Effects of fires on the Soil Physical and Chemical Properties and the Soil Seed Bank in Albaja Area at White Nile State, Sudan

By

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Dedication

To

My son Mohamed (Kabooth) I dedicate this work

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Thanks and praise is due to almighty **Allah**, who provided me with health and capability to study and accomplish this work.

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Abstract

Title: Effects of wildfires on the Soil physical and Chemical Properties and the Soil Seed Bank in Albaja Area at White Nile State, Sudan

The objectives of this study were to assess the effects of wild land fires on the vegetation cover, the physicochemical properties and the seed-bank of the soil in Albaja area, White Nile state. The area lies between latitudes $31^{\circ}\ 36^{'}$ – $14^{\circ}\ 10^{'}$ N and longitudes $31^{\circ}\ 45^{'}$ - $32^{\circ}\ 23^{'}$ E, and is subjected to large scale wild land fires (40% of the total area burns annually). The area was divided into eight sectors according to the number of fire burning frequencies through the analysis of satellite imagery (MODIS). Accordingly, the area was delineated into 8 burning frequency plots (zero-, one-, two-, three-, four-, five-, six- and seven-times burn). Forty soil samples were taken at 30 cm depth, 5 samples in each sector. Eight soil profiles were dug and described in each sector. Vegetation index data were collected during the field work from 10 to 17 May 2007.

The soils in Albaja area are infertile sandy loams (Aridisol). Their texture is mainly composed of sand particles (> 68%) which make them easily workable even by simple hand made implements. Albeit, the soils possess good physical characteristics, yet their chemistry is too poor to support the growth of dense vegetation mantle. Thus the vegetation consists of sparse trees with intervening thin cover of seasonal grasses. The seasonally recurring wildfires have no

pronounced effects on the soils; this is true for both their physicochemical characteristics and the seed-bank. No significant differences were found between the plots of different burning frequencies. The seed bank content of the soil is considerable, the amount of the seeds ranged between 445.2 and 1049.4 million seeds/ha; among which the sound seeds ranged between 95.4 and 477 million seeds/ha and the dead seeds ranged between 349.8 and 572.4 million seeds/ha. Very little germination of the seeds in the nursery and the laboratory conditions was obtained, which might be due to the failure to break the seed dormancy under these conditions.

العنوان: تأثيرات الحرائق علي خصائص التربة الفزيوكيميائية و محتوي التربة من البذور في منطقة الباجة بولاية النيل الأبيض ، السودان

المستخلص:

هدفت هذه الدراسة لتقييم تأثير الحرائق علي الغطاء النباتي و خصائص التربة الفيزيوكيميائية و محتوي التربة من البذور في منطقة الباجة بولاية النيل الأبيض (تقع بين خطي عرض °13 36́ و °14 10΄ ش و خطي طول °31 45́ و °32 23́ ق). تتعرض المنطقة لحرائق برية واسعة حيث تحترق 40% من جملة المساحة سنوياً. قسمت منطقة الباجة الي ثمانية نطاقات إعتماداً علي عدد تكرارات الحرائق و ذلك بواسطة تحليل صور القمر الاصطناعي و تبعاً لذلك ميزت المنطقة الي ثمانية مواقع متكررة الحرائق: صفر-، واحد-، إثنين-، ثلاثة-، أربعة-، خمسة-، ستة- و سبعة-مرات حريقة. أخذت أربعين عينة من التربة علي عمق 30 سم بواقع خمس عينات في كل نطاق. كما حفرت ثمانية قطاعات للتربة و تم وصفها و أخذت العينات للتحليل المعملي. أيضاً جمعت معلومات عن الغطاء النباتي في الفترة من 10 الي 17 مايو 2007م.

أظهرت النتائج أن الترب في منطقة الباجة رملية-طميية و هي غير خصبة (ترب المناطق القاحلة) و يغلب علي قوامها ذرات الرمل (< 68%) و ذلك يجعل خدمتها سهلة حتي بالأدوات اليدوية البسيطة. الترب في عمومها ذات خصائص فيزيائية جيدة إلا أنها فقيرة جداً كيميائياً بحيث لا تتحمل إسناد غطاء نباتي كثيف ، لذلك نجد أن الغطاء النباتي في المنطقة يتكون من أشجار متفرقة و حشائش موسمية فقيرة. و لم يكن للحرائق البرية الموسمية تأثي واضح علي خصائص الترب و محتواها من البذور، و لا توجد فروقات معنوية بين المواقع المحروقة بتكرارات متباينة. مخزون الترب من البذور كبير، إذ تتراوح كمية البذور ما بين 445.2 الي 1049.4 مليون بذرة/هكتار منها ما بين 95.4 الي 477 مليون بذرة سليمة /هكتار و ما بين 349.8 الي 572.4 مليون بذرة ميتة/هكتار. تلاحظ نمؤ ضعيف لهذه

البذور في ظروف المشتل و المعمل و يعزي هذا ربما الي عدم كسر كمون هذه البذور تحت هذه الظروف غير المواتية.

Chapter 1

Introduction

1.1-General

Fire is a dominant disturbance factor in almost all vegetation zones throughout the world. In many ecosystems fire is a natural, essential and ecologically significant force, organizing physical and biological attributes, shaping landscape diversity, and influencing energy flows and biogeochemical cycle, particularly the global carbon cycle. In some ecosystem however, fire is an uncommon or even unnatural process that severely damages vegetation and lead to long-term site degradation. Fire is an important land management tool, but careless or criminal use of fire may have catastrophic impacts. Wildfire can be a major cause of ecosystem degradation and may result in loss of human life, economic devastation, social disruption and environmental deterioration (Stehling et al, 2000). Reliable statistical data on occurrence of wild fires and land use fires, areas burned and losses are available for only a limited number of nations and regions. Forest fire kills most of the micro-flora and micro-fauna within the top soil layer. Vegetation on the forest floor is in most cases completely burned off. Most of the micro-flora and micro-fauna have a function of nutrient re-yielding, once these are killed by excessive temperatures then the nutrient cycling is jeopardized. As temperature rises and then falls soil texture may be changed. This can even be accelerated by the change in nutrients. As the heat of the fire changes the soil texture, the small porous cavities in the soil are gradually filled with loosened soil. The reason for this is that many of the micro-organisms living in the top layers of the soil are killed by the heat; these organisms create the cavities in the soil which then absorb much of the excess water during rains. The absence of the cavities in the soil reduces the water retaining capability of the soil. Repeated fire destroys the natural soil texture, structure and leads to accelerated water run-off. Fast run-off of water is in fact to a large extent responsible for causing the excessive flooding and soil erosion (Heikkila, 2007).

