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EFFECTS OF FIRE ON PHYSICAL AND CHEMICAL PROPERTIES OF SOIL IN FWANGNIN BOKKOS DISTRICT, NIGERIA

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Background: Vegetation burning, a common agricultural practice, has both positive and negative effects on soil fertility. Soil quality, which is critical for ecosystems, shapes biodiversity and productivity, while increased temperatures from vegetation burning can alter conditions for seed germination by reducing nutrient availability. **Objectives:** The study aims to assess the impacts of vegetation burning on soil fertility in Fwangnin, Bokkos, Nigeria, through experimental investigation of the effects of burning on both the chemical and physical properties of soil. The results are expected to contribute to the development of adaptive fire management strategies in land use, and the results will also help monitor soil changes in order to maintain long-term soil fertility. **Methods:** Using purposive sampling, four 500-gram soil samples were taken from 0 – 15 cm depth in burned and unburned areas. The samples were analysed for pH, electrical conductivity (EC), organic carbon (OC), organic matter (OM), nitrogen (N), phosphorus (P), and cation exchange capacity (CEC). Traditional well-proven methods were used for the analysis. **Results:** It was found that the pH of the burnt soil samples ranged from 6.10 to 5.90, while that of the unburnt samples ranged from 5.73 to 5.81; a significant increase in pH occurs at higher combustion temperatures, which increases the alkalinity of the soil due to the alkaline properties of ash. The electrical conductivity value for the samples in the burnt areas was significantly higher (0.08 mS/cm and 0.10 mS/cm) compared to the healthy soil (0.07 mS/cm and 0.09 mS/cm), which can be explained by the release of mineral ions due to the combustion of organic matter. The study found a decrease in organic carbon content in the burnt soil, a significant deficiency of nitrogen and a decrease in the cation exchange capacity, which contributes to the depletion of the fertile layer and a decrease in the ability of the soil to retain essential nutrients. Increased levels of organic phosphorus were also found in burnt soils, which contributes to improved crop growth and increased yields in the short term. **Conclusion:** The current study has filled the gap in deep understanding of the impact of vegetation burning on the fertile properties of agricultural soils. Namely, it has been experimentally established and confirmed by the results of similar studies and statistical analysis that while vegetation burning remains a common agricultural practice in Fwangnin, the long-term implications for soil fertility, structure, and ecosystem health are significant. The soil degradation observed in this study suggests that continued reliance on burning as a land-clearing method may undermine agricultural productivity and environmental integrity over time.

Keywords: agricultural practice; soil fertility; thermal effects; degradation; granulometric composition; nutrients.

INTRODUCTION

African savannas, comprising over half of the world's terrestrial ecosystems, are increasingly altered by human activities like fire usage in agricultural practices, which affects ecosystem dynamics such as nitrogen cycling and soil composition (Lehmann et al., 2011; Bond et al., 2016; Colin et al., 2018). Fire influences soil by modifying its chemical and physical properties, impacting plant nutrient absorption through processes like dust deposition, precipitation, and nitrogen fixation (Ferrán et al., 2005; FOA, 2018). Bush fires date back to early human evolution and have long been used to clear land for agriculture, a practice still common in developing regions (Ambe et al., 2015; Chungu et al., 2020). While fire can boost soil fertility by increasing cation levels and reducing weeds, it also poses risks like vegetation loss and soil erosion, especially in savanna regions where ecological damage is severe (Edwin, 2008; Kowaljow et al., 2019).

Despite these drawbacks, fire helps maintain ecosystems by promoting new plant growth, essential for grazing in areas such as South Africa and Namibia (Mwale et al., 2008). Soil quality, critical to ecosystems, shapes biodiversity and productivity, while increased temperatures from vegetation burning can alter seed germination and nutrient availability (Jon & Jackie, 2015; Hille & den Ouden, 2005). Soil endures significant impacts during the initial stages of a fire, serving as both a structural base and essential nutrient source for plants (Valderrama et al., 2018). Fire rapidly consumes surface organic matter (OM), altering soil composition and often increasing nutrient concentrations (Gonzalez-Perez et al., 2004; Pereira et al., 2018). Changes in OM affect soil properties like electrical conductivity, pH, water retention, and carbon levels (Fonseca et al., 2017).

