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RESEARCH ARTICLE

GRASSLAND MANAGEMENT BY BURNING ALTERS SOIL PHYSIOCHEMICAL PROPERTIES OF SANDY CLAY LOAM SOIL

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ABSTRACT

The influence of fire on the physiochemical properties of grassland soils varies with soil texture. Understanding the nutrient fluxes associated with such fires at different soil depths is important for maintaining soil ecosystem functions and processes as well as grassland aesthetics. The study focused on the post-fire burnt and unburnt lawn at the Faculty of Agriculture, University of Nigeria, Nsukka. Soils were sampled in triplicates at the two sites with the aim of evaluating their physiochemical properties at 0-15, 15-30 and 30-45 cm depth. The results indicate that the unburnt soil was characterized by a sandy clay loam texture, good drainage, acidic, high soil organic matter content and low nutrient reserves. The post-fire burnt soil showed a significant decrease in silt (29%) content, and an increase in coarse sand (19%) content and saturated hydraulic conductivity (18%). Additionally, the burning increased soil C:N (51%) but reduced total N (18%) and soil acidity from 3.98 to 4.42 due to increased Ca^{2+} (38%) and the associated decrease in Al^{3+} (49%). The influence of grassland burning at the soil depths changed the sand, silt and clay content with a textural transformation to sandy loam at 0-15 cm depth. Soil available P decreased with soil depth, in addition to P addition (52%) at 0-15 cm depth. For reasons of climate change due to N loss from post-fire burnt soil, management of the grassland through burning should be avoided.

KEYWORDS

lawn, soil nutrients, soil texture, wildfire, post-burned soil, N-losses

1. INTRODUCTION

Grasslands are an important form of land use with increased diversity of management goals and environmental uses. In addition to the aesthetic role and recreational function, grasslands contribute significantly to controlling erosion and runoff and sediment dynamics, protecting and conserving soil and water resources, providing forage for livestock and habitat for wildlife, thus contributing to the attractiveness of the landscape and the stability of ecosystem (Dickie and Parson, 2012; Pyne, 2021; Kocyigita and Demirc, 2022). In addition, grassland represents an important natural sink for greenhouse gases and thus contributes to climate protection. With an estimated gross primary production of 31.3 Pg C yr^{-1} for tropical savannas and grasslands, grasslands have a huge sequestration rate of 0.5 Pg C yr^{-1} due to high belowground C allocation, root turnover, and rhizodeposition (Lorenz and Lal, 2018).

The University of Nigeria Nsukka (UNN) is a vast community within the derived Savanna ecological zone. Although the area is predominantly grassland vegetation, agricultural activities are often considered the main agents of land vegetation loss in the humid tropics, and burning has become the simplest and most practical way of land clearing in preparation for food production (Edem et al., 2020). Even prescribed fire is also considered a component of modern burning in the management of ecosystems, including grassland (Neary and Leonard, 2020). However, rates of nutrient loss from slash fires are among the highest of all fires, and maintaining site fertility depends on a detailed understanding of the nutrient fluxes and losses that accompany such fires (Kauffman et al., 2015).

Fire is the visual manifestation of the physicochemical combustion process that is typically used as a tool to kill unwanted brush, prevent the invasion of poor native or exotic species, and increase forage production (Neary et al., 1999; Wright and Bailey, 1982). In some ecosystem, fire is an important land management tool, but can be a major cause of ecosystem degradation leading to environmental deterioration (Stehling et al., 2000). Fire changes the properties of the soil through direct exposure to high temperatures and ash accretion (Picone et al., 2003). The overall effects of fire on the ecosystem are complex, ranging from reduction or removal of aboveground biomass to impacts on belowground physiochemical and microbial-mediated processes (Delmas et al., 2000).

Fires can have a positive or negative effect on the entire ecosystem, depending on the severity of the fire. Fire impacts on soil properties vary widely and depend on soil type, type and amount of accumulated fuel, soil moisture content, vegetation type, fire intensity, and the environmental conditions before and after the fire (Bayoumi, 2000; Alcañiz et al., 2016; 2018; Ngole-Jeme, 2019). Low-intensity burning can promote herbal flora and increase plant-available nutrients, whereas severe fires often alter succession rates, above- and below-ground species composition, soil organic matter (SOM) mineralization rates and soil hydrological functions, volatilize nutrients and ash inputs, degrade soil physical properties, and reduce the micro- and macrofaunal populations, and associated processes (Neary et al., 1999).

