THE EFFECT OF LATE AND EARLY BURNING ON SOIL PHYSICO-CHEMICAL PROPERTIES, PLANT SPECIES COMPOSITION AND ABUNDANCE AT FALGORE GAME RESERVE, KANO

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DECLARATION

I declare that the work in the thesis entitled "the effect of late and early burning on soil physico-chemical properties, plant species composition and abundance at Falgore Game Reserve, Kano" has been performed by me in the Department of Biological Sciences under the supervision of Prof. S. P. Bako and Dr. D. B. Dangora.

The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at any university.

Minjibir, Sadiq Adamu _____ _____

Signature Date

CERTIFICATION

This thesis entitled "THE EFFECT OF LATE AND EARLY BURNING ON SOIL PHYSICO-CHEMICAL PROPERTIES, PLANT SPECIES COMPOSITION AND ABUNDANCE AT FALGORE GAME RESERVE, KANO" by Minjibir, Sadiq Adamu meets the regulations governing the award of the degree of Master of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This thesis is dedicated to my parents' late Alhaji Suleiman Abubakar Sambo and Hajiya Rablatu Abdulnafiu.

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ABSTRACT

The effects of early and late burning on Falgore Game Reserve were studied for two seasons from December, 2008 to August, 2009. The Reserve lies in the Guinea Savanna zone of Kano state. Three plots adjacent to each other were selected and subjected to three different burning regimes. Composite soil samples were collected at 0-15 Cm depth and analyzed for particle size distribution, percentage available Water, soil pH, percentage Organic Carbon, percentage Nitrogen, Phosphorus and the cations, Sodium, Magnesium, Calcium and Potassium. Plant species composition and abundance was determined by quadrat method. From the result species diversity index and species evenness were calculated. The data collected were analyzed by SAS statistical software to test for significant differences at 5% level of significance. Where significant differences occur Least Significant Difference (LSD) was used to separate the means. Evaluation of obtained data on the effects of burning on the soil indicated that both early and late burning led to significant increases in soil pH, organic carbon, nitrogen, and phosphorus. Na, K, Ca, and Mg likewise produce increases. The increase was probably due to rapid mineralization of organic matter. This increase was however, higher for plots burnt early. There was a marked increase in percentage silt and clay content. Percentage available water decreased in both late and early burnt plots. Burning decreased species diversity and species evenness. However, number of individual leguminous plants species increased. Positive correlation was noted between most of the physico-chemical soil properties.

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ABBREVIATIONS AND SYMBOLS

O.C	Organic Carbon
N	Nitrogen
P	Phosphorus
Ca	Calcium
Mg	Magnesium
Na	Sodium
K	Potassium
CMol/kg	Meq/100g (Miliequivalent per 100 grams)

DEFINITION OF TERMS

Ashbed effect: The accumulation of thick layers of ashy residue on the soil surface after fire resulting from combustion of concentrated fuels

Cover**:** the area on the ground covered by the combined aerial Parts of plants expressed as a percent of the total area.

Diversity**:** the relative degree of abundance of wildlife species, plant species, communities, habitats, or habitat features per unit of area.

Fire: A manifestation of a series of chemical reactions that result in the rapid release of the heat energy stored in (living and dead) plant by photosynthesis.

Fire behavior: the manner in which a fire burns in response to the variables of fuel, weather and topography

Fire regime: periodicity and pattern of naturally occurring fires in a particular area or vegetative type, described in terms of frequency, biological severity, and areal extent

Forb: A broad leaved herbaceous plant that is not a grass.

Fuel: A combustible plant material, both living and dead that is capable of burning.

Fynbos: A South African scrubland.

Invader species: Plant species that were absent in undisturbed portions of the original vegetation and will invade under disturbed or continued overuse.

Leach: Removal of soluble constituents from ashes or soil by percolation of water.

Litter: The top layer of forest floor typically composed of loose debris such as branches, twigs, little altered in structure by decomposition. Loose accumulation of debris fallen from shrubs, or dead parts of grass plants laying on the surface of the ground.

Native species: A species which is part of the original fauna or flora of the area in question.

Organic matter: That fraction of the soil that includes plant and animal residues at various stages of decomposition.

Prescribed (Planned) fire: Is a deliberate use of fire to meet specific management objectives.

Slash: Concentrations of Wildland fuels resulting from human activities such as logging, thinning e.t.c

Species composition: is a term relating the relative abundance of one species to another using a common measurement; the proportion (percentage) of various species in relation to the total on a given area.
Species richness: A measurement or expression of the number of species of plants or animals present in an area.

Surface fires: Fire that burns surface litter, dead woody fuels, other debris on the forest floor, and some small vegetation.

Surface runoff: This is water flow that has not infiltrated into the mineral soil and flows off the surface to a stream channel.

Tiller: New growth in a graminoids that originates from dormant auxillary buds.

Wildfire: A free burning and unwanted Wildland fire requiring suppression action.

CHAPTER ONE

1.0 INTRODUCTION

Fire is a natural phenomenon that plays a major role in shaping our environment and maintaining biodiversity world wide (Shlisky *et al*., 2007). Fire (along with insects and microorganisms) is responsible for the decomposition of dead organic matter and the recycling of nutrients. Without fire, plant debris can accumulate and nutrients are tied up in dead vegetation (Turshak, 2010). It often determines the distribution of habitats, carbon and nutrient fluxes, and the water retention properties of soils. It is an important factor in many of the world's grasslands especially in semi arid regions where burning, annually or every few years is a well established practice. (Duffy *et al.*, 1974). Fire resulting from natural phenomena (e.g. lightening and volcanic eruption) probably played their part in molding the earth's vegetation and animal life long before the advent of man. Fire has now become an integral part of the environment in many areas, contributing to the evolution and maintenance of plant communities (Raison, 1979). It is used as a tool in the management of forests and grasslands in a number of tropical forests and temperate climates. Farmers in various tropical countries use fire in one way or another in their agricultural practices (Ewusie, 1980). The time of the year, or even the time of the day, when the fire is applied has been shown to be important in nearly every effect of burning. Fire can be used to remove accumulated, inedible grass, stimulate the growth of succulent and nutritious new grass, influence the distribution of animals in the range, remove fire hazard, especially in areas which contain forest, stimulate range grasses to produce seeds and encourage the growth of natural legumes for forage and soil improvement.

Burning is commonly regarded as the fastest, cheapest and most convenient means for the removal of plant residues and other debris from the land in readiness for seed bed preparation for a new cropping season in the West African Savanna ecological zone (Iwaufor, *et al.*, 2000). The slash and burn clearing technique is a wide spread traditional agricultural practice in Africa and indeed Nigeria to remove agricultural residues. However, unplanned fires are often left unattended and can spread, thus negligence is the most common cause of fire throughout Africa. The practice is advantageous for destruction of weed seeds and rapid release of nutrients to crops. It however, causes serious loss of nutrients through exposure to leeching, surface runoff, destruction of organic matter, fauna and flora (Jaiyeoba, 2000).

Volatilization of certain elements and modification of soil particles are two obvious direct effects of fire on the soil and its minerals (Raison 1979, Hesler and Hobbs 1992, Shiqiang *et al.,* 2006, Abdulhameed *et al*., 2006). Typically, fire alters the concentration of soil nutrients (Faulkner and de la Cruz, 1982; Vogl, 1969; Wilbur and Christensen, 1982; Smith *et al.* 2001), although the nature of these alterations can be quite variable. In some cases, nutrient levels increase after fire (Kutiel and Shaviv, 1993; Marion *et al*., 1991; Tomkins *et al*., 1991), while in others no enrichment occurs (Laubhan, 1995; Weiss, 1980). Alternatively, nutrients may be lost through volatilization, leaching, and/or export of ash particles by updrafts during the burning process and wind (Turner *et al*., 1997).

The tropical savanna covers about a third of the world's land surface, including over half of Africa and Australia and 45% of South America. The key determinants of the structure of these savannas are rainfall, soil nutrients, fire and herbivory (Kennedy and Potgieter, 2003). Fire in the savanna ecosystems is a necessary disturbance which influences

vegetation structure, composition, nutrient recycling and distribution and therefore, fires which burn in the natural fire cycle are stabilizing the savanna ecosystems. In Africa, anthropogenic fire originated and has existed longer than any where else (Pyne *et al.,* 2004). Studies based on fire scars showed that Africa is the most fire-prone continent in the world. An estimated 2.3 million km^2 (230Million Hectares) or 7.7 percent of the continent burned in 2000, which is 64 percent of the global total of just over 3.5 million km^2 (JRC-EU, 2005). It also had the highest number of fires (54%) as indexed by the number of fire scars. The same result was recorded in 2004. In Nigeria 3,190, 000 hectares of the country was burned (FAO, 2006).

Falgore Game Reserve is one of the numerous protected ecosystems in Africa south of the Sahara. It is set up to protect the natural biodiversity along with its underlying ecological structure and supporting environmental processes, and to promote education and recreation. Fire in such protected areas is used as a management tool to protect biodiversity and reduce the menace of accidental burning.

Fire occurs almost every where during the dry season in the savanna and it is generally recognized that this ecological factor has fundamentally altered the original vegetation of such regions (Ola-Adams and Charter, 1982). In Nigeria, burning represent a useful cultural tradition that cannot be done away with. Majority of wildfires in Nigeria are caused by human activities and lightening fires are very rare because these occur mainly in the rainy season (Adedoyin and Olanrewaju, 2006). It is expected that through burning, vegetation removal, combined with changes in soil physical properties, will increase the intensity of erosion.