Certain compounds produced have high ion absorption capacity, which influences soil fertility (Ketterings & Bigham, 2000). In Israel, burned soils show reductions in sand, OM, clay, and cation exchange capacity compared to unburned soils (Assaf et al., 2014). OM is crucial for soil stability and nutrient retention, contributing significantly to cation exchange capacity and acting as a chelating agent (Pereira et al., 2012). Soil recovery after fire is affected by multiple factors, including fire intensity, vegetation resilience, ash properties, topography, and post-fire weather (Pereira et al., 2018).

Fire alters soil characteristics, impacting water movement and increasing erosion susceptibility. Loss of root systems combined with water-resistant soil surfaces facilitates erosion, with erosion rates closely linked to rainfall and ground cover levels, and influenced over time by fire regimes The low bulk density and high porosity of forest floors enhance water conductivity compared to underlying soil (Edwin, 2008). Ash accumulation after fires often raises soil pH, especially in neutral soils, due to alkaline carbonates in the ash (Zitta et al., 2022; Kemmitt et al., 2006). Fire also converts organic nitrogen in soil into mobile nitrates, which plants more readily absorb, promoting rapid post-fire growth. However, these nitrates are easily leached, leading to long-term nitrogen deficiency. Regular vegetation burning also reduces soil micro-nutrients and raises soil pH (Pereira et al., 2012; Gonzalez-Perez et al., 2004).

Despite the advantages of vegetation burning, it has contributed significantly to the degradation of terrestrial ecosystems worldwide, including in Nigeria. In Nigeria, vegetation burning is a common practice from the start of the planting season until the middle of the dry season. It remains a widely used method in agriculture and environmental management, helping to clear land for new planting annually. However, the trend towards widespread burning (wildfires) has become a major cause of nutrient depletion in many areas. Jamala et al. (2012) observed that nearly half of all bush fires in Nigeria are intentionally set, resulting in significant environmental and financial damage each year. This issue is doubly harmful: while the heat is intense, it also depletes essential soil nutrients, including fertilizer elements, by heating up the soil.

In Fwangnin, Bokkos, fire has become the most accessible means to clear more land for agriculture each year. To develop effective strategies for arable farming and soil conservation in Bokkos District, Plateau State, it is essential to study the effects of fire on soil fertility and crop productivity. Accordingly, current study aims to assess the impacts of vegetation burning on soil fertility in Fwangnin, Bokkos, Nigeria, through experimental investigation the effects of burning on both the chemical and physical properties of soil. The results are expected to contribute to the development of adaptive fire management strategies in land use, and the results will also help monitor soil changes in order to maintain long-term soil fertility.

MATERIALS AND METHODS

Research region

The investigation area is located in Fwangnin, a settlement within the Bokkos district of Plateau State, central Nigeria, positioned in the Middle Belt region of the country. Bokkos is renowned for its picturesque landscapes, fertile land, and primarily agrarian economy. The district features a moderate climate and diverse vegetation that supports agriculture, which provides the residents of the area with the opportunity to exist in these territories (Figure 1).

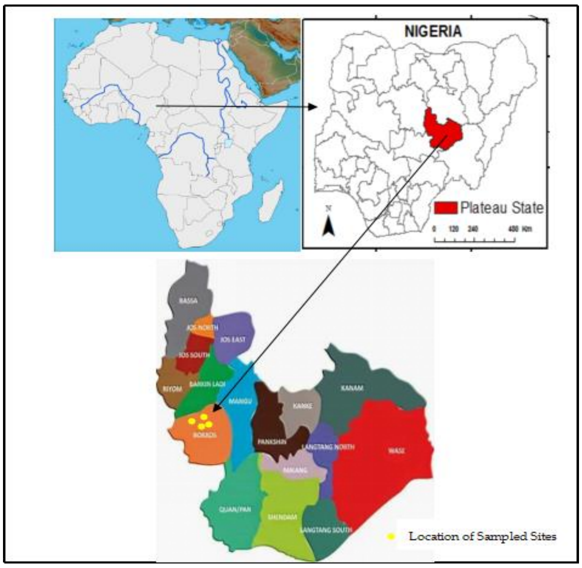

Figure 1. The geographical location of Plateau State and study areas

The study area is situated at an elevation of 1,324 m above sea level and has a population of 171,672 (National Population Commission, 2006). Due to its high altitude, the maximum temperature averages around 20 °C, while the mean minimum temperature is about 18 °C.