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It is also known that grassland burning fires can causes changes in the micro-climate at the soil-atmosphere interface, contributing to increased global warming due to the emission of N_2O and CO_2 gases into the atmosphere (Poth et al., 1995). On the contrary, a group of researchers found that fire does not increase greenhouse gas emissions in post-burned tropical grasslands characterized by acidic, well drained and nutrient-poor soil (Castaldi et al., 2010). There are many studies on the impact of fire on soil texture and structure (Chandler et al., 1983; DeBano, 1990; Hubbert et al., 2006; Quintano et al., 2019; Granged et al., 2011; Gerhard et al., 2022). Changes in soil texture due to burning affects soil porosity, infiltration rates, and water holding capability of the soil, leading to accelerated water erosion and run-off (Chandler et al., 1983; Neary, 2000; Wittenberg, 2012).

On the other hand, fire is considered an active ecological agent capable of mobilizing nutrients and restoring soil fertility (Úbeda et al., 2005; Maksimova et al., 2015). In fact, one of the most common effects of fire is the alteration in soil organic carbon (SOC), which depends on several factors such as fire type, intensity, and slope (González-Pérez et al., 2004). Few studies recorded an increase in SOC content, although other studies showed no significant change or a decrease after a fire (Chandler et al., 1983; Úbeda et al., 2005; Picone et al., 2003; Valkó et al., 2016; Abdulraheem et al., 2021; Gerhard et al., 2021; Salim et al., 2022). The accumulation of ash on the soil surface after a fire enriches it with nutrients due to increases in P, K, and Ca content, leading to an alkaline pH (Maksimova et al., 2015).

In the UNN community, grasslands are managed by mechanical and manual clearing using a mower and cutlass, respectively, but for economic reasons, fire has been used to clear invasive weeds. Understanding the nutrient fluxes associated with such fires is important for maintaining soil ecosystem functions and processes. Although the effects of fire on soil properties in grasslands abound (Sherman et al., 2005; Neary and Leonard, 2020; Abdulraheem et al., 2021), little is known about the response of different soil textures and depths to burning. The main objective of the study was to assess the physiochemical response of grassland soil layers to burning at the UNN, Nigeria.

2. Materials And Methods

2.1 Location of study

The University of Nigeria Nsukka is located between longitude 7⁰ 24' E and 7⁰ 26' E and longitude 6⁰ 51' N and 6⁰ 53' N and is 400 m above sea level. The vegetation of location is mainly derived savanna, 60-70 % of which is covered with grasses (Igbozurike, 1975). The climate is characterized by tropical wet and dry seasons, with most rainfall falling between April and October at very high intensity, followed by the dry season which last from November to March. The average annual rainfall is about 1500-1600 mm, while the minimum and maximum average temperatures are 26^0C and 31^0C, respectively. The soil at the study location originated from weathered Sandstone.

2.2 Soil sampling and laboratory analysis

The lawn in front of the Cardoso building, Faculty of Agriculture, University of Nigeria Nsukka measures approximately 6418 m^2 and has existed since the faculty was founded in 1960. The lawn is characterized by open grassland with predominantly short grasses and sparse growth of tall grass species, that reach a height of about 1–2 m when overgrown. The major grass species are *Axonopus fissifolius*, *Panicum maximum*, *Pennisetum purpureum* and *Andropogon species*. The lawn was managed by mechanical and manual clearing using a mower and a cutlass, respectively. A 274 m2 area of the lawn in front of the Department of Soil Science's general office, extending to the departmental quadrangle, was burned and an adjacent unburnt area used as a control.

The grassland burning occurred in January 2023, during the harmattan dry season. The fire was ignited by human intervention using some dead and dried surface debris. The intensity and rapid grass fires only lasted a few minutes. Tap water was then used to extinguish the fire and prevent it from spreading to an untargeted area due to wind action. After the field burned, the resultant burnt area consisted of a blackened surface, very few strands of consumed grass, and charred litter surfaces. The burnt depth after the fire can be classified as 'light' (Neary and Leonard, 2020). Therefore, the study examined the effect of heat and ash accumulation on some physiochemical properties two weeks after combustion.