Sprouting is an adaptation to fire that is a common attribute of hardwoods and shrubs. Grasses are usually well adapted to fire, mostly by having their survival buds at or below the soil surface. These adaptations include the ability of species to sprout after fire due to protected buds arising from rhizomes, runners (stolons), buds, corms and notable tufted habits. (Cremer, 2004). This ability of a plant to sprout is related not only to the species and the size of the parent plant, but also to the environment in which it is growing and the intensity of the fire (Tappeiner, 2008).

1.1 Statement of the Problem

Fire serves as an important function in maintaining the structure of certain ecosystems, but as a result in misuse of fire, it is now a threat in many forests and savannas and their biodiversities. There is little deposit or accumulation of litter under Savanna conditions. Annual fires to which most of the Savanna is subject soon destroy any accumulation of litter. In consequence, Savanna soils are usually deficient in organic matter and quickly loose the little they have under cultivation. Falgore Game Reserve is one of the numerous protected ecosystems in Africa south of the Sahara. Among the problems of the Reserve is indiscriminate burning of vegetation which can subsequently change the grass composition and forage value of the Reserve. Furthermore, it is generally assumed that much burning in the dry season in the relatively drier savanna exposes the soil to torrential rain impact and facilitates erosion. This is a serious threat to the land resources of the savanna. Repeated grass fires destroy organic matter and bring about other changes affecting fertility. Nitrogen and Phosphorus which are limited in the Savanna soil are lost during the burning process, and although non volatile elements are returned to the soil after fire, many of them may be lost through erosion and leaching.

1.2 **Justification of the Research**.

Soil is the most valued resource endowment in Nigeria second only to that of human resource. Moreover, the fate of the people of Nigeria and the rest of West Africa as well, rest upon fertility of Savanna soil for food production. In Africa there is a serious deficiency of knowledge concerning the behaviour of fires, and its effect on the soil physicochemical properties, especially in the Savanna and grassland areas of the continent. A lot of research have been documented over the years on the effect of fire on soil properties and plant distribution in many Game Reserves in Nigeria (Yankari Game Reserve, Olokemeji and Kainji Game Reserve), but little or none had been conducted at the Falgore Game Reserve.

1.3.Aim of the Research

The aim of the research is to determine the influence of soil burning on the physico-chemical properties of the soil, plant species composition and abundance.

1.4 Objectives of the research.

The objectives of the research are:

- To investigate the influence of time of burning on the soil physico-chemical properties of Falgore Game Reserve.
- To investigate the influence of time of burning on plant species composition and abundance.
- To investigate the effect of different burning regimes on plant species diversity of the Reserve.

1.5 Hypotheses

- Time of burning does not significantly affect the physico-chemical properties of Falgore Game Reserve.
- Time of burning does not significantly influence plant composition and abundance of Falgore Game Reserve.
- Different burning regimes do not significantly affect plant species diversity of the Game Reserve.

CHAPTER TWO

2.0. LITERATURE REVIEW

Fire is a widespread process in the earth system and plays a key role in ecosystem composition and distribution (Bond *et al*., 2005). Wildland fires are a widespread seasonal phenomenon in Nigeria and many parts of Africa and millions of hectares of forests and savannas are burnt annually. Fires can be initiated both by lightning and humans. However, in Nigeria fires are mainly caused by human intervention and its frequency is rapidly increasing. Nomadic cattle herdsmen use fire to stimulate grass growth for livestock, while subsistence farmers use fire to remove unwanted biomass while clearing agricultural lands, and to eliminate unused agricultural residues after harvest (Adedoyin, 2004).

According to Neary *et al.,* (2005) fire is a manifestation of chemical reactions that result in the rapid release of the heat energy stored in (living and dead) plants by photosynthesis. Fire alters the physicochemical properties and even the microbial composition of the soil. This in turn modifies the abundance and distribution of the soil biota and the structure of the vegetation (Afolayan, 1973, Aremu, 2002, Abdulhameed *et al.*, 2006). Fire may adversely affect the physical, biological, and chemical aspects of forested systems, depending on the intensity and duration of the heat produced, degree of biotic destruction, and climatic conditions at the time of fire (Neary *et al*., 1999).

Among the different effects of fire, are the mineralization of organic matter and loss of soil nutrients through volatilization, leaching and accelerated erosion (Marafa, 1998).

Raison (1979) recognized three basic effects of burning on plant communities:

- The direct action of heat on plants and soils.
- The removal of litter and standing crops, thus creating new microclimates and
- The redistribution and changed availability of nutrient elements.

2.1 Fire Behavior

Raison (1979) reported that, wind speed and direction, soil and plant moisture content, and special distribution of fuel have marked effects on the behavior, intensity and consequences of fires. The extent of soil modification varies with fire severity, fire temperature, fuel moisture levels, fuel loads in the soil, plant tissue nutrient concentrations, plant tissue combustibility, and other environmental factors (Kutiel and Shaviv, 1989; Scott and Van Wyk, 1990; Gunderson and Snyder, 1994; Robichaud and Waldrop, 1994; Pantami *et al*., 2010). The factors influencing the behaviour of fires will include fuel, air temperature, relative humidity, wind speed and slope (Trollope *et al*., 2002). Similarly, Paliwal *et al*. (2002) attributed the effect of fire on the nutrients of an ecosystem to the type and frequency of fire, the fuel load, time and season of burn, nature of plant tissues burnt, topography, successional status of the community and post fire climatic and biotic conditions acting there upon.

Moreover, the response of plants to fire is influenced by a variety of fire parameters including intensity, severity (e.g. amount of organic matter consumed), residence time, soil heating, season of burn, and time since last fire, all of which can vary significantly among fires and within a fire. Early- season prescribed burns are often conducted under high fuel moisture conditions than late-season burns, leading to reduced fuel consumption and fire severity (Kauffman and Martin, 1989; Knapp et al., 2005). Severity consists of two components, intensity and duration. Severity is controlled by several environmental factors

that affect the combustion process, such as amount, nature, and moisture of live and dead 'fuel', air temperature and humidity, wind speed, and topography of the site (Certini, 2005; Keely *et al.,* 2005).

2.2.Effects of Fire on Soil

Soil is a heterogeneous mixture of mineral particles and organic matter that is found in the uppermost layer of Earth's crust (DeBano and Neary, 2005). The physical, chemical and biotic properties of soil may be altered by fire through numerous complex processes across spatial and temporal scales (De Bano *et al.,* 1998). Chemically, fire-impacted soils experience changes in nutrient pools cycling rates, loss of elements to the atmosphere, and loss of organic matter. Biological properties are altered by changes or loss of microbial species and population dynamics, reduction or loss of invertebrates, and partial elimination (through decomposition) of plant roots (DeBano *et al*. 1998). Early studies of surface fire effects on nutritional and physical properties of soils in Southeastern coastal plain of Australia suggested that on balance, fire had slightly detrimental effect on physical properties and slightly beneficial effect on nutrition (Boyer *et al*., 1994). Although the most severe impacts on soils occur in stand-replacing wildfires, prescribed fires can produce local effects (Neary, 2004).

2.3.0. Effects of Fire on Physical Properties of Soil.

Physical impacts of fire on soil include breakdown in soil structure, reduced moisture retention and capacity, and development of water repellency, all of which increase susceptibility to erosion. Fire also affects soil bulk density, erosion, hydrophobicity, and moisture. Burning above 300°C increases bulk density, clay and silt content and decreased organic matter and sand content (Stool, 2010). During burning, plant cover and litter layers

are consumed, and the mineral soil is heated, resulting in changes to soil bulk density, porosity, texture, color, moisture content, and permeability (Hubbert *et al*., 2005; DeBano *et al*. 2005). However, several studies by Allen (2006) reported either an increase or no change in bulk density following fire. Negative effects of fire on soil are caused primarily by high temperatures that affect surface as well as deeper soils (Neary *et al.,* 1999; Korb *et al.,* 2004), while low- and moderate-temperature fires generally have long-term positive benefits for fire-adapted ecosystems (DeBano *et al.,* 1998). The extent of fire effects on soil physical properties varies considerably depending on fire intensity, fire severity, and fire frequency. The weather, topography, and available fuel will determine the temperature and intensity of the prescribed burn, and this along with the timing of the treatment; largely determine how the burn impacts the vegetation and the abundance of particular species (Tu *et al*., 2003). In general, most fires do not cause enough soil heating to produce significant changes to soil physical properties (Hungerford *et al*., 1990, Kennard, 2009).

Fire destroys all or part of the organic forest floor and vegetation thereby altering infiltration and percolation capacity of the soil by exposing it to raindrop impacts (Neary *et al.*, 2000). Fire may affect soil water content through changes in infiltration, water repellency, evapotranspiration, and rainfall interception. Most factors indicate burning should dry soils, but soil water is commonly similar between burned and unburned sites (Ewing and Engle, 1988; Soto and Diaz-Fierros, 1997). Fire effects on infiltration have been neutral to slightly negative (Ueck- ert *et al*., 1978; Knight *et al*., 1983; Pierson *et al*., 2001; Mills and Fey, 2004; Vermeire *et al*., 2005).

2.3.1 Soil pH

Soil acidity otherwise known as pH is a most crucial factor in determining the performance of soils with respect to plant growth. Besides controlling the degree of nutrient availability to plants, it also controls microbial environment necessary for optimum crop growth (Okoye, 1995).