The region experiences two distinct seasons: the wet season, which lasts from April to October, and the dry season during the Harmattan period, characterized by dry, dusty winds from the Sahara Desert, occurring from November to March. The weather is generally cool, particularly from July to August and from November to February. Relative humidity varies with temperature; as temperatures rise, the amount of water vapor in the atmosphere increases. Fwangnin receives approximately 5 to 6 months of rainfall, with an average annual precipitation of 1,458 mm (Wuyep et al., 2022b).

The area falls within the northern Guinea Savanna belt, marked by open woodlands and grasses that have suffered significant degradation due to human activities. Remnants of the original vegetation are mainly found in rugged escarpments, hills, and mountainous areas, where land has been cleared for farming or mining (Dung-Gwom et al., 2009). According to the specified work, the soils in the area are ferruginous, characterized by clay texture and forming over biotype granite or gneiss in the sub-surface horizon. The soil has moderate water-holding capacity, is intensely leached, and contains low organic matter. Despite being clayey, the soil has limited fertility, which can support crop production. Agriculture is the primary economic activity, with a variety of crops such as Irish potatoes, tomatoes, onions, carrots, cabbage, and maize grown in commercial quantities and sold within and beyond Nigeria. The geology of the area is part of the Precambrian to mid-Cambrian and Jurassic Northern Nigerian crystalline shield (Dung-Gwom et al., 2009).

Soil sampling and laboratory analysis

Purposive sampling was employed to select four 500-gram soil samples contained in polythene bags from specific locations: Lat. 9°16.2'' Long. 8°56'20.2'', Lat. 9°17'37.6'' Long. 8°58'45.6'', Lat. 9°16'20.5'' Long. 8°58'39.4'', and Lat. 9°16'30.4'' Long. 9°00'16.0''. Two samples each were collected from burnt and unburnt areas, with a depth range of 0 – 15 cm. The analysis focused on several on several of the most important soil properties responsible for fertility, namely pH, Electrical Conductivity (EC), Organic Carbon (OC), Organic Matter (OM), Nitrogen (N), Phosphorus (P), Potassium (K), and Cation Exchange Capacity (CEC). The collected soil samples were air-dried in the laboratory, then ground using a wooden pestle and mortar, and sieved through a 2-mm sieve to assess their overall properties.

To determine the particle size of the samples, the Buoyocuos hydrometer method, as described by Gerenfes (2022), was utilized, and soil texture was derived from the particle size distribution using Marshall's textural triangle. The moisture content was measured using the gravimetric method. Soil pH was assessed using a glass electrode pH meter in a 1 : 2 soil-water suspension and in 0.01M $CaCl_2$. The same suspension was used to measure pH and electrical conductivity. An EC meter was used to measure electrical conductivity. Organic matter was calculated by multiplying the organic carbon content by 1.724. Organic carbon was oxidized with sulfuric acid (H_2SO_4) and potassium dichromate ($K_2Cr_2O_7$), followed by titration with 0.5N ferrous sulphate using a diphenylamine indicator. Total nitrogen content was quantified using the Kjeldahl wet oxidation method, while available phosphorus was determined through a bicarbonate extraction method.

The exchangeable cation content was extracted with 1N neutral ammonium acetate (NH_4OAc), and CEC was assessed using the

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neutral normal ammonium acetate displacement method. A T-test analysis was conducted to evaluate the effects of burnt and unburnt soil samples on their physical and chemical properties.

