo, 1993) and available P were measured in soil extracts by the ascorbic acid method (Bray and Kurtz, 1945). Exchangeable Ca and Mg were determined on an atomic absorption spectrophotometer using perchloric acid while Na and K were analysed on a flame photometer (Udo and Ogunwale, 1986). Ammonium acetate extracts from soil samples were used to determine the exchangeable bases (EB). The determination of exchangeable acidity (H^+ and Al^{3+}) was by the KCl extraction method (McLean, 1965) which was added to the values of all the exchangeable cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+) to obtain the effective CEC (ECEC).

Determination of heavy metals followed the procedure of weighing the powdered sieved soil sample (1g) into a 125ml conical flask and 20ml of conc. HNO_3, 5ml of digested on a hot plate. The flask was cooled slightly and the digest was diluted to about 50ml with distilled water and filtered. The filtrate was made up to 100ml mark and the tested trace metals (Fe, Cu, Zn, Cd, and Cr) were determined with an atomic absorption spectrophotometer (AAS).

Data Analysis

The data obtained from the laboratory were analyzed using SPSS version 26.0 where T-test was used to describe the variation between the burnt and unburned site. The significance difference was tested at $P \leq 0.05$ level.

RESULTS AND DISCUSSION

The results of the mean physicochemical properties of the delineated site before and after burning are shown in Table 1. There was no significant difference ($p \leq 0.05$) in proportion of sand, silt and clay been them. There was only a slight increase in sand (796.66 – 803.33 g/kg) and slight decrease in clay particles (143.33 – 136.66

$HClO_3$ and 2ml of H_2SO_4 were added before the mixture was g/kg), with no change in the proportion of silt. There was no significant difference between the strongly acidic pH (5.55) of the bushy soil and the very strongly acidic pH (4.69) of the burnt site. Soil texture, is hardly affected by fires because sand, silt, and clay exhibit high temperature thresholds (Alcañiz *et al*., 2016). However, clay particles are more affected because their temperature threshold (400-800°C) is lower than that of sand and silt (1,414 °C) as reported by Neary *et al*. (2005).

Lack of significant effect of fire on soil texture and chemical properties observed in this present study is due to the low intensity (<100°C) of burning that occurred. An impact which mainly depends on the severity and frequency of fire (Pérez-Izquierdo *et al*., 2021). Intense fire moving at a slow pace damage soil more than fast-moving ones (Certini, 2005) and soil surfaces with dry, heavy fuel loads, could reach 850 °C which can destroy soil properties (DeBano, 2000).

Table 1: Soil texture and chemical properties before and after burning

Parameter	Before burning	After burning
Sand (g/kg)	796.66	803.33
Silt (g/kg)	60.00	60.00
clay (g/kg)	143.33	136.66
pH	5.55	4.69
C (g/kg)	10.53	10.96
N (g/kg)	0.74	0.78
P(mg/kg)	9.19	12.13
Ca (cmol/kg	1.10	0.95
Mg (cmol/kg)	0.66	0.43
Na (cmol/kg)	0.10	0.20
K (cmol/kg)	0.33	0.41
EA (cmol/kg)	0.26	0.56
EC (uS/cm)	71.63	84.56
ECEC (cmol/kg)	2.47	2.57
BS (%)	87.00	75.63

There were also no significant differences ($p \leq 0.05$) between the burnt and unburnt plots in all other measured fertility parameters. However, slight increase in concentrations (g/kg) of organic C from 10.53 to 10.96 and total N from 0.74 to 0.78 g/kg were recorded. The fire increased the mean value (mg/kg) of available P of the unburnt soil from 9.19 to 12.13. Calcium concentration (cmol/kg) of unburnt soil was 1.10 which was reduced to 0.95 by burning and a decrease in Mg content from 0.66 to 0.43 was caused by the effect. Slight increase in EA and slight decrease in BS were measured due to the effect of the fire. An increase in the EC (µs/m) from 71.63 to 84.56 µs/m due to the same effect was recorded.