Studies on the effects of wildfires on forest and range ecosystem are very few and nearly not found in the Sudan, particularly those addressing effects of wild fires on soil properties. Fire is one of the major causes of ecological, social and economic damage to forests and range in savanna region, destroying or severely damaging every year more than 60 million hectares in the Sudan (Bayoumi, 2000). Grass fires sweep through savanna belt every dry season soon after the arrest of rainfall. The most obvious damage caused by fire is the direct destruction of the trees, resulting in the loss of valuable timber. Fire creates conditions unfavorable to the natural regeneration of valuable timber species which are mostly sensitive to fire. Existing seedlings and samplings of timber species are eliminated. Fires burn readily in dry grass and other plants of forage value. In some cases fire may be of temporary value in burning off a mat of dry dead vegetation and enabling stock to grow new tender green shoots beneath. In the final analysis fire tends to kill the roots of the plants, thus reducing of stock, and to replace good species by those of inferior value for forage. Serious damage to forage can be prevented by grazing so regulated that masses of dry and inflammable forage do not accumulate. Inflammable forage is in some forests the principal fuel for the rapid spread of fires. If this forage is used by stock while green the fire danger is reduced. The dry annual grasses over large parts of the Sudan are the only food for animals in the dry season. It has been said that the greatest scope for increasing the pasture recourses of the Baggara country of Darfur and Kordofan is by fire protection (Badi et al, 1989). Fires convert the natural stands of broad-leaved timber trees to thorny acacias and finally into bush and grass land. Soil nutrients are burnt and the soil is impoverished with considerable changes in structure and water retention capacity. Fires also create conditions for spread of insects and fungal diseases. It destroys the seed bank in the soil and ruins the organic matter layer of the soil (Badi et al, 1989). Sudan is beset with ambiguities in view of the scarcity of available information on wildfires and their detrimental impacts on the environment in general and soil in particular. Wildfires occur frequently and devour sporadic and large swathes of vegetation across the country, especially in the area of savanna ecosystems of low precipitation and marginal vegetation.

Recently, Albaja region of the White Nile State has been the focus of various multidisciplinary researchers, as evidenced by a number of studies conducted on the geology for the search of minerals and groundwater, forests, rangeland and others of environmental concerns. The importance of the region lies in it's seemingly richness of natural resources and pastures, alongside with the distinguished geographical setting. It also represents the first line of the defense (defensive shield) in the face of encroaching sands and desertification which has rolled out or almost being so over the vast area stretching west of the White Nile at Alduem town. The occurrence of recent sands atop the fixed sand dunes of the study area and its surroundings is a glaring attestation of the active desertification. Albaja region, the theme of this research, has been chosen as an example of the areas situated in the belt of savanna ecosystems, typical of little rain, in order to study the impact of wildfire thereon.

1.2- Objectives

The overall objective of this study was to determine the effects of repeated seasonal fires on the ecosystem with emphasis placed on soil. Specific objectives were:

1. To assess the vegetation and the fire-fuel of Albaja area;
2. To characterize the soils of Albaja area;
3. To determine the effects of fire on soil properties (physical and chemical);
4. To determine the effects of fire on the soil seed bank.

Chapter 2

Literature Review

2.1- Introduction

Fire is the visual manifestation of the physicochemical process known as combustion. There must be a source of chemical energy (Biomass fuel), thermal energy (heat from an ignition source), and oxygen (O_2) for the combustion reaction to occur. Fires typically have five phases: Pre-ignition, flaming combustion, smoldering combustion, glowing combustion, and extinction (DeBano et al, 1998). Heat is transferred from burning fuels to the organic and mineral layers of soils by the processes of radiation, convection, conduction, mass transport and vaporization/condensation (Chandler et al, 1983). Fire produces a spectrum of severities that depend on the interactions of burning, intensity, duration, fuel loading (i.e. live and dead materials), combustion type and degree of oxidation, vegetation types, climate, slope, topography, soil texture and moisture, soil organic matter content, time since last burned and area burned. Severity is a qualitative measure of the effects of fire on soil and site resources that control ecosystem sustainability (Hartford and Frandsen, 1992). Fire intensity is an integral part of fire severity in that it refers to the rate at which a fire is producing thermal energy in the fuel-climate environment where it occurs (DeBano et al, 1998). It can be measured in terms of temperature, and heat release.

2.2- Causes of fire

Fire is started in a number of ways mostly by human action. Natural causes of fire are few, mainly lightening for which no incidents were observed or recorded in the Sudan. The other causes may be heat rays concentrated by silica crystals on the edge of grass blades or bottle bottoms thrown away among thick grass. Silica crystals and bottle bottoms are thought to be the cause of grass fires in remote localities where no human settlement exists. Fires are generally started by cultivators preparing the land for the crops, by grazers burning the dry grass to encourage fresh grass to flush and to destroy ticks, by hunters driving game towards traps and by honey collectors to generate smoke to drive away the bees. Fires are also caused by negligence when travelers leave behind burning camp fires or passengers throwing cigarette ends. Malice is among the causes of fires lit intentionally to destroy rival's property or a hostile action against the presence of a forest reserve or an unpopular forester (Badi et al, 1989).

2.3- Main types of vegetation fires

Wildfires (uncontrolled fires) are common in all vegetation zones. They are mostly caused by negligence and are often associated with escaped land-use fires. Both wildfires and land use fires can directly or indirectly cause immediate damages or have long-term environmental or humanitarian consequences. Despite the fact that many ecosystems are well adapted to fire, land use fires often follow traditional and established practices; there is an increasing tendency of fire events causing conflicts with the needs of the rapidly growing populations of the developing countries and at the interface with vulnerable structures of industrialized societies (Stehling, 2000).

2.3.1- Character of forest fires

Forest fires are divided into three classes: Ground, surface and crown fires.

Ground fires occur only where thick accumulations of humus or duff are found and burn in this layer of organic material. On account of the depth of the humus (often one to over two feet in thickness), ground fires apparently burn underground in the soil itself. Actually only the vegetable matter is consumed and the fire is burning above the soil or in pockets formed by decaying roots. Such fires are sometimes termed “duff” fires. When the surface is wet by a light shower, but the duff beneath is dry, a ground fire may burn the lower layer of organic material and leaves the surface intact and it is supported by a network of plant roots. When the fire is burning underground, in this way, its exact location is difficult to determine. Cases are on record where ground fires burned for several months in swamps. Such fires are said to have lasted through an entire winter under a blanket of snow. The feeding roots of the trees extend throughout the thick humus layer and are easily killed by the ground fire. Such fire ordinarily kills all the trees on the area burned over. Deep deposits of humus are formed only under conditions which retard its normal decomposition. In swamps and lowlands, with excess of water, the organic matter does not readily decay. At high altitudes and in northern latitudes, on account of the cold damp climate even upland sites may develop thick beds of duff. This is particularly the case with coniferous stands. Ground fires are relatively rare as compared with other kinds of fires because the material on which they feed does not dry out except in seasons of drought, and sites on which they may occur form a small percentage of the total forest area.

Surface fires are those which burn on or near the ground in the humus, litter, ground cover and underbrush. They are the commonest kind of fires and occur in all parts of the world (Hawley, 1921). Occasionally, surface fires, burning intensely, will spread to the crowns of the trees. Here, the fire will travel through the tree tops at a high rate of spread but will eventually return to the surface fuel layer (Heikkila, 2007).

A crown fire which develops from a surface vertical arrangement of fuels will carry the fire and gases from the surface into the crown fuels and presents a stepladder effect. The crown fire burns on the surface and advances from burning tree top to another with the leading edge outrunning the surface fire bellow. The crown fire usually occurs in conifer stands with a continuous crown cover. Fires burning in the crown layer are extremely difficult to control and spread quite rapidly. However, in tropical forests, there is a very rare chance of a crown fire to take place. Crown fires are an indication of explosive fire conditions. A crown fire may start in the following manner:

- Currents of rising hot air and other gases from a surface fire produce a convection column;
- If this convection column touches the crowns, it will pre-heat them;
- The convention column may also carry burning leaves and branches up to the pre-heated crowns, setting them on fire;
- Once the crown of one tree begins to burn, it may set the crowns of next trees on fire too.