Soil pH is inexorably increased in non calcareous soil by the soil heating as a result of organic acids denaturation. Less intensive burning often increase soil pH, stimulates nitrification, and improves soils chemically (Certini, 2005). Increases in soil pH following fire have been widely reported (e.g., De Ronde, 1990, Diaz-Fierros *et al*., 1990, Kutiel *et al*., 1990, Litton *et al*., 2003), Increases in pH have been attributed to the release of basic cations during combustion and their deposition on the soil surface, this increase in pH increases the availability of Phosphorus, Calcium, Magnesium, and Potassium (Smith *et al*., 2008). The response depends on the amount of ash and buffering capacity of the soil and is considered negligible in grasslands (Smith *et al*., 2008).

2.4 Effects of Fire on Plant Nutrients.

Differences in soil properties, time, duration and even intensity of burning all together would have a particular effect on the availability and concentration of soil nutrient (Abdulhamid *et al*., 2006). According to Sanford (1982), Burning has possible detrimental effects, which include: The wasting of all the energy released by fire, the loss of organic matter so vital in the soil for water-holding capacity and cations exchange, the loss through volatization of nitrogen and sulfur, (these elements are often primary and secondary limiting factors to production in the tropics). The most intuitive change soils experience during burning is the loss of organic matter (Certini, 2005). Organic matter (OM) located

on, or near, the soil surface is rapidly combusted. The changes in OM, in turn, affect several chemical, physical, and microbiological properties of the underlying soil. Fire, especially of high severity or long duration, can result in volatilization of nutrients held on the exchange sites of organic matter. It accelerates the mineralization of organic matter, making inorganic nutrients more readily available (Dunn and DeBano, (1977); Wells *et. al*., (1979).

Fire acts as a rapid mineralizing agent that releases nutrients instantaneously as contrasted to natural decomposition processes, which may require years or, in some cases, decade as in acrid climates, where decomposition of litter and dead wood occurs slowly (St. John and Rundel ,1976). Burning recycles nutrients into the soil as mineral-rich ash, providing a nourishing environment for seed germination and regeneration of post fire plant. Fire tends to temporarily boost fertility, not only by releasing the nutrients in the combusted plant materials, but also by the 'ash bed effect' (Wilkinson *et al.,* 1993, Williams *et al.,* 1995). Although some nutrients are volatilized and lost after fire, most nutrients are made more available (DeBano, 1990). Combustion of live and dead 'fuels' or removal of litter layers may result in enhanced nutrient availability (Raison, 1979, Knapp and Seastedt, 1986, Brewer, 1995). Castelli and Lazzari (2002) agreed that controlled burning on a general note causes a considerable flush of the available nutrients. The increase was however, temporary and generally, the nutrients levels returned to those of the unburned soils during the second or third year after burn. Phosphorus, Magnesium, Potassium, and Calcium increases following fire as a result as an abrupt release of elements, which in the absence of fire would only have become gradually available through the slow decay of plant litter

Nutrients lost due to prescribe burning through convection, runoff, or leaching are generally insignificant. (Bruhjell and Tegart, 2010).

The amount of nutrients lost due to soil heating is dependent on the depth of penetration of volatilizing temperatures. Losses of nutrients may be due to surface erosion (Wells *et al.,* 1979), movement below the root zone from leaching (Stark, 1979), dilution effects of increased runoff (DeBano and Conrad, 1978), and losses in fly ash (DeByle, 1976). Nutrients with low volatilization temperatures, notably N and S, can be lost at relatively low temperatures. Whereas S can be volatilized at 300°C, N can begin to volatilize at temperatures as low as 200°C (Fisher and Binkley, 2000). Because most soil N is contained in organic matter, the amount of N lost by volatilization is closely related to the amount of organic matter lost (DeBano *et al*., 1998). Those nutrients with high volatilization temperatures (i.e., >1000°C), such as Ca, K, and Mg, are usually incorporated into ash (Covington and Sackett, 1984; Fisher and Binkley, 2000; Meyer *et al.*, 2004). These nutrients may thus show an increase in concentration at or immediately below the soil surface where they are subject to movement by wind and or water erosion (Wells *et al*., 1979). Organic material is always lost in fires, as the primary constituent, Carbon (C), volatilizes at 180°C (Allen, 2000).

The amount of nutrients lost due to soil heating is dependent on the depth of penetration of volatilizing temperatures. Soil organic matter (SOM), or humus, increases soil water-holding capacity and aggregation and typically contains 90% or more of soil nitrogen (Dicosty, 2008). Soil organic matter can begin to be lost at temperatures 100°C while 85% can be lost at temperatures 200 to 300°C (DeBano *et al*., 1998). Available Nitrogen and Phosphorous (P) produced during the fire increase the supply of available nutrients in the

soil until plants become established and are able to utilize them. The elevated levels of available N and P found immediately after burning decrease to prefire levels with in 1 year (DeBano, 1997).

2.5.0 Chemical effect of Fire on Soil.

The modification of chemical properties of the by fire is directly related to the degree of soil heating and the biomass and spatial distribution of vegetation and litter accumulation (Castelli and Lazzari, 2002). The soil chemical characteristics most commonly affected by fire are organic matter (OM), carbon (C), nitrogen (N), phosphorus (P), sulfur (S), cations, cation exchange capacity, pH and buffering capacity Some purely chemical reactions occur in soils. These include the exchange of cations adsorbed on the surface of mineral soil particles and humus with their surrounding solutions (Knoepp *et al*., 2005). The chemical changes in soils brought about by burning are similar regardless of the type of burning; it is only the degree that may differ coupled with the type and intensity of burning. Fire may maintain greater soil Carbon stocks than long unburnt stands but depends on frequency and intensity (Oseni *et al*., 2004, Annan, 2009).

2.5.1 Nitrogen

Nitrogen is the most important nutrient lost during combustion and by erosion following fire, because larger amounts are lost, and it is the most limiting nutrient in chaparral ecosystems (DeBano 1989). The amount of Nitrogen lost during burning will vary depending upon the amount of above ground biomass, litter, and soil organic matter pyrolyzed during a fire. Fire intensity, amount of green material, and fuel moisture has been reported to influence the amount of Nitrogen lost through volatilization (Dunn and Debano, 1976, Murphy, 2005). Although there is ample evidence that N in organic matter

is volatilized, some authors report an increase in total soil N (which would include organic N, nitrate, and ammonia) after a fire (Chen, 2010). The amount of total Nitrogen volatilized during combustion has been reported to be directly proportional to the amount of OM combusted (Raison *et al*., 1985).The immediate response of soil organic N to heating is a decrement because of some loss through volatilization (Fisher and Binkley, 2000). However, a substantial portion of soil organic N survives low intensity fires, probably by changing its form. Although total N is lost, available ammonium-N and P increase substantially as a result of burning. Over one-half of the soil N can be lost when the temperature is raised to 500°C (Allen, 2000). Direct volatilization of N during combustion of litter can result in large losses of N from the ecosystem. In a review of the impacts of fire on nutrient cycling, Boerner (1982) reported net losses of 30-100% of litter N during fire as the result of direct volatilization and ash convection. During fire and soil heating, N can be transformed into N_2 and volatilize into the atmosphere (DeBell and Ralston, 1970).

2.5.2 Phosphorous (P).

Forest fires do not necessarily have the same impact on soil P as on N, because losses of P through volatilization or leaching are small. Nevertheless, the combustion of Vegetation and litter causes impressive modifications on biogeochemical cycle of P. Burning converts the organic pool of soil P to orthophosphate (Cade-Menun *et al*., 2000), the sole form of P available to biota. Furthermore, the peak of P bioavailability being around pH 6.5 (Sharpley, 2000), any fire-induced change in soil pH toward neutrality has a positive effect in this regard. Schrissema (1977) found the availability of phosphorus to vary by treatment site. However, others have found availability to increase with burning (Christensen, 1976,

and Raison, 1979). Fires result in an enrichment of available P (Serrasolsas and Khanna, 1995), but this enrichment is destined to decline sooner or later. White and Gartner (1975) found an increase in available P only if temperatures did not exceed 392° F (200° C).

2.5.3 Exchangeable ions

Chemical ions generally become more available in the top soil as a result of fire. Grove *et al*., (1986) found that immediately after fire, extractable nutrients increased in the 0-3 cm depth. Concentrations of Sulphur(S), Ammonia (NH_4), phosphorous (P), Potassium (K), Sodium (Na), zinc (Zn), Calcium (Ca), and Magnesium (Mg) increased. All nutrients except Zn and organic C increased in terms of total nutrients.

Sanford (1982) has reported that in Nigerian savanna, mild fires at the beginning of the dry period resulted in increase in cation exchange capacity, available phosphorus, exchangeable calcium, magnesium and potassium and in percentage base saturation. However, hot fires coming late in the dry season were found to reduce the cation exchange capacity and exchangeable calcium and potassium, while exchangeable phosphorus and exchange capacity remained unchanged and the percentage base saturation only slightly increased. Reports by Christensen (1976), Raison (1979) indicated that, availability of Potassium (K), calcium (Ca), and magnesium (Mg) may increase after fire. Concentrations of cations, such as Ca^{2+}, Mg^{2+}, and K^{+}, and the anion SO_4^{2-} increase considerably in the soil solution immediately following burning (Khanna and Raison 1986 In Certini, 2005). Fire often causes increases in soil exchangeable Ca^{2+} and Mg^{2+} because their relatively high volatilization temperatures (>1240°C and >1107°C, respectively) are not usually reached during wildfires (Raison *et al*., 1985; Neary *et al*., 1999; Allen, 2006). Losses of Ca and Mg from the forest floor during fire are usually limited to particulate forms in

smoke and fine ash (Raison *et al*., 1985; Trabaud, 1994). Potassium, phosphorus, and sulfur volatilize at lower temperatures (>760, >774, and >800°C, respectively) and may be volatilized in intense fires such as under downed logs (Raison *et al*., 1985) or left in ash in less intense fires.