Soil samples were collected using an auger from the post-fire burnt and unburnt areas at three representative points of the entire treatment areas in triplicate at soil depths of 0-15, 15-30 and 30-45 cm. In addition, undisturbed core samples were trim and saturate for 48 h and used for bulk density, total porosity and saturated hydraulic conductivity determinations. Soil handling and sample preparation, including soil analysis were carried out in the Department of Soil Science laboratory, UNN and according to standard laboratory procedures. The auger soil samples were air-dried under laboratory condition and passed through a 2-mm mesh sieve prior to laboratory determinations described below.

2.3 Particle size analysis

Particle size distribution was determined by the hydrometer method, using sodium hexametaphosphate as the chemical dispersant (Gee and Bauder, 1986). The soil bulk density was determined by the core method as described by Blake and Hartage and calculated using the formula in equation 1, while the soil porosity was determined by equation 2 (Blake and Hartage, 1986). Saturated hydraulic conductivity of the soil samples was determined using the constant head method (Klute and Dirksen, 1986).

$$\text{Bulk density} = \frac{\text{Dry soil weight (g)}}{\text{Volume of soil core (cm}^3)} \quad (1)$$

$$\text{Soil porosity} = 1 - \frac{\text{Bulk density(g cm}^3)}{\text{particle density (g cm}^3)} * 100 \quad (2)$$

The pH of the soils was measured in 1:2.5 suspension of soil in 0.1 N KCl using a pH metre. The SOC content was determined by the Walkley and Black wet oxidation method (Nelson and Sommer, 1996), and total nitrogen (TN) determined by the Kjeldahl distillation method (Bremner and Mulvaney, 1982). Soil available P was extracted using Bray II method and measured colorimetrically following the procedure by (Olsen and Sommers, 1982). Exchangeable bases were extracted in ammonium acetate (NH_4OAC) solution, The Na^+ and K^+ were measured by flame photometer, whereas Ca^{2+} and Mg^{2+} were determined by the complexometric EDTA titration. The exchangeable acidity (H^+ and Al^{3+}) were determined using extracts from 1 N KCl (McLean, 1983). Cation exchange capacity (CEC) was determined by the NH_4OAC method at pH 7 (Thomas, 1983).

2.4 Statistical analysis

The experiment was a 2 x 3 factorial in a completely randomized design (CRD). Factor A consists of the post-fire burnt and unburnt soils, while factor B includes the three soil depths (0-15, 15-30 and 30-45 cm). A two-way analysis of variance of the data collected on the different parameters was performed using GenStat (11th edition) for PC/Windows. The test for the significance of treatment means was at 5 % probability, while the separation of means was performed using the least significant difference (LSD).

3. Results And Discussion

3.1 Physical properties of the soils

Table 1 shows particle size distributions of the soils and some soil physical properties. In general, the sand fraction dominated compared to the silt and clay fractions, attributable to the sandstone parent material of study site (Jungerius, 1964). The sand and silt contents averaged 61.67 g kg^{-1} and 15.89 g kg^{-1} in post-fire burnt soil, and 54.56 g kg^{-1} and 20.56 g kg^{-1} in the unburnt soil. Soils from this region are characterized by a high sand and a very low proportion of silt (Igwe 2008; Okebalama et al., 2022). There were significant differences ($p \leq 0.05$) in the proportion of silt and coarse sand between the post-fire burnt and unburnt soils. The 29.39 % decrease in silt content in the post-fire burnt soil is likely due to the aggregation of finer silt particles into larger coarse sand fractions, which was significantly higher in the post-fire burnt soil than the unburnt soil. Despite the observed changes in the silt and coarse sand content of the post-fire burnt soil, there was no change in soil texture as both soils were sandy clay loam.

Table 1: Particle size distribution and some physical properties of the study soils at different depths