Wind will cause the spread of fire from crown to crown and the crown fire will spread ahead independently of the surface fire below (Heikkila, 2007). Crown fires burn in the crowns of the trees, and in tall timber the main fire may be one to two hundred feet above the ground (Hawley, 1921).

2.3.2- Wildfires in forests

In the temperate and northern boreal forests, wildfires are occurring regularly during the dry northern summers. In North America and Eurasia between 5 and 20 million hectares are burned annually. In the less populated high latitudes, the ignition sources are dominated by lightning, while in more frequently populated regions humans become the dominating fire cause. In the Mediterranean region an average of 0.6 million hectares of forest and other land is burned annually.

2.3.3- Wildfires in tropical grass, brush and tree savannas

The equatorial rain forests are usually too moist to allow the propagation of wildfires. However, extreme droughts in association with forest exploitation creating conditions of flammability and fuel availability periodically cause fire spread in the equatorial rain forest. Such events regularly occur in the forests of the tropical south Asia in association with cyclic climate variability caused by the El Nino Southern Oscillation (ENSO) phenomenon. Some examples of large-scale catastrophic fire events are given further below. The largest areas affected by uncontrolled wildfires in tropical forest are in the seasonal forest biomes (deciduous and semi-deciduous forests, sometimes also referred to as monsoon forests. Here, the fires are burning in short term intervals of 1 to 3 years. The tropical sub-mountain coniferous forests (pine forests) are also subjected to regular fires (Stehling, 2000).

Tropical savannas cover an area of 2.3 - 2.6 billion hectares worldwide. Savannas typically consist of a more or less continuous layer of grass with interspersed trees and shrubs. There are numerous transition types between savannas and open forests. The surface fuels in these ecosystems which are dominated by grasses and leaves shed during the dry season, are burned periodically at intervals which may range from one to four years. This fire frequency is increasing in some regions as a result of increasing population and more intensive use of rangeland. The area of savannas potentially subjected to fire each year is up to several hundred million of hectares. As a result, savanna burning releases about three times as much gas and particle emissions to the atmosphere as deforestation burning. It is estimated that more than 3 billion tons of vegetative matter are burned in tropical savannas annually (Stehling, 2006).

In Africa, savanna fires are responsible for over 90% of all biomass burned (Trigg, 2002; Delmas et al, 1991). Every year, large areas of savanna-type mixed forest/grassland formations are affected by fires, particularly in the dry zones of Africa (FAO, 1 999). Although, southern Africa has some of the most extensive biomass burning in the world (Dwyer et al, 2000), there are no adequate data on the regional occurrence. Size distribution trends in fire numbers or areas burned annually that meet the information needed for policy and decision-makers are lacking (Frost, 1999). Resource managers need such information to identify areas that are most under threat of too-frequent burning, the likely points of origin of such fires, and what management strategies and operations would best enable more effective control of fire (Roy et al, 2005). The seasonal spatial-temporal dynamic of fires in savannas influence their detection by remotely sensed data. In general areas which burn early in the season are small and fragmented. They are therefore likely to be missed on maps that rely on coarse spatial resolution (e.g. 1 km) data. Fires that burn later in the season are generally and are more likely to be resolved using coarse spatial resolution data (Trigg, 2002; Parr and Brockett, 1999).

Sudan is a vast country with an area of 2.5 million square kilometers. It is divided into a number of ecological zones according to the ecological classification of Harrison and Jackson (1958). These are desert; semi-desert; low rain fall savanna; high rainfall savanna and montane. The forest vegetation follows the rainfall and soil types. The soil varies from permeable sands with poor water-retention to impermeable clay soils in the central parts to acid soils in the south and fertile silt soils along river banks. The natural forests cover more than 20 per cent of the country`s area, but only 0.5 per cent of forest is reserved (1278165 hectares). Rainfall ranges between zeros in the north to more than 1500 mm in the south. In very general terms this is caused by the domination of the dry northern and North-Eastern winds and the humid south-Western winds respectively. The rainfall concentrates in the period between June and September. The length of dry months ranges between 8 - 12 months in the north to 5 - 8 months in savanna region and 3 - 5 dry months in high rainfall wood land savanna. The prevailing winds are north easterly, cold and dry with high speed in October/January, gaining higher speeds in February. As from March, the winds are warm and dry with slow speeds. In the Sudan, the maximum temperature ranges between 34 to 44 °C and the minimum temperature ranges between 8 to 21 °C. More than 40% of the country's area is desert or semi-desert, but the largest area of the Sudan is some form of savanna: a mixture of grasses and trees (Noordwjik, 1984). Bayoumi (2000) reported that wildfires break out in forests, pastoral and range lands by reason of natural causes (e.g. lighting) and different man-made activities in these domains. Most of wildfires are man made, and it is very seldom that wildfires initiate by natural causes in the Sudan. Wildfires may occur during any season of the year but they are normally rampant in hot arid seasons due to the prevalence of the swift wind, low rate of relative humidity, rise of temperature, presence of inflammable materials and the causative agents of the spontaneous fire. Fire is the most important factor affecting forest range land in the Sudan. Grass fire sweeps through the savanna belt (both low rainfall and high rainfall) every dry season. The low rainfall savanna zone is the legitimate product of repeated annual burning with its fire resistance species. This zone lies between latitudes 10° and $14^{\circ}N$ and covers about 69000 km^2 (27% of the total surface land of the country). Badi (1999) described in details the rainfall savanna covering the central Sudan as inflammable environment because highly inflammable grasses such as *Hyparrhenia pseudocymbaria, Penisetium purpreum and Sorghum halpense* occur in gaps within the forest stands and the open grassland plains. These tall grasses dry up suddenly and vastly over extensive areas of land immediately after the last rain in October. Bush and grass fires are the phenomenon in central Sudan. Bush and grass fires are caused by man in his daily and seasonal activities. Farmers and nomadic pastoralists are responsible for 81% of the incidents, while 13% are attributed to travelers. In the southern Sudan it has been found impossible to prevent fires entirely, except in small areas such as plantations, and so a policy of early-burning has been adopted, and the grass is burnt off when it is dry enough to burn at all. The resulting fire is much less fierce and does relatively little damage to the trees. Thus as a result trees grow more vigorously and suppress the grass, and so there is often a gradual advance to a better type of vegetation. This rate of advance is slower than if complete fire protection could be given, but it is more certain for if an area had been protected from fires for a number of years, and a large amount of dry grass accumulates on it, and then an accidental fire does enter the area, the extra amounts of dry grass cause an extremely fierce and dangerous fire. This was seen in the Loka Forest Reserve, which had been protected from fire for about three years, and then was burnt. The trees within the reserve took several years to recover and were in a much worse state than trees outside the reserve in areas which had been burnt each year. Fire causes serious damages to forest stands, burning the standing trees to ashes and/or weakening them and reducing growth. It destroys the seed bank in the soil and ruins the organic matter layer of the soil. Fire stimulates changes in the species composition and encourages the spread of insects and fungi. Ali and Bayoumi (1999) estimate an annual loss of 250000 cubic meters of growing stock that is destroyed by fire annually. Bayoumi (2000) estimates an annual loss up to 50% gum yield from *Acacia senegal*, which is considered a big economic loss. On the average, fires affect about 70% of the open range land. In Africa, Sudan is rated second to the Democratic Republic of Congo as far as the incinerated land of forest is concerned.