RESULTS AND DISCUSSIONS

Physio-chemical characteristics of burned and unburned soils

Soil sampled for degree of acidity and basicity

Soil pH was assessed on a scale from 1 to 14, where values below 7 indicate acidity, a value of 7 signifies neutrality, and values above 7 represent alkalinity. The burned soil samples exhibited an index pH ranging from 6.10 to 5.90, while the unburned samples had a pH between 5.73 and 5.81. The observed increase in pH among burned samples is linked to the accumulation of ash, with the degree of this impact influenced by both the quantity of ash present and the soil's buffering capacity. In burned areas, pH levels ranged from moderately acidic to neutral, while unburned areas remained extremely to moderately acidic (Figure 2). The rise in pH after burning may be attributed to the formation of oxides and carbonates. Studies indicate that soil pH is elevated in burned areas compared to unburned ones, with substantial pH increases occurring at higher combustion temperatures, which enhance soil alkalinity due to the alkaline properties of ash (Figure 2). This moderate pH level can benefit crop yields, as many plants grow best in slightly acidic to neutral conditions (Zhao et al., 2016). However, if pH levels rise too much, the risk of nutrient imbalances or toxicities may negatively impact crop productivity.

Soil electrical conductivity

The Electrical Conductivity (EC) value in the water-extracted solution from burned areas is notably higher, ranging from 0.08 to 0.10 mS/cm, compared to 0.07 to 0.09 mS/cm in unburned areas. As shown in Table 1, this increase may be due to the release of mineral ions resulting from the combustion of organic matter, which raises EC levels. This finding aligns with previous studies (Certini, 2005; Mehdi et al., 2012; Terefe et al., 2008), which observed that burning organic matter on the forest floor releases basic cations, leading to higher soil reactivity and increased electrical conductivity. This increase in electrical conductivity can enhance nutrient availability, potentially benefiting crop growth in the short term. However, excessively high EC levels may lead to salt accumulation, which can hinder plant water absorption and ultimately reduce crop productivity.

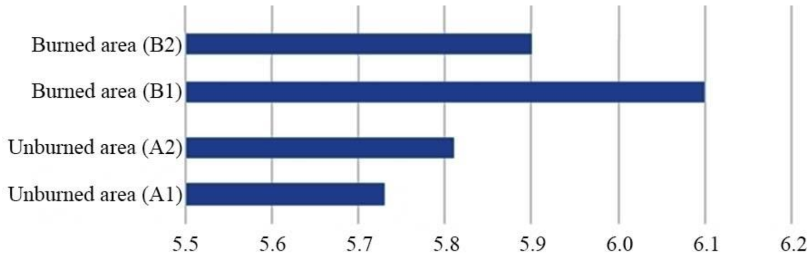

Figure 2. pH of the studied soil samples

Soil organic carbon

The analysis shows that the unburned area has an organic carbon range of 1.26 – 1.66%, while the burned area shows a reduced range of 0.68 – 0.95% (Figure 3), indicating a decline in soil organic carbon. This reduction reflects a thinning of the soil's organic layer, especially following high-severity or frequent fires, which reduce the depth of the organic stratum (Neill et al., 2007; Wuyep et al., 2022). These findings align with Mehdi et al. (2012), who observed decreased organic matter after high-severity fires in the oak forests of the Zagros region.

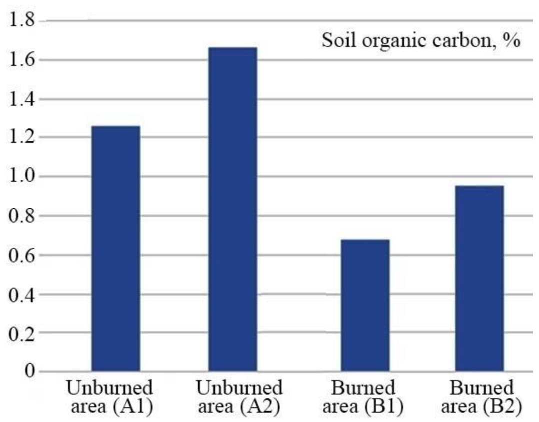

Figure 3. Soil organic carbon

Typically, moderate-severity fires may temporarily increase soil carbon content (González-Pérez et al., 2004). Reduced organic carbon in burned soils impacts agriculture by weakening soil structure, decreasing microbial activity, and limiting nutrient availability, all of which are essential for healthy crop growth (Six et al., 2002). This depletion can lead to lower yields and may require increased use of fertilizers to maintain productivity, adding to costs for farmers. For ecosystems, reduced organic carbon undermines soil resilience, potentially slowing vegetation recovery and diminishing habitat quality for soil organisms, which play a role in nutrient cycling and supporting plant diversity. This loss of organic carbon, therefore, affects both immediate agricultural productivity and long-term ecosystem stability.