Treatment	Soil depth (cm)	…….. Particle size distribution ……				Textural class	Bulk density (g cm-3)	Porosity (%)	Ksat
		Clay	Silt	Fine Sand	Coarse sand				
		………………% ………………							
Treatment effect									
Post-fire Burnt		22.44	15.89	17.89	43.78	SCL	1.35	49.80	56.70
Unburnt		24.89	20.56	17.78	36.78	SCL	1.29	51.24	47.90
	LSD $_{0.05}$	NS	3.18	NS	2.76		NS	NS	8.65
Soil depth effect									
	0-15	19.33	13.33	22.67	44.67	SL	1.31	50.75	55.40
	15-30	24.67	20.00	17.50	37.83	SCL	1.31	50.44	52.40
	30-45	27.00	21.33	13.33	38.33	SCL	1.34	49.43	49.00
	LSD $_{0.05}$	3.48	3.89	4.92	3.39		NS	NS	NS
Interaction effect of treatment and soil depth									
Post-fire Burnt	0-15	15.33	10.33	25.33	49.00	SCL	1.29	51.32	62.50
	15-30	25.33	17.00	15.33	42.33	SCL	1.36	48.80	56.50
	30-45	26.67	20.33	13.00	40.00	SCL	1.39	47.42	51.00
Unburnt	0-15	23.33	16.33	20.00	40.33	SCL	1.32	50.19	48.30
	15-30	24.00	23.00	19.67	33.33	SCL	1.27	52.45	48.40
	30-45	27.33	22.33	13.67	36.67	SCL	1.29	51.45	47.10
	LSD $_{0.05}$	4.93	NS	NS	NS		NS	NS	NS

Ksat = Saturated hydraulic conductivity; LSD $_{0.05}$ = least significant difference at 5 % probability level

On the other hand, the interaction effect of the study site and soil depth showed some significant changes in the percentage content of clay and coarse sand. At a depth of 0-15 cm, the increase in the percentage coarse sand content could have resulted from the cementation of clay particles at the corresponding soil depth, as evidenced by the 52.19 % reduction in clay content in the post-fire burnt soil compared to the unburnt soil. A group of researchers found that intense fires (> 400 ^{o}C) can permanently alter soil texture by aggregating clay particles into stable sand-sized particles and coarser texture (Chandler et al., 1983). This shows that grassland burning has a considerable impact on the clay minerals at the surface soil (0-15 cm depth), which contradicts the report by some researchers that clay minerals are usually not altered to any great extent during a fire due to their low content in surface soil horizons, and the high temperatures > 460 °C required to produce a loss of OH- groups (Giovannini et al., 1988). Thus, the alteration in clay and sand content at 0-15 cm soil depth led to a transformation of the soil texture from sandy clay loam to sandy loam. A group of researchers showed that colour and soil texture are among the soil physical properties that can be altered by fire (Quintano et al., 2019). Additionally, the change in clay and sand content is an indication that the fire caused sufficient soil heating to produce the observed changes, thus supporting the claim of high fire intensity mentioned previously.

The mean bulk density values of the post-fire burnt, and unburnt soils were 1.35 g cm^{-3} and 1.29 g cm^{-3}, respectively, while the soil porosity was 49.80 % and 51.24 %, respectively. The bulk density of the soils was low, indicating that the soil was loose and porous, allowing better air movement and water infiltration, as well as better root penetration. Although the soil bulk density and porosity values are statistically similar in the post-fire burnt and unburnt soils, this is primarily because there was no loss of OC content. A group of researchers also report no significant changes in bulk density at 0-15 cm depth after grassfire burns (Gerhard et al., 2022). However, the saturated hydraulic conductivity in the post-fire burnt was significantly higher (18.37 %) than in the unburnt soil, which could be due to the increase in coarse sand content mentioned above. Therefore, the post-fire burnt soil could be found to have better drainage. Soil saturated hydraulic conductivity is an important determinant of proper hydrologic functioning, especially water movement and storage in the soils.

All the content of the soil separates differed significantly with soil depth without changing the soil textural class. The influence of soil depth on soil particle size distribution showed a significant increase in percentage clay and silt content with increasing soil depth, while the reverse was the case with percentage fine sand content. The trend in clay content with soil depth, which was also determined by the interaction of study site and soil depth is indicative of a clay illuviation process across the soil depth layers of both treatment soils.

3.2 Chemical properties of the soils

The chemical properties of the soils (Table 2) showed a moderately to strongly acid status. The acid pH of the soil could be related to the low concentrations of the base cations due to severe leaching and erosion caused by heavy rainfall in the study region (Igwe, 2004). There was a significant increase in soil pH from 3.98 to 4.42 (pH-KCl solution) in the unburnt and post-fire burnt soils. The slight increase in pH, as also reported by many researchers in post-fire burnt grassland could be due to the high buffering capacity of the soil and the short duration of the fire burn (Sherman et al., 2005; Úbeda et al., 2005; Abdulraheem et al., 2021; Picone et al., 2003). The increase in pH of the post-fire burnt soil could be related to organic acids denaturation by combustion and the liming effect of ash accretion due to the release of oxides, hydroxides, and carbonates and of Ca (Raison et al., 1990). The significant increase in Ca^{2+} (37.74 %) and an associated decrease in Al^{3+} concentration (48.98 %) supports this assertion. The reduced acidity implies improved essential plant nutrients availability, as well as soil microbial nutrient cycling in the post-fire burnt soil.