2.3.4- Conversion of forest and brush to plantations, agricultural land and pastoral systems

Two types of forest clearing for agricultural use are common, predominantly in the tropics: shifting agriculture, where the land is allowed to return to forest vegetation after a relatively short period of use, and permanent removal of forest to be converted to grazing or crop lands. In instances, the clearing and burning follows initially the same pattern: trees are felled at the end of the wet season and after extraction of marketable and otherwise usable trees, the vegetation is left for some time to dry out in order to obtain better burning efficiency. In shifting agriculture, which is practiced by several hundred million peoples worldwide, the cleared areas are used for agriculture for a few years until yields decline and then are abandoned and new areas are cleared. The generally observed shortening of shifting agriculture cycles is increasingly associated with site degradation and makes this traditional land use technique one of the leading causes of global tropical deforestation. The conversion of primary or secondary forest into permanent agriculture and grazing land, including tree plantations, is driven by expanding human populations that require additional food and living space, but also by large-scale resettlement programmes and land speculation. The net amount of plant biomass which is combusted in the process of vegetation clearing is somewhat in the range of 1 to 2 billion metric tons (Stehling, 2000).

2.3.5- Burning of agricultural residues, control of bush and weeds and nutrient cycling on grazing and crop lands

A substantial amount of agricultural residues, e.g. straw and stalks is disposed off by burning. The magnitude of this practice is extremely difficult to quantify because of its distributed nature. No statistics are available, mostly because no material of direct economic value is involved. It has been estimated that between 800 and 1200 million tons of agricultural residuals are burned annually making this practice a major source of atmospheric pollution, mainly in the tropics. By tradition fire is also a common practice to control bush and weed encroachment on grazing and crop lands (Stehling, 2000).

2.4- Environmental impacts of wildfires

The overall effects of fire on ecosystem are complex, ranging from the reduction or elimination of above ground biomass to impacts on below ground physical, chemical and microbial mediated processes. Since a key component of overall ecosystem sustainability occurs belowground, recovery is laid to soil's physical, chemical, and biological functions and processes. Depending on several fire severity measures, changes in below ground components can either be beneficial or deleterious to the entire ecosystem. Low impact burning can promote an herbaceous flora, increase plant available nutrients, and thin over crowded forests, all of which foster healthy systems. Severe fire can often cause changes in successional rates, alter above and below ground species composition, generate volatilization and entrainment of nutrients in smoke columns, produce rapid or decreased mineralization rates, alter C/N ratios, and result in subsequent nutrient losses through accelerated erosion, leaching or nitrification. In addition, changes in soil hydrological functioning, degradation of soil physical properties, decreases in micro- and macro-fauna, and alterations in microbial populations and associated processes can occur. The direct effect of fire on belowground systems is the results of the burning severity, which integrates above ground fuel loading (live and dead), soil moisture and subsequent soil temperatures, and duration of the burn. The time for recovery of belowground systems will not only depend on burning intensity and its effects on key ecosystem processes and components, but also on the previous land use practices. Thus, the impacts of fire on belowground systems can be highly variable and may not be predictable (Daniel et al, 1999).

2.4.1- Forestry

Fire can cause injury to trees containing merchantable material. The damage may range from slight fire-scars at the base to complete consumption of the tree. The latter occurs rarely even in exceptionally severe fires. Frequently large trees are killed outright. Death is caused by the killing of the cambium or living layer between the bark and the wood. A temperature of 54 $^{\circ}$C is sufficient to kill the cambium. If the cambium is killed all the way round, the tree is girdled and dies. Dead cambium can usually be noticed by its dark color in contrast to its light shade when in normal condition. It is not necessary that the bark be burned off to cause death of the tree. Heat which only scorches the outer bark is often sufficient to kill the cambium. During the early part of the growing season when cell division in the cambium layer is at its height, the cambium is more sensitive to heat than later on in the summer or during the dormant period. Power of resistance to fire differs for different species of tree. These differences between species are due primarily to the character and trickiness of bark. Layers of cork, which act as non-conductors of heat, are developed to a greater or lesser extent in the bark. A tree which develops thick corky bark is better protected than one with thinner and less corky covering. Tree bark may be soft, easily inflammable and apt to burn through to the wood underneath, or it may be hard, ignited with difficulty and rarely burned through. Old trees of any given species are better protected against fire than the young trees because with age the bark thickens and tends to become corkier. Trees which secrete resin in the bark or exude pitch as a result of insect attacks are easily injured. Where the pitch is plentiful a fire may run up the tree killing the cambium on one side for many feet above the ground and leaving a long scar called a “cat’s face”. Conifers suffer more severely from fire than hardwoods. When heat from a fire reaches the roots of trees, severe injury or death may occur. This is the case because tree roots are less thoroughly protected by thick bark than the portions aboveground, and probably are more sensitive to heat. Trees with shallow root systems suffer more than the deep-rooted species. Old trees can be found all hollowed out at the base by fires. In some cases spaces big enough to admit one or more men have been burned out. Such hollows are rarely if ever the works of one fire but represent the effects of several fires; once the bark has been burned away on one side succeeding fires burn more readily in the exposed wood. Where trees containing merchantable material are killed outright they should be cut and utilized before the timber decays or is attacked by insects. This is not always possible if the trees are few in number, catered or located in inaccessible places. Frequently fire-killed timber can be salvaged for a large percentage of its value before the next fire incidence. Burned timber in some cases is valueless a year after the fire but in other cases it remains sound for several years. Climatic conditions, the species, and the question of whether the bark falls from the trunk soon after the fire are the main factors influencing the length of time during which fire-killed timber remains sound. In a dry climate with species relatively free from insects and fungi and under circumstances causing the tree to shed its bark deterioration is delayed (Hawley, 1921). Recovery from injury to the productive power of the forest may be sustained either in reduced quantity or quality of production. This is primarily dependent on the condition of the soil, climate and the extent to which the individual trees have been damaged. Fire injury to the productive power of the forest may be classified as follows:

A/ Injury due to replacement of good by poor species or to failure of the burned areas to restock: Frequently the natural reproduction following a fire is of species inferior to those previously occupying the ground. In some cases this situation is reversed and a more valuable species, preferring an open burned over seedbed, and seizes the opportunity to restock the burn. This is an example of the beneficial influence of fire. In numerous instances no natural reproduction follows the fire and the burn becomes barren;

B/ Injury due to reduction in the density of stocking: Fires which do not destroy the whole stand may break the canopy and have the general effect of making the stand more open by reducing the number of trees below the density required for highest production;

C/ Injury due to the poor growth of individual trees: Trees partially girdled at the base have lost part of their equipment for transporting food materials and water for building wood structure. This throws an added burden on the cambium layer of the engirdled portions. Increased growth may take place here, as a result of the enlarged food supplies which pass through, or in response to the greater mechanical strains following the injury. Except on cross sections through the burned part of the tree at which the growth will show a decrease. Analyses of fire injured trees made several years after the fire show, as contrasted to growth before the fire, increases in rate of growth on the stump section and reduction on sections above the wounds;

D/ Injury due to forced cutting of merchantable material before financial maturity: Where trees without present merchantable value are killed, it is quite evident that a sacrifice is involved which may be estimated on the basis of the future value of the stand discounted to the present time. Equally true is that the loss in the case of fire-killed trees of merchantable size is not alone the reduction in present value but should include the sum lost by not allowing these trees to grow longer and be harvested at the time of their financial maturity.