Nitrogen in soil

The results in Table 1 show that nitrogen levels vary between burned and unburned areas, with burned areas having higher mean values 0.67 – 0.88 cmol/kg compared to unburned areas 0.09 – 0.10 cmol/kg. This increase in nitrogen in burned areas is likely due to the fixation of nitrates from decomposing and burned plant residues. Studies have shown that plant litter, especially when decomposed or burned, releases more nitrate nitrogen into the soil (Bárcenas-Moreno, 2011). Fire-induced volatilization of nutrients, particularly nitrogen, is temperature-dependent, with nitrogen starting to volatilize around 200°C and converting to ammonium and then nitrate, which may leach from the nutrient pool if not retained. Contrasting studies have shown varying effects of burning on nitrogen levels, suggesting factors like rainfall, land use, and biological nitrogen fixation may also play a role (Mitro et al., 2002; Edem & Alphonsus, 2016). This boost in available nitrogen, often due to the release of nutrients from burned

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organic material, can lead to improved crop yields in the short term. However, for ecosystems, elevated nitrogen levels may disrupt natural plant communities by favouring nitrogen-loving species over others, potentially reducing biodiversity (Suding et al., 2013). Additionally, nitrogen may leach into nearby water sources, leading to nutrient pollution that can impact aquatic ecosystems (Carpenter et al., 1998).

Soil phosphorus

Available phosphorus (P) in the soil at a depth of 0 – 15 cm ranges from 7 to 8 ppm in unburned areas, while burned areas exhibit higher values of 12 to 16 ppm (Figure 4). The increase in P, as shown in Figure 4, is attributed to the transformation of organic phosphorus into mineral orthophosphate and the accumulation of ash from burned plant materials. These results align with previous studies (Tabi et al. 2013), indicating that recently burned soils generally contain higher levels of absorbable phosphorus compared to unburned soils (DeBano et al., 2005). Banj et al. (2010) confirmed similar observations, noting that areas affected by high-severity fires have more phosphorus. Kutiel & Inbar (2007) added that the initial spike in phosphorus after a fire is due to the burning of organic phosphorus, but this increase may decline over time as the soil's organic content and microbial community recover. This elevated phosphorus, resulting from the transformation of organic phosphorus into mineral orthophosphate and the accumulation of ash from burned plant materials, can lead to improved crop growth and higher yields in the short term (Pereira et al., 2018). However, in the ecosystem context, the influx of phosphorus may disrupt natural nutrient cycling, potentially favouring certain plant species over others and reducing biodiversity. Over time, excessive phosphorus can lead to nutrient runoff into water bodies, contributing to eutrophication and negatively affecting aquatic ecosystems (Carpenter et al., 1998). Therefore, while increased phosphorus can initially benefit agriculture, careful management is essential to mitigate its impact on ecosystem (DeBano et al., 2005).

Soil cation exchange capacity

According to the findings presented in Table 1, the cation exchange capacity (CEC) of the burned soil was significantly lower, ranging from 2.92 to 2.76 cmol/kg, compared to the unburned soil, which ranged from 3.87 to 3.48 cmol/kg. The rapid decrease in CEC observed in the burned area suggests a reduction in organic matter and the clay-sized fraction in the unburned soil. It is likely that the combination of intense heat and the combustion of organic matter in the burned soil led to the formation of calcite (Inbar et al., 2014). This decrease in CEC indicates a reduction in the soil's ability to retain essential nutrients, which can hinder crop growth and lead to lower agricultural yields. The loss of organic matter and clay-sized particles further exacerbates nutrient depletion, making the soil less fertile and more susceptible to erosion (Baldock et al., 2000). In an ecological context, this reduction in cation exchange capacity may disrupt the balance of nutrient cycling, affecting plant health and biodiversity. Overall, the diminished nutrient retention capacity in burned soils underscores the need for careful soil management to sustain agricultural productivity and ecosystem (Inbar et al., 2014).