2.6.0 Biological effects of Fire

Soil heating directly affects microorganisms by either killing them directly or altering their reproductive capabilities. Indirectly, soil heating alters OM (energy source) and increases nutrient availability, thereby affecting subsequent microbial growth (DeBano, 1990). Fire alters the soil microbial community composition and activity directly (in the short-term) through selective heat-induced microbial mortality (DeBano *et al*., 1998). For instance, bacteria tend to be more resistant to heat induced by fire than fungi; hence, bacteria generally increase in relative abundance compared to fungi immediately following even moderate-intensity fires (Pietika¨inen and Fritze, 1995). Jurgensen *et al.* (1979) reported a decrease in bacterial populations, after a burn but increase three- to tenfold within a month because soil temperatures and nutrients for their growth are more favorable. An important group of soil microorganisms that are particularly sensitive to soil heating during a fire are endo- and ectomycorrhizae (DeBano, 1990). In many ecosystems, microbial C and N increase after the first year of burning and decrease after prolonged annual burning compared to unburned controls (Ojima *et al*., 1990; Fritze *et al*., 1994; Pietikäinen and Fritze, 1995; Anderson *et al*., 2004, Dai *et*. *al*., 2006). Although the relationship between soil heating and microbial populations in soil is complex, it appears that duration of heating, maximum temperatures, and soil water all affects microbial responses (Dunn *et*. *al*., 1985).

Eom *et al*. (1999), found that annual spring burning increases fungal abundance while decreasing species richness. On the contrary, a study by Badia and Marti (2003) indicated that heating soils in a simulation of fire effects significantly decreased fungal abundance.

2.6.1. Effect of Fire on Plant Species

High temperatures during fires can result in direct damage to plant tissue through combustion, and indirect damage to the physiological processes through radiant heating (Levitt, 1972). Plant tissue that is metabolically inactive or dehydrated can withstand greater heating than tissue that is metabolically active or hydrated (Whelan, 1995). Thus, burning during a plant's active growing season often results in the highest mortality rates (Brooks, 2006). Plants are more susceptible to fire injury when they are actively growing compared to periods of dormancy or early growth (Anderson *et al.*, 1970, Gross, 2005). Growing season burns have been shown to cause higher mortality and result in less postfire biomass of grasses and forbs, relative to dormant season burns (2005).

Fire effects on plants depend on the timing of burning (Towne and Owensby, 1984; Brown and Whelan, 1999). Burning increases, flowering, enhance vegetative vigour, and productivity, increased as well as decreased mortality, and increase seed germination and recruitment (Glen-Lewin *et al*., 1990, Lesica, 1999). When used correctly (with respect to timing, frequency and intensity), fire and disking not only set back succession, but also determine plant species composition and structure, which directly influence quality of habitat and forage quality. Temporal variability in carbohydrate reserves may make plants more or less vulnerable to the effects of burning at different times of the year (Dahl and Hyder, 1977; Caldwell, 1984; Busso *et al.*, 1990; Kowalenko and Romo, 1998).

In chaparral, both diversity and aliens species increased markedly several years after fire (Keeley *et al*., 2003). Akinsoji (1988) found shrub cover was significantly reduced after a fire, but cover of other fire resistant species of forbs and grasses increased compared with an adjacent unburned area. Early rising soil temperatures stimulate the increase of certain bacteria that decompose organic matter. This allows warm-season grasses to grow at an optimum rate if moisture is adequate. Most of the fertilizing effects after a fire result from nitrates released by bacteria consuming organic matter, not from nutrients in the ash (Sharrow and Wright 1977). On the other hand, Launchbaugh (1973) stated that yield reductions were associated with the removal of dormant growth by burning. The net effect was less soil moisture available for plant growth due to exposure to extreme winter temperatures and increased respiration. He added, however, that when mulch accumulations are excessive, burning will result in greater yields.

Besides creating favorable sites for pioneer species, grassland fires directly affect seed germination and seedling establishment of native annuals. Vareschi (1962) found that soil temperature in many types of grassland can reach 140 F (60°C) for several hours after a fire due to solar radiation. This was not detrimental to the seeds of native annuals; soil surface temperatures of even 194 F (90°C) for a few seconds were not harmful to most seeds. Fire can influence seed production and mortality, release seed from dormancy, reduce competitive inhibition from overstorey and grass layers and often enhance soil nutrient availability (Whelan 1995; Bond and van Wilgen 1996). A fire of mild intensity may stimulate high seedling establishment and growth by raising the soil temperature and nutrient status by removal of plant litter and vegetation cover (Mallik and Gimingham, 1985; Paliwal and Sundaravalli, 2002). Seedling emergence in many fire-prone

communities occurs primarily in the first wet season following fire (Williams *et al.*, 2005). This has been documented for species of Californian chaparral (Keeley and Bond, 1997), South African fynbos (Pierce & Cowling, 1991).

In tropical savannas, fire is known to enhance seedling emergence of some perennial grasses, such as *Heteropogon contortus* (Williams *et al.*, 2005). The abundance of some savanna species in north-eastern Australia increases in the year following fire (Williams *et al*., 2003) and may result from increased vegetative reproduction and/or seedling emergence. It also promotes survival of seedlings by, reducing competition (for light, water and nutrients) and improving the contact between soil and any newly shed seed (Stoneman, 1994 in Williams *et al*., 1995). Spring burning stimulates the growth, tilering, and seed production of warm season grasses. Cool season grasses and woody plants decrease in abundance with frequent fires. Fire has been demonstrated to break seed dormancy of several forbs and grass species of this community, with a greater proportion of legume seeds released from dormancy by late rather than early dry season fires (Williams *et al*., 2005). *Acacia* seed germination is stimulated by fire, through heat or smoke (Auld *et. al*., 1991; Enright *et. al*., 1997). Germinable soil seed bank size, suggesting the density of seed available to be influenced by fire, is also larger in the late dry season than the early dry season (Williams *et al*., 2005).

Fires tend to eliminate the more sensitive species and thus favour the more resistant species. Frequent fires favour species that recover by sprouting, not those that depend on seed (Wilkinson *et al*., 1993). Some invasive species can successfully be managed using fire but in cases where the species are fire adapted the result may be an increase in vigor and abundance of the invader species (Tu *et al*., 2001).

2.7. Effects of Fire on Erosion

Fire has tremendous effect on both physical and chemical properties of soil, wind and water erosion (Morgan, 1991). Burning lays bare the soil surface and so runoff and erosion are often increased. Increase in runoff lead to a reduction in the amount of percolating and subterranean stored water. Severe heating of soil breaks down the structures of the organic parent materials, destabilizing soil. After severe fire, the loss of plant nutrients and destabilization of soils can inhibit plant regeneration resulting in increased runoff and erosion (Smith *et al*., 2008). The greater the soil heating, the slower the recovery of vegetation and organic matter pools, which are essential for reducing erosion potential on bare soil (Meyer, 2004). Surface runoff can increase by as much as 70% when less than 10% of the soil surface is covered with plants and litter. Erosion can be three or more times more severe in burnt areas (Robichaud *et al*., 2000). Singh (1995) reported that discouraging burning of vegetation and over grazing may reduce the menace of erosion. Uncontrolled burning can prevent plants from re-establishing and, by increasing the extent of bare ground result in serious erosion; however, controlled burning is essential for the removal of undesirable plant species. Areas that have experienced substantial erosion due to fire are less productive and become difficult sites for vegetation establishment (Weber, 2004).

2.8. Effects of Fire on Fauna

Fire plays an important role in shaping the habitat for many animal species. Like plant species, some animal species benefit from regular firing of their habitat whilst others are disadvantaged. Three levels on which fire affects animals were identified (whelan *et al*., 2002, Engstrom, 2010). First, fire can cause injury or death to individuals, or it can motivate

individuals to move from or into the burned area. Second, if enough individuals within a population survive, processes after the fire, such as starvation, predation, or immigration within the post-fire environment, will determine population viability. Third, the fire regime can modify a species over time to create adaptations to fire. Generally, the direct effects of fire on soil-dwelling invertebrates are less marked than those on microorganisms, due to the higher mobility that enables invertebrates a greater potential to escape heating by burrowing deep into the soil. However, the indirect effects of fire, particularly litter mass reduction, are effective at decreasing drastically both total mass and number of species of soil dwelling invertebrates (Certini, 2005).

Studies have also suggested that insect population are depressed immediately during the first prescribed fires but will increase gradually after consistent annual fires, once burn-sensitive species are eliminated. A study conducted by Anderson *et al*., (1989) found that total insect biomass decreased after the first year burn, but was not affected after being burned more times.

CHAPTER THREE

MATERIALS AND METHOD

3.1 Study Area

The study was conducted at Falgore Game Reserve, Kano. The Reserve occupied parts of the boundries of Tudun Wada, Doguwa and Sumaila local governments in the North, South and North-East respectively of Kano state. It borders Saminaka local government, Kaduna State in the extreme South West; it also shares boundaries with Lame-Burra Forest Reserve, Ningi local government, Bauchi State on the South east. It lies between latitudes 10° 50′N and 11° 20′N and longitude 8° 35′E and 8° 45′E. The Reserve lies in the Nigerian Northern Guinea Savanna zone and covers a total area of about 920 sq km. The mean annual temperature is about 24°C, but mean monthly values ranges between 21°C in the coolest months(December/January) and 31°C in the hottest months(April/May) (Olofin, 1987). The mean annual rainfall was 738.1mm spread through the months of April to October with highest rainfall recorded in August. The soils are highly leached, acidic, high in silt clay particles and very low in organic matter (<0.5%) (FAO, 1974).