2.4.2- Range

Fires burn readily in dry grasses and other plants of forage value, wild land fires play an important role in causing reduction of the number of valuable fire-sensitive species of trees, shrubs and grasses most valuable for animals (Elgamri, 2007). The practice of range management done both by professionals and some locals, which almost clears the old grasses and giving room for new ones to germinate, is most efficient to delay burning. The new grasses seem good for animals but in the long run the fertility of the soil is very much deteriorated. Elgamri (2007) stated that some of fire-sensitive species are economically important to livelihood of the nomads because they are palatable and of high nutrition value to their animals. The damage caused by wild land fires, plays a great role in increasing the poverty of the local people and the nomads coming seasonally to Albaja (the study area). If range lands continue to be encroached upon by wild land fires, the future of animal resources will be threatened (Elgamri, 2007). Fire frequency may influence the distribution of palatable species. For example, Abu Assabi (*Dactyloctenium aegyptium*) in Albaja area is very good fodder for animals and the local people prefer it because it contains grains of high nutritional value to their animals and also it can be eaten by the people especially during the period of famine. Wild land fires reduce the area of range land and this may lead in some locations to overgrazing conflicts between farmers and nomads and finally destruction of the range and decrease or loss of the animal resources. Fire tends to kill the roots of the plants, thus reducing the density of stocking, and replace good species by those of inferior value for forage (Elgamri, 2007).

In some cases fire may be of temporary value in burning off a mat of dry dead vegetation and enabling stock to get at the tender green shoots beneath. In the final analysis fire tend to kill the roots of the plants, thus reducing the density of stocking and replacing good species by those of inferior value of forage. Serious damage to forage can be prevented by grazing so regulated that masses of dry and inflammable forage do not accumulate. Inflammable forage is in some forests, the principal fuel for the rapid spread of fires. If this forage is used by stock while green the fire danger is reduced (Hawley, 1921).

2.4.3- Soil seed bank

The soil seed bank is the seed reserve in the soil, which comes from either plant species in the site or seeds transferred from elsewhere, through dispersion or by other means. The viable seeds in soil are of two kinds, ephemeral and persistent. Ephemeral seeds are of species with only brief viability in forest soils, which germinate quickly when water for imbibitions is available; otherwise, they die (recalcitrant seeds). Persistent seeds are of species with extended viability in soil, often several to many years (orthodox seeds). These can be stored for long periods because they have low moisture content and are tolerant to desiccation. This kind of seeds accumulates over time and is distributed to greater depths in the soil (Swaine, 2001). The importance of soil seed bank studies is to understand recent vegetation history, determine the future vegetation and its contribution to seed production. This information could be of great use for natural assessment of field management. The use of soil seed bank to restore forests is more preferred, because restoration by planting resulted in ecosystems of low biodiversity (Middleton, 2003). In the arid ecosystems, seed banks are characterized by high spatial and temporal variability and are particularly affected by spatial patterns of vegetation (Aguiar et al, 1997). In these environments both perennial and annual species accumulate seeds in the soil but the distinction between permanent and transient seed bank is weak (Baskin and Baskin, 1998).

The abundance of several species of the soil seed bank varies with time (Pugnaire and Lazaro, 2000). Rainfall variability strongly affects community composition between the field and the seed bank; this is mainly caused by less frequent species, like weeds (Pugnaire et al, 1996).

Ecosystems and habitat may affect the seed bank size in the following way:

- Perennial grasses seed bank is often quite small because seed production is very small relative to seed production in annual species;

- Annual weed species ecosystems have very large seed bank, especially under grazing;
- It is unclear why grazing increases seed bank size? It may be due to:
- Dormancy in seeds maintained in the animal faeces;
- Opening of habitat by tight grazing allows annuals with a high seed production to thrive and produce many seeds;
- Trampling may create conditions in which seeds retain greater viability in the soil.

The majority of seeds in grassland are located in the top 2 cm of soil profile, nearly the entire seed bank is in the upper 10 cm, but in cultivated soils, it is in the upper 15 cm and can be found as deep as the soil is tilled.

Direct heating on the soil and the seed bank may affect seed germination by breaking seed dormancy (Tyler, 1995) especially acacia seeds which have impermeable hard seed coat this kind of dormancy is called physical dormancy (Willan 1985; Gwarazimba, 1987; Okoro, 1987; Kariuki, 1987; Fox and Fox, 1994). Many studies showed the positive effect of dry heating as simulation of fire in natural conditions in enhancing germination percentage (Willan, 1985; Gwarazimba, 1987; Entright and kintrup, 2002; Watanbe et al, 2002; Rajas and Herrera, 1989; Maruyama et al, 1989). The effect of fire on seed depends on seed properties and characteristics of fire such as fire intensity, rate of spread, energy release rate and residence time (Trabaud, 1987). Severe fires will kill the seeds, but light to moderate fire may induce seed coat impermeability by cracking seed coats and stimulating germination (Sabuti et al, 1987; Auld and Connell, 1991; Gashow and Michelsen, 2002). The effect of fire depends on time or season, if it is just after the plant has flowered but before it produces seeds, the pattern of regeneration will be different to that had it been burnt when it was a reservoir of viable seed (Fox and Fox, 1994). Fire duration and position of seed in the soil have effects on seeds; if seeds of acacia shrubs were buried too deep they will not be sufficiently heated to break the dormancy (Fox and Fox, 1994). Fire may change soil seed bank (Tyler, 1995; Sabiiti et al, 1987). Ross (1979) recorded a 92% decline in soil-stored seed after one fire at a South African site. There was a new seed biological phenomenon suggested that in nature desiccation by fire could break the exotesta and the endotesta as well if the fire is fallowed soon by rain (Brits et al, 1993).

2.4.4- Other forms of injuries

A- Injury to Stream Flow and Industry

Erosion was shown to be a consequence of forest fires. Damage from erosion is felt not only on the lands eroded but in the down stream course where the eroded material is deposited. River channels and reservoirs are filled with detritus and deposits of rock and soil left on lands near the stream. Where the soil deposited is of fine texture and fertile, the lands covered may be rendered beneficial. The harmful effects of erosion far outweigh any such advantage. A bare soil prevents the forest from performing its function as a regulator of stream flow. Lacking the sponge-like cover of litter and humus, a bare soil causes rapid surface run-off of water instead of absorbing it and feeding it out slowly from springs. Floods with their attendant damage are thus caused and low and high water stages made more pronounced. This fluctuation in water level together with the eroded material in the channel interferes with navigation, and often necessitates expensive dredging operations. Power plants and factories relying on water power require a continuous and uniform supply of water rather than one which fluctuates widely in volume. Smoke from forest fires interferes with industry and causes extra expense by producing dark days and dry fogs (Hawley, 1921).