Table 2: Chemical properties of the study soils at different depths

Treatment	Soil depth (cm)	pH KCl	SOC	Total N	C:N	Avail. P	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	H^{+}	Al^{3+}	CEC	BS
			.......%			mg kg^{-1}	------------------- cmol$_c$ kg^{-1}------------------							%
Treatment effect														
Post-fire Burnt		4.42	0.94	0.11	8.75	3.44	0.73	0.44	0.04	0.08	0.67	0.49	6.58	20.30
Unburnt		3.98	0.76	0.13	5.79	3.11	0.53	0.51	0.03	0.07	0.82	0.73	7.20	17.90
	LSD $_{0.05}$	0.34	NS	0.02	2.34	NS	0.10	NS	NS	NS	NS	0.23	NS	NS
Soil depth effect														
	0-15	4.40	1.05	0.14	8.16	4.70	0.70	0.53	0.04	0.08	0.63	0.47	6.47	23.30
	15-30	4.08	0.80	0.13	6.36	3.03	0.57	0.47	0.03	0.07	0.77	0.63	6.33	18.70
	30-45	4.12	0.71	0.10	7.29	2.10	0.63	0.43	0.03	0.07	0.83	0.73	7.87	15.30
	LSD $_{0.05}$	NS	NS	0.03	NS	0.59	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect of treatment and soil depth														
Post-fire Burnt	0-15	4.77	1.25	0.12	11.00	5.66	0.80	0.67	0.05	0.09	0.60	0.40	6.27	26.50
	15-30	4.23	0.76	0.12	6.75	2.80	0.67	0.33	0.03	0.07	0.53	0.47	6.40	17.50
	30-45	4.27	0.81	0.09	8.49	1.87	0.73	0.33	0.03	0.08	0.80	0.60	7.07	17.00
Unburnt	0-15	4.03	0.84	0.15	5.31	3.73	0.60	0.40	0.04	0.07	0.67	0.53	6.67	20.10
	15-30	3.93	0.83	0.15	5.96	3.27	0.47	0.60	0.03	0.08	1.00	0.80	6.27	19.90
	30-45	3.97	0.62	0.10	6.09	2.34	0.53	0.53	0.03	0.07	0.80	0.87	8.67	13.60
	LSD $_{0.05}$	NS	NS	NS	NS	0.84	NS	NS	NS	NS	NS	NS	NS	NS

SOC = soil organic carbon; C:N = carbon-nitrogen ratio; Avail. P = available P; CEC = cation exchange capacity; BS = base saturation; LSD $_{0.05}$ = least significant difference at 5 % probability level.

The SOC concentration was statistically similar between the post-fire burnt (0.94 %) and unburnt (0.76 %) soils, consistent with the report (Sherman et al., 2005). Conflicting reports of a decrease in SOM of up to 69 % or an increase of about 30 % abound (Picone et al., 2003; Abdulraheem et al., 2021; Salim et al., 2022; Chandler et al., 1983). The SOC concentration was quite high compared to the low total N concentration. The high and similar SOC concentration in both sites and across depths could be due to the intensive litter recycling within the 0-45 cm soil depth, which constitute an important C sink due to the high C sequestration potential of grassland soils (Bai and Cotrufo, 2022). Grassland soils consist of herbaceous fine root turnover that contributes to the development of deep organic matter horizon (Neary and Leonard, 2020). Ecosystems with greater proportions of OM reserves may be less vulnerable to fire-related nutrient losses and sustainability declines (Anderson, 1991).