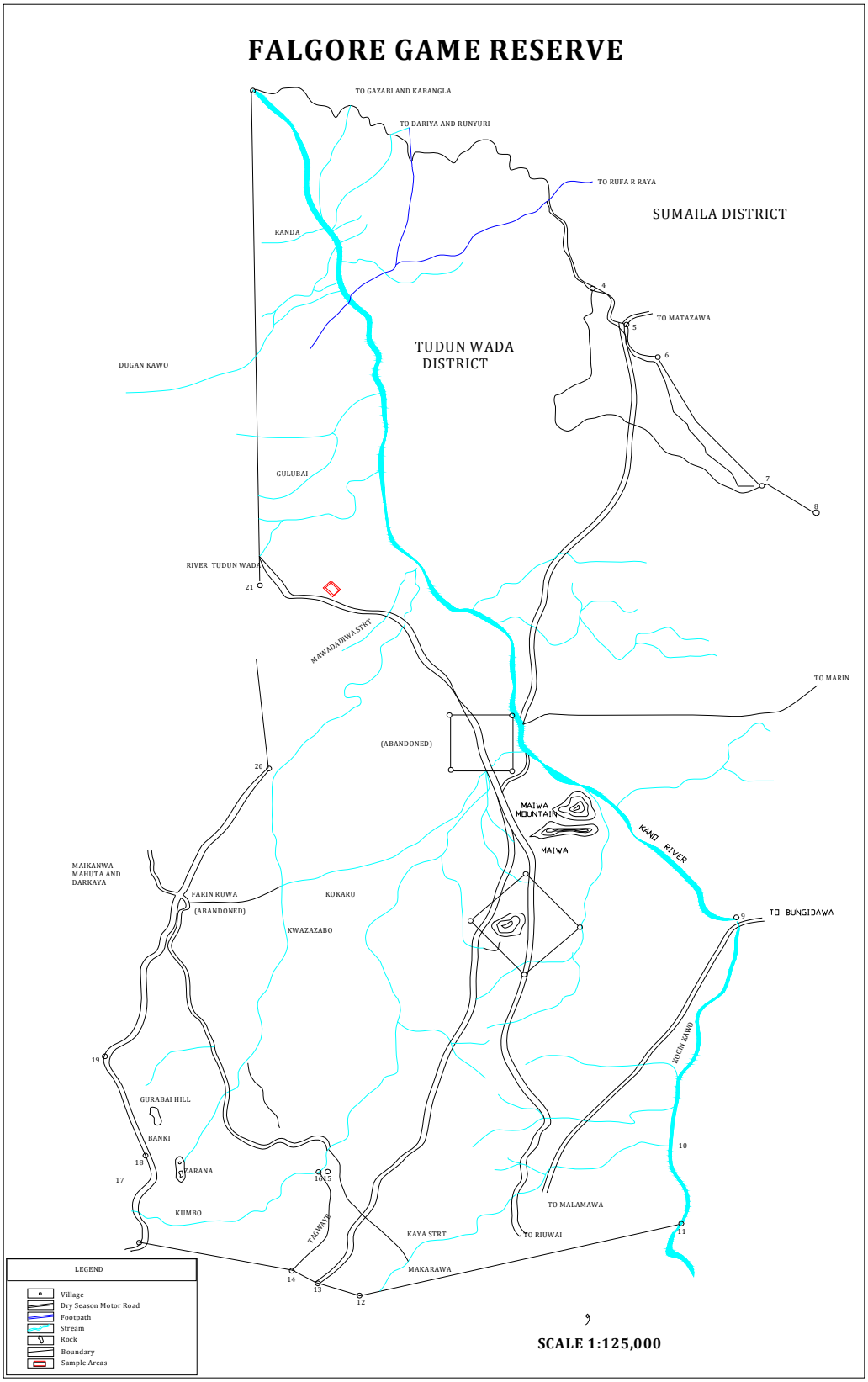


Fig 1: Map of Falgore Game Reserve Showing the Sampling Site

3.2. Field Layout

Three plots were selected within the Reserve. Each plot was $100m^2$ and separated from other vegetation by fire traces of 10m wide to prevent uncontrolled burning. The plots were adjacent to each other and were labeled, A, B and C. plot A was subjected to burning in the early dry season of December (Early burning), plot B was burnt in the late dry season in March (Late burning), while plot C was left unburnt (control).

3.3. Soil Sampling and Preparation.

In each of the plots, five sub plots were established each measuring $20m^2$. Three soil samples were collected in each of the subplots from the upper (0-15cm) using a 5cm diameter soil auger and mixed to make a composite sample. Thus five soil samples were taken in each plot. The soil samples were collected 2 weeks after each burning treatment and in August at the peak of the rainy season. The soil samples were thoroughly mixed and spread out on a piece of polythene to air dry under the shade (25-35°c). The soil samples were taken to the laboratory for preparation in polythene bags. In the laboratory, the dried soils were grinded with a porcelain mortar and pestle and passed through a 2mm sieve to remove debris and coarse fragments. The soil samples were then stored in polythene bags for laboratory analysis.

3.4. Experimental Design:

A completely randomized block design was employed during the study. The set up was replicated three times.

3.5.0. Physicochemical properties Analysis

3.5.1. Particle Distribution

Soil particle distribution was determined using hydrometer method as described by Gee and Bauder (1986).

Procedure: Fifty grams of processed soil was taken in a 1 litre glass cylinder. About 50 ml 0f 5.0% sodium hexametaphosphate (Calgon) together with 100ml of distilled water was added. The suspension was stirred with a glass rod and allowed to stand for 30 minutes. The glass cylinder was filled with water up to the 1000ml mark. The suspension was highly agitated and the hydrometer was placed in the suspension and the reading taken after 40 seconds. The suspension was allowed to stand for about 2 hours. A second .reading was taken with the hydrometer.

Calculations:

$$\text{Percentage clay} = \frac{corrected\ 2hr\ reading - blank}{weight\ of\ sample} \times 100$$

$$\text{Percentage silt} = \frac{corrected\ 40sec\ reading - blank}{weight\ of\ sample} \times 100$$

Percentage sand = 100-(% silt + % clay).

The blank was run in distilled water and calgon without the soil sample.

3.5.2. Moisture Content

Soil moisture content was measured gravimetrically as outlined by Agbenin, (1995).

Procedure: Aluminium moisture pans were heated in an oven to dry off any moisture that may have adhered to the surfaces, and then cool in a dessicator. The cooled pans were

weighed on a balance and the weight noted. Approximately 2g of air dried 2mm sieved soil was added to each pan and the weight noted. The pans were placed in an oven and the temperature was raised to 110°C and left for 10 hours or over night. Prolong heating may lead to organic matter destruction. The soil was transferred to the dessicator and allowed to cool for 15-20 minutes. The pan and dry soil were reweighed. Long exposure of the soil to moisture was avoided.

The percentage water was calculated using the oven-dried soil as given by the equation:

$$\text{Percentage water} = \frac{\textit{Weight of air dried soil} - \textit{Weight of oven dried soil}}{\textit{Weight of oven dried soil}} \times 100$$

3.5.3. Soil pH

Soil pH was determined using glass electrode pH meter both in distilled water and 0.01M $cacl_2$ using 1:1 soil solution ratio.

Procedures: Soil pH was determined in the ratio 1:1 soil to water and 0.01M $CaCl_2$ suspensions, using glass rod electrode pH meter (Model 290MK2). About 20g of air dried soil was placed into a 50ml plastic beaker. Twenty milliters of distilled water was added and stirred with a glass rod; it was allowed to stand for 30 minutes and re-stirred. The suspension was allowed to stand undisturbed for about 30 min before the glass electrode was immersed into the beaker, care taken not to touch the bottom. The pH was recorded after 30 sec this was also done in 0.01M $CaCl_2$ suspension. The pH meter was however, calibrated using pH buffers 4, 7 and 9 before recording commenced. The electrode of the pH meter (Model 290MK2) was inserted into the partly settled suspension and the pH was observed. The soil pH in $CaCl_2$ was also determined in the same way and reported as soil pH measured in water and $CaCl_2$ respectively.

3.5.4. Soil Organic Carbon

Soil organic carbon was analyzed using wet oxidation method of Walkley and Black (1934) as described by Okalebo *et al.* (2002).

Procedure: One gram of soil was weighed into 250ml Erlenmeyer flask and 5ml of 1N Potassium permanganate ($K_2Cr_2O_7$) pipette into it and gently swirled to disperse the soil. 10ml of conc. H_2SO_4 was immediately added and also swirled for a minute. This was allowed to stand for 30 minutes before 100ml of water was added, followed by 3-4 drops of ferrion indicator. This was then titrated with $FeSO_4$ solution. A blank was determined in the same manner except that no soil was included.

Percentage organic carbon in soil = (me $K_2C_20_7$-me $FeSO_4$) × 0.003 × 100 × (f)

Where correction factor, f = 1.33, and

me = Normality of solution × ml of solution used.

3.5.5. Total Phosphorus

Total Phosphorus was determined by Bray No 1 acid Floride method as outlined by Juo, 1979.

Procedure: Seven milliliters of P extractant was added to 1g of soil into a centrifuge tube with a stopper. The mixture was shaken on a mechanical shaker for 1 minute and the suspension centrifuged at 2000rpm for 15 minutes. Two milliliters of supernatant was pipetted into a 20ml test tube. About 5ml of distilled water and 4ml of ascorbic acid was added and make up to the mark with distilled water. It was allowed to stand for 15 minutes for the colour to develop. The colour development was measured at 660nm on Corning

Colorimeter 253 and the absorbance read. The standards were also measured in the same way.