B- Injuries to other property

Buildings, live stock, and property of all kinds are at times threatened by forest fires and serious losses result. The principal loss is to property found within the forest or in small clearings surrounded by woods. Whole towns have been wiped out by forest fires (Hawley, 1921).

C- Injury to human life

Rarely if ever in the United States does a year pass without loss of human lives as a direct consequence of forest fires. The greatest loss of life on record in any one fire took place in the Peshtigo fire of October 1871 in Wisconsin where fifteen hundred persons perished in that fire (Hawley, 1921).

D- Ecological stability

By a change of nutrients, flora and fauna, and soil texture, the ecology is checked by changing the environment to suit a different type of species community. This is very much pronounced when there is a lot of fuel (i.e. woody plants) on the ground (Heikkila et al, 2007).

E- Global temperature

Accumulation of pollutant gases after burning is a growing concern. This has caused the global temperature to rise. This rise of temperature will in the long run have a very negative effect on living organisms and plants. Fire is therefore an enemy to the environment and hence also to human life (Heikkila et al, 2007).

2.4.5- Soil

Soil is a thin layer on the earth's crust on which depends all life on the land and contains or constitutes of mineral particles, water, organic matter, air and most of organisms and differ from few centimeter in depth to several meters. Soils support critical processes such as hydrologic and biogeochemical cycling, and they contain a wide array of organisms ranging from bacteria, nematodes, fungi, cyanobacteria, etc., to earthworms, ants, termites, rodents, etc. They also provide nutrients and hydrologic reservoir crucial for both below and above ground structure and function. Disruption of the below ground components may have immediate and long-lasting consequences to the whole ecosystem (Perry et al, 1989). One of the most common, but potentially devastating perturbations on ecosystem dynamics is fire, both natural and anthropogenic.

2.4.5.1- Fire effects on physical properties of the soil

Fire may alter several soil physical properties, such as texture, structure, bulk density, porosity, wetability, infiltration rates, and water holding capacity. The extent of fire on these soil physical properties varies considerably depending on fire intensity, fire severity and fire frequency. In general, most fires do not cause enough soil heating to produce significant changes to soil physical properties (Hungerford et al, 1990). This is particularly true for low intensity prescribed fires. Even where fires do cause direct change to the soil physical properties, their indirect effects on soil hydrology and erosion will vary greatly depending on the conditions of the soil, forest floor, topography and climate. Intense burns may have detrimental effects on soil physical properties by consuming soil organic matter. Soil organic matter holds sand, silt, and clay particles into aggregates. In most soils, primary particles (e.g. sand, silt, clay) are aggregated together into structural units under the influence of organic matter and clay minerals. Some soils remain structure less as loose accumulations of sand grains or massive deposits of clay minerals. Organic matter is more crucial to the formation of structure in the surface A_1 horizon. Clay minerals and soil solution cation contents have the dominant role in structure development in the deeper horizons. Structure is an important determinant of proper hydrologic functioning in soils. Well-structured soils provide the macro-pore spaces needed for water movement and storage and root growth (Neary et al, 1990). Water that infiltrates the soil is not only available for plants but also for microbial and micro-faunal use, sustains the base flow of streams, and does not produce erosion of the soil surface. Soil structure can be affected by fire through alteration of clay minerals and organic matter combustion. Clay minerals are usually not altered to any great extent during a fire because of their low content in surface soil horizons, and the high temperatures > 460 $^{\circ}$C are needed to produce a loss of OH^{-} groups (Giovannini et al, 1988) or irreversible changes in water of hydration (> 980 $^{\circ}$C) (DeBano et al, 1977). Therefore, a loss of soil organic matter results in a loss of soil structure. By altering soil structure, severe fires can increase soil bulk density (DeByle, 1981) and reduce soil porosity (Wells et al, 1979) mostly through the loss of macro-pores (> 0.6 mm diameter). Soil porosity can also be reduced by the loss of soil invertebrates that make channels in the soil (Kettrege, 1938). When fire exposes mineral soils, the impact of raindrops on bare soil can disperse soil aggregate and clog pores, further reducing soil porosity (Ralston and Hatcher, 1971). Intense fires (> 400 ^{o}C) may also permanently alter soil texture by aggregating clay particles into stable sand-sized particles, making the soil texture more coarse and erodible (Chandler et al, 1983). In some cases, increasing the coarseness of clays can make soils more permeable to air and water.

Intense burns may also induce the formation of a water repellent soil layer by forcing hydrophobic substances in litter down wards through the soil profile (DeBano, 1969). These hydrophobic organic compounds coat soil aggregates or minerals creating a discrete layer of water repellent soil parallel to the surface. Water repellent soil layers are reportedly formed at temperatures of 176 to 288 ^{o}C (Neary et al, 1999). Extensive water repellent layer can block water infiltration and contribute to runoff and erosion. Fire induced changes in soil structure and texture can potentially impair soil hydrology. Decreased soil porosity and the formation of water repellent layer decreased water infiltration rates (DeBano, 1971). Loss of soil organic matter and increased bulk density can decrease the water storage capacity of soils. In flat terrain, this contributes to soil desiccation, particularly in the surface soil layer (Dyrness and Youngberg, 1957). However in steep terrain it can significantly accelerate runoff, ash transport, erosion, and mass wasting (Neary et al, 1999). Just exposing soil surface can also cause soil erosion. Without the mitigating effects of vegetation on the impact of raindrops, bare soil surface can form a sealed surface layer resulting in much higher rates of surface runoff. Surface erosion by wind or gravity can also increase when ground cover, surface litter, and/or druff protecting the mineral soil are removed. For this reason, re-establishment of ground cover naturally or by seeding is the most effective erosion control following fire (Wells et al, 1979). Recent evidence suggests that charcoal can also affect soil hydrology; fine charcoal particles enhance the water-retentive properties of a soil and can make a sandy soil behave like clay (Moore, 1996). Thus, this effect could be ecologically significant in bottomland site where it could contribute to poor drainage and waterlogged conditions. By altering soil physical properties and soil hydrology, fire can also have indirect effects on plants. Plant uptake of nutrients and water is slowed in structurally degraded soils through the combining effects of lower soil moisture and lower soil porosity (Nye and Tinker, 1977). Root growth can also be impeded by increased bulk density and soil strength (Gerard et al, 1982). The long-term effects of fire on soil physical properties range from a single season to many decades, depending on the fire severity, rate of recovery as influenced by natural conditions, post-fire use, and restoration and rehabilitation actions. Persistent soil degradation following fire is more common in the cold and/or arid climates.