There was a significant decrease in the total N concentration of the post-fire burnt soil, which may be associated with the release of N_2O gases through volatilization from the combustion of biomass and nitrogen containing OM. Raison linked reduced N content in burned soils to volatilization losses due to fire intensity (Raison, 1979). Nitrogen is most susceptible to losses when soil temperature exceeds 200 ^{o}C; however, a group of researchers reported a significant increase in N immediately after a low-intensity fire and when surface soil temperatures did not exceeded 200°C (Mataix-Solera and Guerrero, 2007; Úbeda et al., 2005). The 18.18% N loss was substantial compared to the reported 7% N loss in post-burnt grassland soil (Picone et al., 2003). This implies that the use of fire to clearing grassland results in minimal emission of nitrous oxide, a greenhouse gas that contributes to global warming. The amount of N lost through volatilization depends on the intensity of the fire, the amount of green material, and the moisture of the fuel (Dunn and DeBano, 1977). Accordingly, the difference in C:N ratio of the post-fire burnt (8.75) and unburnt (5.79) soils suggests that the N loss was indirectly proportional to the oxidized C.

The effect of fire on the chemical properties across the soil depths indicated significant variation in total N and available P concentrations. Although the higher total N in the 0-30 cm depths compared to that in the 30-45 cm depth could have resulted from the degradation of SOM due to heat action, the significantly lower N in the 30-45 cm depth suggests reduced chemical reactions due to reduced heat intensity (Raison 1979). According to a study, only about 5% of the heat from a surface fire is transmitted downwards to the soil (Campbell et al., 1995).

There was no significant variation in the available P concentration between both treatment sites. However, the interaction between study site and soil depth showed a significantly higher available P in the post-fire burnt soil at 0-15 cm depth than in the unburnt soils. The 51.74 % increase in available P in the 0-15 cm layer, indicating the beneficial effect of burning on plant nutrition, could be due to grass burning and the associated release of P as $H_2P0_4^-$ by heating and also by P addition in ash, mainly in the form of Ca polyphosphates (Fassbender, 1975; Úbeda et al., 2005; Raison 1979). A group of researchers also reported a 47.77 % increase in available P at 0-5 cm soil depth in burned grassland soil (Picone et al., 2003). Comparatively, the non-depletion of available P within the 15-30 and 30-45 cm soil layers may probably be due to reduced heat intensity with increased soil depth. Phosphorus is moderately sensitive to heat and can react at a threshold temperature of 774 ºC (DeBano, 1990). This suggests that possible chemical reactions on the colloidal surfaces of heated minerals and/or burned OM were impeded due to insufficient heat, as most of the energy released by combustion of surface fuels was not transmitted beyond 30 cm soil depth.

With the exception of of Ca^{2+} and Al^{3+}, the other exchangeable Mg^{2+}, K^{+}, Na^{+} and H^{+} concentrations, as well as the CEC and percentage BS values, were not affected by the burning, consistent with other studies (Picone et al., 2003; Sherman et al., 2005). However, some studies have reported an increase or decrease in these parameters after fire burn (Arocena and Opio, 2003; Úbeda et al., 2005; Abdulraheem et al., 2021). Due to the high OM content of the study soil, the immediate changes in these parameters may not be significant. Nonetheless, disturbances of both surface and subsurface soil components by burning can have immediate and long-term impact for the entire ecosystem. Immediate impacts arise from the burning of biomass and the release of chemicals in the ash resulting from fire (Neary and Leonard, 2020). In addition, some researchers have shown that each nutrient element has a certain threshold temperature and therefore responds differently to heat (DeBano, 1990; Pellegrini and Jackson, 2020). According to DeBano, sensitive elements such as N and S have a threshold temperature between 200-300 ºC, moderately sensitive elements as K and P have a threshold temperature of 774 ºC, and relatively sensitive elements as Mg and Ca have a threshold temperature between 1107-1962 ºC (DeBano, 1990).

4. Conclusions

The grassland soil studied were mainly sandy clay loam, strongly acidic, rich in OM and available P but poor in total N and exchangeable cations. Grassland burning changed the soil particle size content and improved the saturated hydraulic conductivity of the post-fire burnt soil, thereby improving drainage. Grassland burning depleted total N and reduced soil acidity through effects on Ca^{2+} and Al^{3+} concentrations. The change in soil texture from sandy clay loam to sandy loam, and the improvement in available P concentration due to grassland burning was limited to 0-15 cm. Thus, the effect of grassland burning on soil physiochemical properties varies with soil depth. Therefore, grassland burning has a positive effect on some soil physiochemical properties and a negative effect on increasing atmospheric N_2O, a greenhouse gas that contributes to global warming.

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