3.5.6. Total Nitrogen:

Total Nitrogen was determined by macro-Kjeldahl digestion procedure as described by Nelson and Sommers (1982).

Procedure: Two grams of processed soil was weight into a dry 500ml digesting tube. 20ml of distilled water was added and the flask was swirled for a few minutes and allowed to stand for 30 minutes. About 5g of catalyst and 20ml of conc. H_2SO_4 were added. The mixture in the tube was cautiously heated in a digesting block for 2hrs. The tube was allowed to cool before washing content into a volumetric flask and made up to the mark with distilled water.

Ten milliliters of 40% boric acid (H_3Bo_3) was added into a 500ml Erlenmeyer flask which was then placed under the condenser of the distillation apparatus. Ten milliliters of 10N Sodium hydroxide (NaOH) was slowly added to the 10ml pipette. About 50ml of the distillate was collected and titrated with 0.025N H_2SO_4 using 2-3 drops of indicator and the end point of titration was observed (green to pink). A blank was run without soil sample.

Calculation:

$$\text{Percentage N (\%)} = \frac{0.014 \times VD \times N \times 100 \times TV}{Wt\ of\ soil \times AD}$$

Where VD = Volume of digest =100ml

N = Normality of acid =0.025N

TV = Titre value

And AD = Aliquot of digest =10ml

3.5.7. Exchangeable Bases

Exchangeable bases (Na, K, Ca, and Mg) were extracted in 1N neutral ammonium acetate solution according to Chapman, as described by Anderson and Ingram (1998).

Procedure: Two grams of soil was taken and 10ml of 1N Ammonium acetate was added. The mixture was shaken on a mechanical shaker at high speed (200 oscillations per minute). The solution was centrifuge at high speed for 5 minutes. The supernatant was poured into plastic specimen bottles for analysis. The cations Ca and Mg were estimated by the more sensitive atomic absorption spectrophotometer (AAS), while Na and K were determined by flame photometry which is less sensitive and does not require very high temperatures.

3.6.0. Plant Species Composition and Abundance

3.6.1. Plant Species Distribution: Plant species composition was determined by throwing a quadrat (50×50cm) and then counting the total number of species and the total number of individuals of each species within the area (Cox, 1995). Plot samples were replicated three times, in a simple random way to ensure that the data represent an unbiased picture of the system. The plant Species were collected, pressed and taken to Department of Biological Sciences Herbarium, Ahmadu Bello University (A.B.U.), Zaria for identification.

3.7. Statistical Analysis

The data collected were analysed using Analysis of variance (ANOVA) using SAS computer statistical software to test for significant differences in soil physicochemical properties between the late and early burnt plots and between soils collected during the dry and rainy seasons. Where significant difference exists means were separated by least significant difference (LSD).

Pearson correlation coefficient was used to test if there is relationship between soil physic-chemical properties. Shannon Weiner diversity index was used to determine plant species diversity.

CHAPTER FOUR

RESULTS

4.1 Soil Physical Properties

The mean texture values (Table 4.1) generally indicated higher sandy content. The general pattern was sandy > silt > clay. There was an increase in percentage silt and clay content of the soil with burning; this increase was however, greater in the late burnt plots than the early burnt. From the textural triangle the soil type is sandy loam.

Table 4.1 Soil Particle Size Analysis of the Unburnt (Control), Early Burnt and Late Burnt Plots.

Soil particle	Unburnt (control) (%)	Early burnt (%)	Late burnt (%)
Sand	71.5±3.7	68.3±4.41	63.7±3.07
Silt	16.1±2.11	18.5±1.63	21.7±1.50
Clay	12.4±1.38	13.2±0.93	14.6±1.10

The pattern of effect of fire on the soil particle size is as indicated below:

	Control	Early burn	Late burn
Sand	>	>	>
Silt	<	<	<
Clay	<	<	<

Burning reduced percentage available water; it ranged between 9% in the late burnt dry season plot to 14% in the unburnt wet season plot (Table 4.2). Burning and season significantly affected percentage available water. The interaction between burning and season was also significant (Appendix B).

The soil pH in water was significantly higher in the burnt plots. The pH ranged from 5.35 in the unburnt wet season plots to 6.84 in the late burnt plots in the dry season. Same results were recorded for soil pH in $CaCl_2$ with higher pH in the both the early and late burnt plots than the unburnt plots. However, the pH was higher in the dry season plots than the wet season plots (Table 4.2).

Table 4.2 Mean Values of Soil pH, Percentage available Water for Early, Late, and Unburnt plots for Falgore Game Reserve.

Dry season	pH water	pH $CaCl_2$	% Available Water
Early Burnt	6.49b	5.27b	11.03d
Late Burnt	6.84a	5.45a	9.52e
Unburnt	5.91c	4.77c	12.11b
Wet season			
Early Burnt	5.63d	4.35d	12.08b
Late Burnt	5.56d	4.67c	11.43c
Unburnt	5.35e	4.47d	14.27a
S.E.±	0.044	0.039	0.09
L.S.D.	0.125	0.122	0.31

Means with the same letter in the same column are not significantly different 0.05%

4.2. Soil Chemical Properties

Percentage soil organic carbon (OC) recorded a significant increase with burning. It ranged from 0.86% late burnt in the wet season to 1.52% recorded in the early burnt wet season plot indicating a 76% increase (Table 4.3). The mean square table indicated a highly significant difference with burning treatment. However, no significant difference was recorded between seasons (Appendix B). Similarly no significant difference was noted in the interaction between burning, season, and subplots.

Soil of the early burnt dry season plot had approximately 48% higher Nitrogen (N) than soil from the unburnt dry season plot. The percentage soil Nitrogen ranged from 0.05 to 0.08 (Table 4.3). This difference was highly significant. However, the interaction between burning, season, and subplot was not significant. There was also no significant difference between seasons (Appendix B).

Table 4.3 Mean values for Soil Chemical Properties for Falgore Game Reserve

Dry Season	OC (%)	N (%)	P (Mg/Kg)	K(Cmol/Kg)	Mg(CMol/Kg)	Na(CMol/Kg)	Ca(CMol/Kg)
Early burnt	1.20b	0.08a	8.47b	0.22c	1.79a	0.15a	3.87a
Late Burnt	1.18b	0.07b	4.90d	0.27b	1.00b	0.13a	2.58b
Unburnt	0.98c	0.06c	3.94e	0.14a	0.65c	0.09b	2.60b
Wet Season							
Early Burnt	1.52a	0.07b	11.18a	0.25b	1.10b	0.14a	2.25c
Late Burnt	0.86d	0.05d	2.36f	0.30a	0.74c	0.13a	1.85d
Unburnt	0.95c	0.06c	5.80c	0.29a	0.61c	0.12a	2.32c
S.E.±	0.038	0.003	0.168	0.024	0.057	0.019	0.067
L.S.D.	0.108	0.009	0.480	0.068	0.164	0.054	0.193

Means with the same letter in the same column are not significantly different 0.05%

Burning significantly increased Phosphorus (P) ($P< 0.01$).The increase in P with burning in the dry season was approximately 115% recorded in the early burnt plot. In the wet season the burnt plot had a 93% increase. No significant difference was noted between seasons in both the burnt and unburnt plots. The early burnt plots recorded a higher increase in P than the late burnt plots, in both the dry and wet season.

Soil from the dry season early burnt plot had significantly higher Calcium (Ca) than soil from the dry season late burnt and unburnt plots (48% and 50% respectively). However, soil from the wet season late burnt plot had significantly lower Ca than soil in the wet season early burnt and unburnt plots (3% and 20% respectively). Moreover, the result indicated a highly significant difference between seasons (Appendix B). No significant difference was recorded on the interaction between burning, season and subplot.

The highest mean Magnesium (Mg) of the soil samples of 1.79 Cmol/Kg for the dry season was recorded in the early burnt plots (Table 4.3). The lowest mean recorded was in the unburnt plot (0.65 Cmol/Kg). Similarly in the wet season the highest mean recorded was 1.10 Cmol/Kg in the early burnt plot and the lowest value of 0.61 Cmol/Kg for the unburnt plot. The mean square value has indicated a highly significant difference with burning. Significant difference ($P< 0.01$) was also observed between seasons. However, no significant difference was noted for the interaction between burning, season and subplot.

Soil mean Sodium (Na) content was highest (0.15 Cmol/Kg) in the early burnt dry season plots, lowest mean Na (0.09 Cmol/Kg) was recorded in the unburnt dry season plots. However, soil from the wet season plots and the late burnt dry season plots do not differ significantly. Burning significantly effect Sodium. However, there is no significant effect

between seasons. The interaction between burning, season and subplot was also not significant.

Dry season late burnt plots had significantly higher Potassium (K) (0.27Cmol/Kg). The lowest mean K value of 0.14Cmol/Kg was recorded in the dry season unburnt plots. No significant difference was recorded between the mean values of K in the wet season. Highly significant difference was noted with burning. Similarly there was a highly significant difference between seasons. However, no significant difference was observed in the interaction between burning, season and subplot.

4.3. Plant Species Composition

A total of 3462 individual plants were recorded in the 45 Quadrats sampled. The early burnt plots had the highest number of plants 1477, ($\bar{x}$-36). This was followed by the unburnt plot with 1065, ($\bar{x}$-25) plants, while the least 903, ($\bar{x}$-21) were recorded in the late burnt plot. A total of 14 plant species representing 7 families were recorded in the study. Both late burnt and unburnt plots were represented with 12 species each while the early burnt plots had 11 species.