2.4.5.2- Fire effects on chemical properties of the soil

The organic horizon is a critical component to ecosystem sustainability in that it provides a protective soil cover that mitigates erosion, aids in regulating soil temperature, provides habitat and substrates for soil biota and can be the major source of readily mineralizable nutrients. Many arid and semiarid systems have most of their organic inputs from belowground sources. The organic horizon contains newly fallen and partially decomposed plant, animal and microbial residues which are made up of readily decomposable materials (cellulose), slow to decompose material (holo-celluloses) and recalcitrant humus materials (lignins) (Gressel, 1995). Organic matter input from above- and belowground can significantly affect the nutrient pools and storage in soils, and is the major factor controlling total cation exchange capacity (organic and clay mineral) (Gressel, 1995). As mentioned earlier, fire can alter soil physical properties but one of the most important impacts on belowground systems is on combustion of organic matter. Soil organic matter or humus, increases soil water-holding capacity and aggregation and typically contains 90% or more of nitrogen. Prescribed fire in forests decreases organic matter, carbon and nitrogen in the forest floor, while having either no effect or a weak positive effect on organic matter and N in the mineral soil. Prescribed fire in Pine forests of the southern coastal plains of USA has been reported to both increase and decrease the conversion of organically bound N to plant-available forms (ammonium and nitrate). Charcoal in burned soils is a relatively stable from of soil organic matter, and may affect plant nutrient uptake and the competitive balance between plant species (DiCosty, 2000). Analysis of aboveground/belowground allocation of organic carbon pools provides a means of assessing ecosystem risks for fire disruption. Ecosystems with greater proportions of organic matter reserves may be less susceptible to fire-related nutrient losses and sustainability declines (Anderson, 1991). Humid tropical forests are the most sensitive to fire-related nutrient losses, since only 45% of their carbon pool is belowground. Grassland and savanna are the most fire-adapted ecosystems, with 83 - 85% of their carbon in belowground. This rationale, of course, is subject to the fire severity and intensity. Depending on the intensity, the dryness of the surface organic matter and underlying soil, thickness of the organic layer itself, consumption of organics can range from scorching (producing black ash) to complete ash (producing white ash). Nutrients that reside in the remaining organic material can be further lost through biological and non biological processes (Campbell et al, 1977). Physicochemical disruptions occur at much higher temperatures than biological ones. Organic matter distillation normally starts in the 200 - 315^{o} C range. However, substantial organic matter loss can occur at lower temperatures (DeBano et al, 1998). Litter scorch and distillation of volatile organic compounds occurs at temperatures up to 180 – 200 ^{o}C. Nutrient volatilization (particularly N) begins when temperature climb to 200 -400 ^{o}C; in the 180 – 300 ^{o}C range, destructive distillation and combustion of about 85% of the litter layer occurs. At temperatures >300 ^{o}C, the entire surface organic horizon of the soil is usually consumed. Nearly all the organic matter is consumed in regions of the soil heated to 450 ^{o}C. Fire increases or decreases soil nutrient amounts, depending on the intensity and duration of the burn. Two obvious direct effects are volatilization of certain elements and modification of soil particles due to heat. Volatilization sends carbon, hydrogen and oxygen into the atmosphere along with varying amounts of sulfur and phosphorus depending on the composition of the organic matter burned and the degree of combustion (Raison, 1979). Nutrients in mineral form are affected by the changing physical properties of soil particles due to heating and subsequent cooling. When micaceous minerals and clays dehydrate or fracture, the solubility of elements such as P and K can increase or decrease (White et al, 1973). Chemical changes at mineral surfaces can be caused by alkaline or alkaline earth compounds from the heated minerals or by organic matter combustion. Solubility of P and K can increase or decrease depending on the chemical compounds formed when the material cools. Rapid heating and cooling may break a mineral apart as it expands or contracts. Fresh unaltered surfaces could release P and K more rapidly than weathered surfaces. Direct loss of nutrients to the atmosphere is temperature dependent. Nitrogen is the element most prone to this type of loss as it starts to volatilize at 200 ^oC. At temperatures > 500 ^oC, over half the N in organic matter can be volatilized. Higher temperatures are needed to vaporize potassium (>760 ^oC), phosphorus (>774 ^oC), sodium (>880 ^oC), magnesium (> 1107 ^oC) and calcium (> 1240 ^oC) (Weast, 1988).

A- Fire effects on nitrogen

One effect of fire on N is volatilization (Anderson, 1980). Fire intensity, amount of green material, and fuel moisture has been reported to influence the amount of N lost through volatilization (Dunn and DeBano, 1977). 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 (Gartner, 1975). Schripsema (1977) thought lower levels of ammonia and nitrate may have reflected increases in plant uptake. The reported increases in all forms of N could be due to stimulation of legumes (Mayland, 1967), the washing of charred surface material into the soil (Metz et al, 1961), formation of ash which increases growth of nitrifying bacteria (Burns, 1952) and increased growth of nitrogen-fixing microorganisms (Isaac and Hopkins, 1937). Nitrifying bacteria are protected from heat and recover quickly to produce nitrates from organic matter (Wright, 1977). Ammonia increases have also been attributed to increases in biological activity after heating. Ammonifying bacteria can withstand heat up to 100 ^{o}C, while nitrifiers die at 53-58 ^{o}C (Raison, 1979). Depending on fire intensity certain forms of N increase or decrease. Heat also intensifies the physiochemical processes which lead to the decomposition of nitrogen-containing organic matter and release of ammonia from soil minerals (Arefyeva and Kolensnikov, 1964). Ammonia loss peaks at 2 50 – 300 ^{o}C, which might explain why ammonia could increase while organic N decreases as a result of volatilization at 200 ^{o}C (Raison, 1979). A guide to determine N loss is the appearance of the ash. At up 200 ^{o}C material is charred. At 200 – 400 ^{o}C grayish ash skeleton becomes apparent. At 400 – 500 ^{o}C the litter and mor become grayish ash while the A_1 horizon becomes reddish or grayish (White et al., 1973).

B- Fire effects on phosphorus

The main pool for P, a critical plant nutrient, is in the soil (94 - 98%) and not in the litter. Severe burning of vegetation and litter does not necessarily have the same potential impact on P pools as on N. However, organic forms of P in the litter are more readily available to plants. Thus, the impact of complete litter combustion on P cycling can be more severe than that indicated by the size of the individual nutrient pools. Also, P in soils with high Ca levels can be complexed into non-available forms which have detrimental consequences for ecosystem productivity. Since the cycling of P is primarily through the organic-P pools, removal of vegetation, all at the same time, by burning results in depletion of the aboveground P pools at a rate greater than mineral weathering can replace P (Klopatek, 1987).

C- Fire effects on the other nutrients

Comparatively few studies discuss nutrients other than N and P. Availability of K, Ca and Mg may increase after fire (Christensen, 1976; Raison, 1979). Soluble K will increase in the litter, mor and A_1 horizon if temperatures do not exceed 200 ^oC (White et al, 1973). Ohr and Bragg (1985) found that Ca, Fe and Mn decreased. However, they also found that if the plot was burned in consecutive years, then K, Cu, Fe and Zn availability is increased. This was attributed to different rates of plant uptake for each nutrient. Although an overall increase of most cations is well documented, fire can induce losses in some cases. Losses may be due to surface erosion (Wells et al, 1979), movement below the root zone from leaching (Stark, 1979), dilution effects of increased runoff (Conrad, 1978) and losses in fly ash (DeByle, 1976). These findings confirm that actual effects on soil nutrients at any given site will be variable depending on the condition of the vegetation, character of the soil and topography, and climatic factors (Vogi, 1974). Although Nutrient levels are important, nutrient availability must also be high if plants are to benefit. One effect of fire is to make water-soluble cations immediately available for plant uptake (Bailey, 1982). Raison (1979) found cation exchange capacity to be lowered by presence of oxidized organic matter, but light burns did not affect the exchange system (Scotter, 1963).