The impact of bush burning on trace elements in soil shows that only the concentration of Zn was significantly ($p \leq 0.05$) reduced (7.19 – 0.93 mg/kg) while reductions in the concentrations of the other elements were not significant as shown in Table 2. The concentration of Zn after burning was below the critical level of 0.6 – 2.0 mg/kg (depending on the method of Zn extraction) for deficiency to occur in plants (Singh *et al*., 2005). Reduction in concentrations of all the trace metals may have been due to environmental factors. Accelerated post-fire erosion due to heating, combustion, removal of vegetation cover and redistribution of soil can enhance surface runoff and erosion (Shakesby and Doerr, 2006). Concentrations of these micronutrients in soil relates to the growth and development of vegetation (Zhanbin *et al*., 2013).

Table 2: Impact of burning on trace element concentrations (mg/kg) in soil

Time	Fe	Cu	Zn	Cd	Cr
Before burning	10.1[a]	2.98[a]	7.19[a]	0.99[a]	1.4[a]
After burning	5.46[a]	0.80[a]	0.93[b]	0.36[a]	0.6[a]

Mean with same letters in the same column are not significant ($P \leq 0.05$).

Reduction of soil pH affects many chemical processes including plant nutrient availability and nutrients such K, Mg, Ca and Zn which can limit plant growth and influence ecosystem behaviour if not enough (Sardans and Peñuelas, 2015). Such reduced soil pH implies that relatively fewer nutrients would be available for uptake by crops in the burnt soil. Similar effect was recorded by Dhungana *et al*. (2024) who speculated that the cause may have been due to the release of cations during burning.

Insignificant ($P \geq 0.05$) impact of fire on organic C recorded in this present study is highly supported by Dhungana *et al*. (2024) who studied this effect on the tropical forest of Nepal. Significant variation of C levels depends on various factors which include duration of the fire, the amount of available biomass, soil moisture content, and intensity of fire (Reyes *et al*., 2015). The impact of fire on soils are highly variable between low-intensity and high-intensity fire; while the former cause slight increase in carbon levels, the latter reduce the nutrient (Caon *et al*., 2014). Loss of organic matter begins at in the range of 200–250°C, while its complete combustion occurs from 460 to 500°C (Vega *et al*., 2013).

Losses of N can occur when soil temperature experiencing fire exceeds 200 °C; however, if the temperature is lower, as is common in prescribed fires (Alcaniz *et al*., 2018), the nutrient may be unaffected or even increase due to the deposition of N-rich materials from partial combustion of vegetation and incorporation of ash into the soil (Scharenbroch *et al*., 2012). This explains the lack of significant increase in N levels observed in this present study.

Increase in P concentrations encouraged by low pH have been observed in different ecosystems after prescribed fires applied at different frequencies and seasons can be related to the duration of heating of the organic horizon, addition of ash and thermal mineralization of organic P (Guinto *et al*., 2001). Such enhancement may also be related to overall P status of the ecosystem: forests and shrublands on coarse grained, sandy soils typically cycle P very efficiently and little may be released from consumed litter (Wright and Westoby, 2003).

Relatively low Ca and Mg in burnt soil recorded in this present study can be explained by the inability of organic matter to retain cations as soil becomes more acidic (IPNI, 2011) due to the release of cations. Ash produced from burning of biomass usually fertilizes the soil by rapidly releasing mineral nutrients such as Ca, Mg, P and K (Are *et al*., 2009). Losses of exchangeable cations may occur as a result of ash erosion and leaching, as well as plant absorption during post-fire succession, due to their high vaporization thresholds (Caon *et al*., 2014).

Murphy *et al*. (2006) opined that low-intensity fires can enhance soil nutrient levels; particularly for nonvolatile elements such as K, P and mineral forms of S and P. However, some nutrients are more vulnerable to fire than others: K, Ca and Mg may be increased or unaffected while S and N usually decline.

Relative higher values of EC determined for the burnt field in this present study implies burning increased plant nutrients. This parameter estimates the concentrations of ions: anions Cl^-, $SO4^{2-}$, and HCO^{3-} and the cations Na^+, Ca^{2+}, K^+, and Mg^{2+} in soils (Friedman, 2005; He *et al*., 2012). It is cost-effective and reliable measurements of soil salinity, nutrient availability and loss, soil texture, and available water capacity (NRCS, 2014).