The family Poaceae was the dominant family with 6 species. This was followed by family Papilionoideae with 3 species. The families Euphorbiaceae, Araceae, and Amaryllidaceae were each represented by 1 species (Table 4.4). The dominant plant is *Thelepogan elegans* with a mean of 142 plants per quadrat. *Dactyloctenium aegyptium* followed with 69 plants per quadrat. The least represented was *Pennisetum hordeoides, Acalypha ciliata, Amorphophallus abyssinicus* and *Crinum arnatum* with 1 individual each (Table 4.5).

Table 4.4 Mean Values of Individual Species for Early, Late and Unburnt Plots

Family Species	Early burnt	Late burnt	Unburnt (Control)
Poaceae			
Thelepogan elegans **Ruth**	203	84	140
Dactyloctenium aegyptium **(L) Wild**	72	63	72
Setaria pallidefusca **(Schumach) B.K. Simon**	59	36	48
Pennisetum purpuream **Schumach**	26	16	22
Pennisetum hordeoides **(Lam) Steud**	-	-	1
Eragrostis spp **Latz**	19	13	16
Papilionoideae			
Senna tora **(L) Roxb**	47	55	10
Desmodium scorpiorus **Desv (S.W.)**	23	12	11
Desmodium triflorum **(L) D.C.**	38	16	31
Liliaceae			
Urginea indica **Kunth**	4	2	1
Euphorbiaceae			
Acalypha ciliata **Forssk**	-	-	1
Acanthaceae			
Nelsonia canescens **(Lam) Spreng.**	5	1	2
Araceae			
Amorphophallus abyssinicus **(A.Rich) N.E. Br**	-	1	1
Amaryllidaceae			
Crinum ornatum **Linn (L.F. ex Aiton)**	1	2	1
Mean number of individuals(N)	497	301	357
Number of species(S)	11	12	12
Shannon-Weiner index (D)	1.837	1.929	1.773
Evenness index (E)	0.571	0.573	0.491

Table 4.5 Mean Values of Individual Plant Species Count

Plant species	Count
Thelepogan elegans **Ruth**	142
Dactyloctenium aegyptium **L (Willd**)	69
Setaria pallidefusca **(Schumach) B.K. Simon**	48
Senna tora (**L.) Roxb.**	37
Desmodium triflorum (**L) D.C.**	29
Pennisetum purpuream **Schumach**	21
Eragrostus sp **Latz**	16
Desmodium scorpiorus **Desv (S.W.)**	15
Nelsonia canescens (**Lam) Spreng.**	2
Urginea indica **Kunth**	2
Amorphophallus abyssinicus (**A.Rich) L.E. Br**	1
Acalypha ciliata **Forssk**	1
Pennisetum hordeoides (**Lam) Stued**	1
Crinum ornatum **Linn. (L.F. ex. Aiton)**	1

Mean square for plant species composition indicated a highly significant difference with both early and late burned plots. Similarly the interaction between burning, quadrat, and species was also significant ($P< 0.01$) (Appendix B)

Early burnt plots have the highest mean number of plants, (37.87). It was followed by the unburnt plot with 25.37 plants. The least mean number of plants was recorded on the late burnt plot (21.49) (Table 4.6), this implies that mild burning encourages phytobiodiversity.

Table 4.6 Mean Values of Plant Count by Burning Treatment, Early, Late and Unburnt Plots

Treatment	
Early Burnt	35.87a
Late Burnt	21.49c
Unburnt	25.37b
S.E. ±	1.43
L.S.D.	4.09

Means with the same letter in the same column are not significantly different 0.05%

4.4 Correlation

Soil pH was highly significantly related to Nitrogen, Calcium and Magnesium (Table 4.7). Magnesium was positively significantly correlated to all the soil parameters analyzed except potassium ($P<0.01$). Calcium was significantly correlated with soil pH, Nitrogen, and Magnesium ($P<0.01$), while it was significant ($P<0.05$) with Phosphorus and organic carbon. Highly significant correlation also exists between Organic Carbon and Nitrogen, Phosphorus, and magnesium. It was also significant for sodium ($P<0.05$). Nitrogen was also significantly correlated with Phosphorus, Calcium, and Magnesium. Sodium was positively correlated with Potassium and Magnesium ($P<0.01$) and Phosphorus and Organic carbon ($P<0.05$). K had a negative correlation with pH, O.C, N, and Ca, although it was not significant.

Table 4.7 Trellis of Correlation Values

	pH water	pH $Cacl_2$	O. C	N	P	Ca	Mg	Na	K
pH water	1.000								
pH $Cacl_2$	0.869**	1.000							
O C	0.215*	-0.014	1.000						
N	0.271**	0.175	0.524**	1.000					
P	0.028	-0.085	0.549**	0.447**	1.000				
Ca	0.501**	0.47**	0.237*	0.318**	0.238*	1.000			
Mg	0.439**	0.405**	0.384**	0.355**	0.474**	0.586**	1.000		
Na	0.01	0.152	0.238*	0.072	0.252*	0.187	0.407**	1.000	
K	-0.143	-0.042	-0.085	-0.058	0.011	-0.161	0.114	0.0304**	1.000

CHAPTER FIVE

DISCUSSION

5.1 Soil Physical Properties

A marked increase in percentage silt and clay were recorded in both the early and late burnt plots. This increase suggested the fragmentation of large sand particles into finer particles thereby changing soil textural characteristics which attended soil physical properties. This agrees with observations of Abdulhameed *et al*., (2006). Stool *et al.* (2010) who also recorded increase in bulk density, clay and silt content and decrease organic matter and sand after burning to above 300°C. Conversely, Hubbert *et al*., (2006) reported a significant reduction from 5.4% to 3.1% in clay fraction after burning. Soil moisture content was significantly reduced with burning. This may be due to evaporation of most of the water near the soil surface and evapotranspiration. DeBano, (1979) reported a moisture decrease of 80% from 20.1cm^3 cm^{-1}pre fire to 4.1cm^3 cm^{-1} post fire at soil depth of 0-1cm beneath chaparral vegetation. The late burnt plots observed an increase in pH of 14.33% and 4.97% respectively for the dry and wet seasons. The increase in soil pH of the burnt plots may be due to destruction of organic acids and liberation of bases and addition of charcoal to the soil by burning. The decline in pH in both late and early burning during the wet season may be attributed to the loss of ash due its removal by being blown away by wind and run off by rain. A decrease in soil acidity was reported by several authors. Mott and Popence, (1977), Litton and SantelIces, (2003). Di Tomaso and Johnson, (2006) reported increase in soil pH after burning. Mican and Abrams, (1995) reported an increase of 0.25 units in pH after burning.

5.2. Soil Chemical Properties

An increase of 22% and 60% in percentage Organic carbon content with early burning in the dry and wet seasons was noted respectively. This increase may be due to an abrupt release of carbon from the litter layer. This concurs with findings of Boerner *et al*. (2000) that observe slight increase in Organic Carbon after burning. Soil of the early burnt wet season plot had approximately 48% more Nitrogen than soil from the unburnt dry season plot. This difference was significant ($P< 0.01$). Wan *et al*. (2001) has recorded an increase in mineral N concentrations in the soil surface after burning. An increase in available Nitrogen pool was also reported by Boerner *et al*. (2000), Knoepp *et al*. (2004). Chen *et al*., (2010) also reported significantly higher total N, and total P values than those of non burnt plot. However, losses recorded in the wet season may probably be due to surface erosion, leaching or transport of ash. Neff *et al*. (2005) recorded that OC and N may be reduced by as much as half for high intensity wildfire as unburned soils.

Phosphorous is probably the second most limiting nutrient found in natural ecosystems. A high effect was noted in the amount of Phosphorus increase with burning, a value of 115% increase in P was recorded after burning in the dry season, while an increase of 93% was noted for the wet season plots, and this was significant at ($P < 0.01$). The early burnt plots recorded a higher increase in P than the late burned plots, in both the dry and wet season. Phosphorus levels probably increased as a result of ash deposition following fire. DeBano (1989) reported an increase in P of 200% during a prescribed fire in Arizona. Nadel *et al*. (2007) recorded a short-term increased in available Phosphorus. Grove *et al*. (1986) reported increase in concentration of P immediately after fire .This increase can be

followed by a long-term decline due to decrease in organic P, Phosphate activity, and myccorhizal infection (Klopatek *et al*., 1988, Saa *et al*., 1998).

Calcium and Magnesium has experience a significant increase with burning. Whereas Ca recorded 32% increase in the dry season plots and a loss of 3% in the wet season plots, Mg experience a 175% increase after burning. The decline in mean Ca may be attributed to the leaching effect during the rainy season. Mican and Abrams, (1995) reported an increase of 12.1 times in Ca and 4.8 times in Mg after burning. Increase in Ca and Mg after burning was also reported by Knighton (1977), Afolayan (1977) and Bruhjell and Tegart (2010). Neff *et al*., (2005) reported unchanged content of Potassium, magnesium and Phosphorous. In contrast Pantami *et al*. (2010) recorded lower Ca and Mg value in both late and early burnt plots than the unburnt plots. Similarly, Abdulhameed *et al*. (2006) recorded a decline in Na and Ca with burning; which is significant for Ca in the late burnt plot.

About 67% and 13% increase in Na was noted after burning during the dry and wet seasons respectively. This is as a result of its release by burning and the inability of Na to be volatilized at temperatures below 1,450°C. This agrees with the work of Abdulhameed *et al*. (2006) at Yankari Game Reserve that reported an increase of 50% and 40% in Na for late burnt and early burnt plots respectively. Conversely, Pantami *et al*. (2010) reported a decrease in Na for both light and intense burned plots in dry sub humid Savanna agro ecological zone of northern Nigeria.