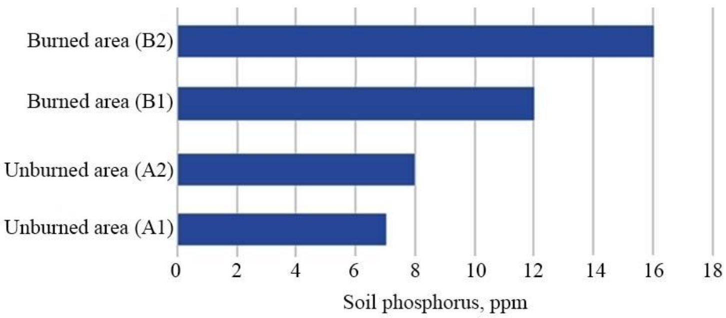

Figure 4. Phosphorus content

Table 1. Some indicators of burned and unburned sampled of soil

Plot	EC, mS/cm	Nitrogen content, cmol/kg	CEC, cmol/kg
Unburned area (A1)	0.07	0.10	3.48
Unburned area (A2)	0.09	0.09	3.87
Burned area (B1)	0.08	0.67	2.92
Burned area (B2)	0.10	0.88	2.76

Organic Matter

The analysis of organic matter (OM) in burned and unburned samples, as shown in Figure 5, indicates that unburned samples had OM levels ranging from 2.17 to 2.85 ppm, while burned samples ranged from 1.18 to 1.64 ppm. The decrease in OM in burned areas may be attributed to oxidation and volatilization, as fire consumes organic matter (Simard et al., 2021). Terefe et al. (2008) noted that severe fires significantly reduce soil organic matter and alter the physicochemical properties of the topsoil. Additionally, frequent or intense fires can decrease the thickness of the organic layer in the soil profile (Neill et al., 2007). Chungu et al. (2020) reported that soil organic matter increased in burned sites over time, from 1.5% one-year post-fire to 2.0% three years later, attributed to the accumulation of residues from felled trees. This increase was statistically significant compared to unburned sites.

Other studies have also shown similar trends in organic matter increases following fires (Francos et al., 2018; González-Pérez et al., 2004). Kalbitz et al. (2000) concluded that a pH increase of 0.5 units could lead to a 50% rise in organic matter due to enhanced soil microbial activity, including earthworm activity, which significantly contributes to organic matter accumulation (Kemmitt et al., 2006).

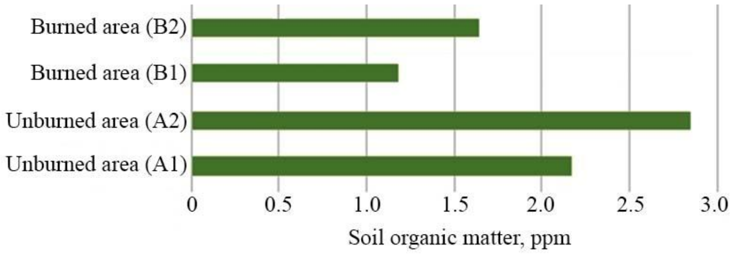

Figure 5. Organic matter content

Chemical and Physical Characteristics of the burned and unburned soils

Table 2 outlines the chemical and physical characteristics of burned and unburned soils, focusing on clay, silt, and sand content. In burned areas, sand content ranges from 71.12 to 71.12%, while unburned areas range from 69.12 to 72.12%. This indicates a notable increase in coarse soil texture due to the loss of fine particles like clay and silt, which may raise the risk of erosion. Obale-Ebanga et al. (2003) also observed a similar rise in coarse particles on the soil surface after fires in Cameroon.

Soil texture significantly affects water retention, and the high proportion of coarse sand in burned plots diminishes their water-holding capacity (Mehdi et al., 2012). Besides, high temperatures during fires can dissolve the binding cements in soil minerals, thereby reducing soil stability (Badia & Marti, 2003; Inbar et al., 2014). The complete loss of the organic layer also lessens the soil's ability to absorb and retain water, leading to increased closure of soil pores due to ash and newly released clay minerals. These further decreases water retention and raises the risk of runoff and erosion (Martin & Moody, 2001). Granged et al. (2011) confirmed a reduction in fine particles like clay and silt as a result of erosion following an increase in coarse soil texture from intense fires.