Similarly, higher ECEC values of burnt soil, recorded in this present study, implies according to Ulery *et al*. (2017), the higher capacity of its clay or humic organic matter to hold and make cations available to plants which can be used to predict its fertility. Bush burning had no significant effect on soil fertility and acidity in this present study because only a slight increase in concentrations of ECEC and EA occurred. Effective CEC (ECEC) considers the addition of H^+ and Al^{3+} which are more prevalent in acid soils compared to the dominant ions associated with CEC (IPNI, 2011). The fraction occupied by EB cations (especially Mg^{2+}, Ca^{2+}, and K^+) are usually exchange relatively easily for H^+ by plants roots. Other micronutrient cations (e.g. Cu^{2+}, Fe^{2+}, Mn^{2+}, Zn^{2+}, Ni^{2+}) only form a small percentage of the total exchangeable cations.

Relatively high ECEC and low BS observed in this present study implies that the soil exposed to burning would become a little more resistant to pH changes which will require larger amounts of lime to neutralize its acidity. Although in this case such amounts would not be relatively significant in comparison to the unburnt field.

Most short duration impacts of low fire intensity on soil properties assessed in northern Thailand (Arunrat *et al*., 2022) can be compared to this present study. These include insignificant effects on organic C, total N, P, K, Ca, in contrast to significant increase in soil pH and EC. Similarly, some of the findings of this present study are same as those of Ubuoh *et al*. (2017) who revealed reduced pH, BS, increase in sand, SOM, N, P, K and Na due to the effect of slash-and -burn on soil properties at Akwa Ibom, located in the coastal southern part of Nigeria. However, the authors observed increased Ca, Mg, as well as reduced EC contrary to this present study.

Low-intensity wild fires usually through rapid organic matter mineralization enhance macronutrients (Pereira et al., 2011; Alcaniz *et al*., 2016) and trace elements such as Fe, Al, Zn, Ni, Cd, and Pb (Murphy et al., 2020) and their concentrations depend mainly on the severity of the fire and the type of burnt vegetation (Santin *et al*., 2015). While macronutrients (N, K, Ca, Mg, and S) are more available within a pH of 6.5 to 8; besides P, which is most available at pH of 6-7, most micronutrients (B, Cu, Fe, Mn, Ni, and Zn) are more available in the range of 5-7 (McCauley, 2009). Thus, these cations are more strongly bound to soil and not as readily exchangeable as pH approaches 8. Some metals (Cu, Fe, Mn, Ni, and Zn) are very tightly bound to soil at high pH; being relatively more available at low pH. A phenomenon that can cause potential toxicities for crops in acid soils usually when pH decreases below 5.5 due to availability of Al and Mn. Conversely, base cations (Ca, K, Mg) are weakly bound to the soil and prone to leaching at low pH.

Mobility and solubility of Zn in soils increases with decrease in soil pH (Rutkowska *et al*., 2015) as observed in this present study and relative vulnerability of Zn to leaching which may have caused its significant reduction among other tested elements can be supported by the findings of DeMatos *et al*. (2001). The authors reported a retardation trend of Pb > Cu > Cd > Zn in leaching columns of these trace elements in two ultisols and one oxisol from Brazil indicating that Zn has the highest mobility. This implies that soil pH influences the concentrations of Zn nutrient more than other tested elements.

Most traditional and modern use of fire on soil usually have no direct significant impact, unlike severe naturally occurring wildfires (Santin and Doerr, 2016). However, they can be complicated by the soil type, topography and weather conditions of the environment which can alter soil properties through removal of vegetation cover and erosion. Consequently, the wide variations observed among many studies which revealed positive, negative, or no effect (Fontúrbel *et al*., 2021).

CONCLUSION

This study showed that the immediate impact of low intensity bush burning carried out at Okha did not significantly ($p \leq 0.05$) affect the soil texture and chemical properties such as pH, organic C, N, P, K, Ca, Mg, Na, EC, ECEC, and BS, besides only significantly reducing Zn concentrations. Although, there were slight decreases Ca and Mg concentrations as well as slight increase in organic C, N, P, K, Na, EC, and ECEC values but soil acidity was reduced by almost 9 folds. Burning can caused the availability of relatively less nutrients to crops in a more resultant acidic soil and the need for application of Zn fertilizer for enhance of the nutrient concentration in crops.

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