Potassium had an increase of between 3.4% and 93% increase with burning. However, the highest increase was in the late burnt wet season plots. Total Potassium content was significantly higher than those of non burnt land (Chen *et al*., 2010). Afolayan (1977)

reported increase in K for both late and early burnt plots in Nigerian northern guinea Savanna ecological zone. Neff *et* al. (2005) recorded no change in amounts of Potassium, Magnesium, and Phosphorous between the burning treatment plots.

Early burnt plots has significantly higher nutrients than the late burnt and unburnt plots, this indicated that the time of burning has significant effect on soil physicochemical properties. This result agrees with findings of other reserves; Yankari, Kainji, and Olokemeji.

5.3: Plant Species Composition and Diversity.

The grass family Poaceae was prominent with a total of 6 plant species. It was closely followed by the family Papilinoideae with 3 species. *Thelepogan elegans* was the prominent individual plant. It agrees with the findings of Abdulhamid and Barau (2008) on the assessment of flora of the Reserve. There was a significant increase in the number of plants after burning. Early burning had a 45% increase while late burning had a 40% reduction in number of individual plants. This finding concurs with the results of Siswoyo (2002) that observed an increase in the ground cover of shrubs and resprouting species. He asserted that Seedlings were more abundant and species richness greater in burnt sites than unburnt. Late burning encourages better growth of perennial grasses while annual burning does the opposite. Sanford (1982) recorded much less herbaceous production in protected areas; higher production with early burning in warmer, drier regions; higher production with late burning in moisture Guinea savanna in Nigeria.

In this study the late burnt plot had the highest Shannon-Weiner index (H) of 1.929 and species evenness, (e) of 0.5734, this was followed by the early burnt plot, H 1.837, e =

0.5708. The unburnt plots had the lowest diversity index of 1.773 and species evenness of 0.4907 (Table 4.4). The difference was not significant for both early and late burnt plots. Afolayan (1979) and Shesh (2004) reported increase in species diversity and species evenness with burning at Kainji Lake National Park, Nigeria and Thailand respectively. Sanford (1982) reported decrease in plant species diversity but an increase in evenness with burning. Similarly, Knapp *et al*. (2007) recorded a decrease in plant species richness the first year after late season burns, largely the result of decline in richness of forbs and graminoids. Early season burns, on the other hand, did not significantly affect richness. They also reported significant reductions in non tree cover relative to unburnt (control) by 62% a year after late season burns. On the other hand, early season burns had a less dramatic effect on understory vegetation, with no change in overall species cover the following growing season. However, after 3 growing seasons after the season burns all the herbaceous growth that were initially reduced had recovered and no longer differed below levels found in the unburned plot.

According to the findings of this work no significant change in species richness in the late burnt plot was noted while a slight reduction in the early burnt plot was observed. In contrast, Knapp et *al*. (2007), Willkinson *et al.* (1993) recorded a decrease in species richness the first year after late season burns, early season burns, on the other hand, did not significantly affect richness. Fires tend to eliminate the more fire sensitive species and thus favour the more resistant species. Frequent fires favour species that recover by sprouting, not those that depend on seed. Conversely, Cremer (2004) Reported that, lack of fire tends to favour the abundance of more sensitive species to fire.

Early burned plot recorded a 108% increase in individual legume species; however, late burned plot had an increase of 59.6% in individual legume species. Isichei (1982) indicated that legume species and number of individual species may increase with burning: the fire protected plot at Olokemeji contain 9.34% legume species, early burnt 29.67% and late burnt 29.03%.

5.4. Summary

The effects of early and late burning at Falgore Game Reserve were studied for 2 seasons from December, 2008 to August, 2009. The Reserve lies in the Guinea Savanna zone of Kano state. Due to the lack of available data on effect of burning on the soil physicochemical properties and plant species composition, abundance, and diversity in the Reserve led to of this work. Three closely adjacent plots were randomly selected within the reserve. The first plot was subjected to burning in late December (Early burning), another was burnt in early march (Late burning), while the last was kept unburnt (Control). Composite soil samples were randomly collected from each of the plots 2 weeks after burning and at the peak of the rainy season in August. These samples were air dried in the laboratory for further laboratory analysis. A 50×50 cm quadrat was randomly used to determine the number of plant species and individual number of each species within each quadrat to assess their distribution, and abundance. Shannon-Weiner diversity index was determined from the data. The soil samples collected were analyzed for soil particle size distribution by Hydrometer method, soil available water by the gravimetric method, while pH in water and $CaCl_2$ was determined by electrode pH meter. Percentage organic carbon was determined by wet oxidation method, percentage Nitrogen by macro Kjeldah digestion procedure and total phosphorus was determined by calorimeter method. Exchangeable

bases Na, K, Ca and Mg were extracted in 1N neutral Ammonium acetate. Na and K were estimated by flame photometry, while Ca and Mg by absorption spectrophotometry.

The data collected was analyzed using SAS, 2002 and PAST, 2005 statistical packages. Evaluation of collected data on the effects of burning on the soil indicated that both early and late burning lead to significant increase in soil pH, organic carbon, Nitrogen, and Phosphorus ($P< 0.01$). Na, K, Ca, and Mg produce similar increase. This increase was however, higher for the early burnt plots. There was a marked increase in percentage clay content. Burning affected phytobiodiversity by increases species diversity and species evenness. Similarly, the number of individual leguminous plants increased with burning.

5.4. Conclusion

The finding of this study has revealed that both early and late burning had significant effects on the physical and chemical properties of soil in the Game Reserve. There were significant increases in pH, Organic carbon, Nitrogen, and Phosphorus. Other nutrients notably; Calcium, Magnesium, Sodium, and Potassium also recorded significant increase. The increase in nutrients was higher in the early burnt plots than the late burnt plots. Percentage silt and clay increased with burning. Percentage soil moisture decreased significantly with burring. The research showed that phytobiodiversity was affected by burning treatments. Late and early burning recorded increases in the composition of leguminous species.

Low intensity fires encourages phytobiodiversity, particularly of grasses whereas, high intensity fires discourage phytobiodiversity. Therefore early burning was considered the most appropriate method of burning that may be applied at the Reserve as it favours, soil

properties and plant species composition and abundance. It also increases number of leguminous species and individual number of leguminous plants.

5.5. Recommendations

In view of the importance of the soil for food production and conservation of the savanna ecosystem the following recommendations were made:

- The Government should create conservation awareness among the community through extension services
- Encourage the prescribed burning in protected areas to avoid accumulation of `fuel' so as to reduce the risk of accidental fires.
- Further research should be undertaken at Falgore Game Reserve in order to investigate the long term effect of burning on both soil properties and plant species composition and diversity.
- Extensive Research on microbial activity of the soil should also be conducted.
- Despite accelerating the cycling of nutrients in the soil, efforts should be geared towards enlightening the public on the long-term negative impacts of frequent burning on soil properties and structure of the vegetation.
- Further Research should be embarked upon with the aim of understanding the influence of fire on the function and structure of terrestrial ecosystem.

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Appendix A

Table I Mean Square for Soil pH and Percentage Available Water.

Source	**DF**	pH Water	pH $CaCl_2$	% Available Water
Burning	2	5.36**	2.79**	13.65**
Season	1	18.31**	10.34**	12.33**
Subplot	4	0.07^{ns}	0.10^{ns}	
Burning×Season	2	1.96**	1.65**	0.48**
Burning×Subplot	8	0.27^{ns}	0.18^{ns}	
Season×Subplot	4	0.04^{ns}	0.01^{ns}	
Burning×Season×Subplot	8	0.18^{ns}	0.18^{ns}	

***-Significant, **-Highly Significant, ns-Not significant.**

×- Interaction

Table 2 Mean Square values for Soil Chemical Properties for Falgore Game Reserve

Source	DF	OC	N	P	K	Ca	Mg	Na
Burning	2	2.74^{**}	0.01^{**}	645.54^{**}	0.08^{**}	13.11^{**}	10.73^{**}	0.03**
Season	1	0.01_{ns}	0.01^{ns}	10.34^{ns}	0.11^{**}	12.00^{**}	2.37^{**}	0.0^{ns}
Subplot	4	0.09	0.01^{ns}	21.63^{ns}	0.01^{ns}	0.61^{ns}	0.20^{ns}	0.01^{ns}
Burning×Season	2	1.59**	0.02^{**}	118.69^{*}	0.07^{**}	10.56^{**}	1.61^{**}	0.0^{ns}
Burning×subplot	8	0.17^{ns}	0.0^{ns}	39.27^{ns}	0.02^{ns}	1.33^{ns}	1.31^{ns}	0.01^{ns}
Season×subplot	4	0.03^{ns}	0.0^{ns}	2.90^{ns}	0.01^{ns}	1.15^{ns}	1.15^{ns}	0.01^{ns}
Burning×Season×subplot	8	0.12^{ns}	0.01^{ns}	18.62^{ns}	0.02^{ns}	2.23^{ns}	1.42^{ns}	0.02^{ns}

*** Significant, ** Highly significant, ns Not significant**

×- Interaction

Table 3 Mean Square Values for Plant Species Composition

Source	DF	
Burn	2	22269.07**
Quadrants	4	6830.44**
Species	13	895524.52**
Burn×Quadrat	8	7781*
Burn×species	26	112376**
Quadrat×Species	52	67266.54**
Burn×Quadrat×Species	104	86971.01**

***-Significant, **-Highly Significant, ns-Not significant**

×- Interaction