Table 2. Chemical and physical characteristics of burned and unburned soils

Plot	Clay, %	Silt, %	Sand, %	Textural class
Unburned area (A1)	11.88	18	69.12	Sandy Loam
Unburned area (A2)	9.88	18	72.12	Loamy Sand
Burned area (B1)	12.88	16	71.12	Sandy Loam
Burned area (B2)	12.88	16	71.21	Sandy Loam

Table 2 shows that unburned clay samples range from 11.88 to 9.88%, while burned clay samples range from 12.88 to 12.88%, indicating a decline in soil texture and mineralogy in burned samples. The loss of clay can negatively affect the soil's colloidal properties and structure, as clay is particularly vulnerable to high temperatures that can permanently alter its crystalline structure (Ketterings & Bigham, 2000). Additionally, DeBano et al. (2005) noted that high temperatures during fires may cause clay particles to merge into larger sand-sized particles, resulting in decreased clay content. The Table 2 also shows that burned silt samples measure 16%, compared to 18% for unburned silt samples, suggesting a reduction in silt levels after burning, which could negatively impact the soil's nutrient content due to the loss of organic matter.

Exchangeable Bases (Ca, Mg, Na and K)

From Figure 6, Ca, ranged between 0.98 – 1.30 cmol/kg with the unburned area recorded the lowest values while burned areas had the highest values of 1.30 – 1.35 cmol/kg. For Mg, it indicates that unburned area had 0.40 – 0.50 cmol/kg while the burned areas had 0.49 – 0.51 cmol/kg. This indicates an increased in the cation of the soil. Conversely, sodium (Na) levels have a value of 0.017 – 0.014 cmol/kg for unburned area while burned area has 0.018 – 0.019 cmol/kg hence, there is an increase in Na. From Figure 6, Ca, Mg and Na were higher in all the burned areas therefore, increase the amount of Ca, Mg and Na contain in the soil due to the alkalization effects. Also, these results are in agreement with other studies (Francos et al., 2018; Pereira et al., 2018). Similarly, it was observed that Potassium (K), ranged between 0.094 – 0.087 cmol/kg for unburned area while the burned area has 0.002 – 0.046 cmol/kg. This indicates a decreased in the level of K. This finding is in conformity with the results of Alcañiz et al. (2016), Verma et al., (2019) that the soil's exchangeable K content decreases quickly after a fire.

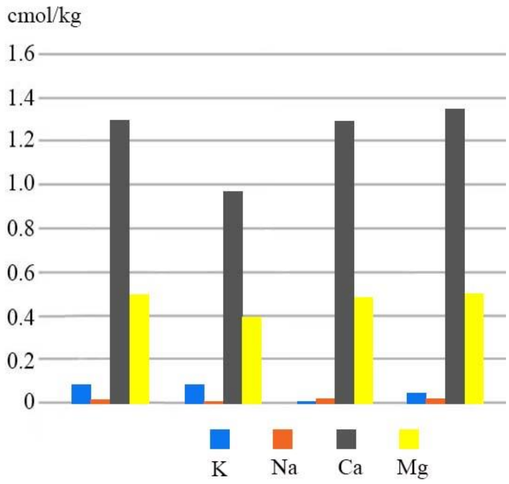

Figure 6. Soil exchangeable bases: Ca, Mg, Na and K

Paired sample T test

The results from the T-Test analysis presented in Table 3 reveal a significant difference between burned and unburned soil samples, with a p-value of less than 0.021 and a mean square of -2.622 at a 95% confidence level. This statistical evidence underscores the profound impact of fire on the chemical and physical properties of the soil. As noted by Fonseca et al. (2017) and Thomaz & Fachin (2014), such alterations can fundamentally change the soil's composition, which may influence its fertility and overall health. The observed differences indicate that fire is a crucial factor affecting soil dynamics, necessitating further exploration of its implications for land management and agricultural practices. Moreover, the findings align with the assertions of Eggleton & Taylor (2008) and Inbar et al. (2014), who emphasize that fire not only modifies the chemical characteristics of the soil but also alters its mineral content. These changes can lead to shifts in nutrient availability, which are essential for plant growth and ecosystem stability. The modification of mineral content may have long-lasting effects, particularly in regions where soil health is already compromised. Understanding these dynamics is vital for developing effective land management strategies that consider the role of fire in shaping soil properties and its broader implications for agriculture and ecological balance.

Table 3. Paired Sample T-Test of burned and unburned soil physical and chemical properties

Particulars	Mean	Standard deviation	Standard Error	Correlation	T statistic	P - value
Burned	9.4454	18.71005	5.00047	0.992	-2.622	0.021
Unburned	-7.7271	18.09067	4.83493			

CONCLUSION

The current experimental study found that bush burning can improve soil fertility in the short term in the Fwangnin area of Bokkos, Nigeria, but also creates conditions for long-term soil degradation. Experimentally, bush burning altered the chemical and physical composition of the soil, resulting in increased soil pH, EC, nitrogen and phosphorus levels. These changes, although potentially beneficial for crop growth immediately following a fire, have significant drawbacks when considered in a broader context. In particular, the increase in alkaline compounds from ash temporarily increases pH and EC levels, enhancing soil reactivity and nutrient availability. However, this alteration disrupts the natural soil environment and promotes nutrient imbalances that can reduce plant productivity over time if left unchecked.

A comprehensive soil study following vegetation burning found a substantial reduction in essential soil components such as organic carbon (OC), organic matter (OM), and cation exchange capacity (CEC). These declines are concerning because they indicate a loss of the soil's structural integrity and nutrient-holding capacity, both of which are vital for sustainable crop production and soil resilience. Organic matter, for instance, serves as a cornerstone of soil health, supporting microbial activity, water retention, and nutrient cycling. Its reduction following fire weakens the soil's stability and resilience, making it more vulnerable to erosion and less effective at supporting diverse plant life. This erosion risk is further amplified by the shift towards a coarse soil texture in burned areas, which diminishes water-holding capacity and exacerbates soil loss during rain events.

Another notable observation is the elevated nitrogen and phosphorus levels in burned soil samples, which can initially boost crop yields but also pose environmental risks. High nitrogen content from burned plant residues may lead to rapid vegetation growth; however, excess nitrogen, if not managed, may leach into surrounding water bodies, contributing to nutrient pollution and eutrophication. Likewise, the increased phosphorus levels, while beneficial to plants in the short term, may disrupt local ecosystems, favouring certain species over others and potentially diminishing biodiversity. Thus, while vegetation burning may offer temporary agricultural benefits, these are outweighed by the adverse environmental impacts and the eventual decline in soil productivity and ecosystem stability.

In addition, the study's statistical analysis underscores the significant difference in chemical and physical properties between burned and unburned soil samples, further validating the transformative effect of fire on soil composition. This transformation extends beyond immediate nutrient shifts, as repeated vegetation burning can fundamentally alter soil mineralogy, leading to long-lasting changes in soil function and quality. These findings underscore the need for effective land management practices that mitigate the adverse effects of fire on soil while optimizing its benefits for agricultural productivity. Sustainable practices, such as reduced or controlled burning and alternative land-clearing methods, could offer solutions to maintain soil health, promote biodiversity, and support resilient ecosystems in the Fwangnin area and similar regions.

Thus, the current study has filled the gap in deep understanding of the impact of vegetation burning on the fertile properties of agricultural soils. Namely, it has been experimentally established and confirmed by the results of similar studies and statistical analysis that while vegetation burning remains a common agricultural practice in Fwangnin, the long-term implications for soil fertility, structure, and ecosystem health are significant. The soil degradation observed in this study suggests that continued reliance on burning as a land-clearing method may undermine agricultural productivity and environmental integrity over time. Moving forward, targeted education and sustainable management practices are essential to balance immediate agricultural needs with the preservation of soil resources for future generations.

Author's statements

Contributions

All authors contributed to the study's conception and design. Conceptualization: S.Z.W.; Data curation: M.I.; Formal analysis: M.I.; Investigation: S.Z.W.; Methodology: M.I.; Project administration: I.T.R.; Supervision: I.T.R.; Validation: I.T.R.; Visualization: A.P.I.; Writing – original draft: S.Z.W.; Writing – review & editing: I.T.R.

Declaration of conflicting interest

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