D- Fire effects on pH

Increases in pH have been attributed to ash accretion (Smith, 1970). The response depends on the amount of ash and buffering capacity of the soil (Tryon, 1948) and is considered negligible in grasslands (Nye, 1959). Timing of the burn and pH level of the existing soil may be important. Vlamis et al (1955) found pH to rise in neutral but not in acid soils. Owensby and Wyrill (1973) found a larger increase in pH from winter and mid-spring burning than after late-spring burns. This rise in pH is because mineral substances are released as oxides or carbonates that usually have an alkaline reaction (Schripsema, 1977). This is supported by others who have found that ash is dominated by carbonates of alkaline and alkaline earth metals (Daubenmire, 1968). Mayland (1967) found pH to be 0.5 higher, and Christensen (1976) found no change at all. There is also the possibility of pH rising 0.5 to 0.4 but only persisting for 1 or 2 years (Wright and Bailey, 1982).

2.4.5.3- Impacts on biological characteristics

Regulation of nutrients availability to vegetation is a property resulting from action of soil biota on substrate quality and quantity. Sustainability in the general sense depends upon synchrony between vegetation demand and the microbial process regulating the storage and flux of nutrients. Nutrient storage depends not only on immediate actions of biota, but upon their past activities. The structure of the soil and its capacity to hold water and nutrients, and indeed to sustain life, are the results of long years of activity by soil biota (Read et al, 1985). Fire effects on microorganisms are greatest in organic horizons and top 1 - 2 cm of soil where micro-organisms population are most abundant. This is where heating effects are the greatest or where fire reach moderate to high severity. Depending on the microbe, soil heating can be lethal (50 – 210 ^{o}C) or can alter their reproductive capabilities (Klopatek et al, 1988). Where temperatures as high as 210 ^{o}C may be needed to kill specific groups of bacteria in dry soils, soil moisture can reduce lethal levels around 110 ^{o}C (Wells et al, 1979). Fire can significantly alter microbes that affect large scale processes such as nutrient cycling. For example following a moderate or greater intensity fire, the general trend is significant decline of heterotrophic microbes. These microbes can be killed directly through consumption. Indirectly, heterotrophic microbes can be affected by totally or partially oxidizing organic matter in and above the soil surface or remove the vegetation completely, thus, reducing the potential on inputs in soil. Conversely, can be the primary carbon source for heterotrophic microbes, often resulting in a long efflux in CO_2 and, hence a carbon loss in the system (Klopatck, 1987). These processes can then alter C/N ratios, mineralization rates, etc. In contrast to the various heterotrophic responses certain autotrophic microbes may increase dramatically above pre-fire levels. Increased nutrient levels due to the effect on soil microbes and/or residues are more important. Particularly affected are organisms involved in N cycling. Fire can release or increase soil inorganic N concentration through a biotic and non-biotic means that can result in net N losses. In most environments, *Nitrosomonas* and *nitrobacter* species, which are involved with nitrification are normally in low densities when systems are in the steady state; this is believed to be a result of strong competition for NH_4^+ by vegetation as well as growth inhibition due to the presence of allelopathic compounds, such as terpenes and phenolics in the litter (White, 1991). Through consumption of the organic layer, any available NH_4^+ can then be oxidized by nitrifiers (klopatek et al, 1990). Without any potential plant uptake, resulting NO_3^- can either be denitrified or leached; this loss of N can have subsequent impact on plant succession and carbon cycling and hence ecosystem restoration. The importance of mycorrhizae in ecosystem function is well documented (Allen, 1991). The abundance and frequency of Vesicular-Arbuscular Mycorrhizae

(*VAM*) propagules decrease precipitously from a moderate disturbance, such as live stock grazing, to a severe disturbance, such as surface mining. However, the effects of natural disturbances, such as fire, have shown contrasting results (Allen, 1991). Dhillion et al (1988) found that colonization levels of *VAM* fungi in little bluestem roots were significantly reduced on burned sites when compared to unburned sites, but increased significantly after one growing season. Their results suggest that the response of *VAM* fungi to fire may be attributed to change in the host plant rather than the direct effect of fire. Fire temperatures usually do not reach a level high enough to kill all the plants, thereby leaving a large residual *VAM* pool in the soil and in plant roots. In fact, some research has shown that fire actually stimulated plant growth. In contrast, Vilarino and Arines (1991) examined a forested ecosystem in Spain a year following a wildfire and found lower soil propagule densities and lower *VAM* colonization in post-fire herbaceous vegetation in neighboring unburned areas. Biological disruptions begin in the 40 – 70 ^{o}C range with protein degradation and plant tissue death **(**Table 1). At soil temperatures of 48 – 54 ^{o}C, roots can desiccate or are killed, and seed mortality occurs in the 70 – 90 ^{o}C range. Depending on the microbe, mortality generally occurs between temperatures in the 50 – 120 ^{o}C range with fungi usually less resistant to thermal effects than bacteria. Burning under wet and dry conditions can have varying effects on soil mircoflora. For example, Klopatek et al (1990) showed that 90 days following a burn, soil microbial biomass was lower when burned under wet than under dry conditions. This trend was also seen for *VAM* populations (Klopatek, 1987). In contrast, nitrifier populations in the same experiment were more affected by burning under dry than wet conditions (Klopateck et al, 1990).

Increased nutrient level due to the effect on soil microbes and residents is more important. Bacterial populations, for example, decrease after a burn but increase three to tenfold within a month because soil temperatures and nutrients for their growth are more favorable (Jorgensen et al, 1979). Although fire is needed for seeds of most chaparral species to be released from dormancy, excessive heating apparently kills much seeds (Keely, 1977). Invertebrates play an important role in litter decomposition, carbon and nutrient mineralization, soil turnover, and soil structure formation. For example, termites and beetles can be particularly critical in arid and semi-arid systems as they are the initial decomposer colonizers of surface litter followed by microbes (Whitford, 1987). Ants have been shown in a variety of ecosystems to increase OM, N, and P concentration, as well as to increase densities of mycorrhizal spores (Friese and Allen, 1993; Gentry and Stiriz, 1972; Wagner, 1997). Many of the macro-pores that govern rapid movement of water into, and through, soils are created by invertebrate activity. The effects of fire on invertebrates and subsequent effects on belowground sustainability are difficult to assess and generalize because of fire severity variability, high pre–fire invertebrates' species variability, and selective modification of the balance of species by fire, and post–fire invertebrates' community response to change in litter and OM change

(Campbell and Tanton, 1981). Indirect effect of fire, such as litter mass reduction can decrease both the number of species and density of soil and litter invertebrates (Springett, 1976). Particularly susceptible are those belowground dwelling invertebrates which are not highly mobile and primarily reside in litter or the surface soil horizons as they are most vulnerable to the direct effects of intense surface fire or ground fires (DeBano et al, 1998). Fire adaptations (high mobility, water conservation, and heat resistance) exhibited by invertebrates in fire affected ecosystems appear to be more species-specific characteristics rather than fire–specific. In fire–adapted ecosystems, such as tall grass prairies, increased plant productivity seems to be intimately closely linked with greater earthworm activity as well as nutrient mobilization (James, 1982). In grassland ecosystems, fires rarely reach the severity needed to adversely affect invertebrate populations. In forest ecosystems, both adverse (Sgardelis et al, 1995) and neutral (Coults, 1945) effects of fires on predominantly litter dwelling macro-invertebrates have been documented. However, as Campbell and Tanton (1981) stated, cause and effects of fire on invertebrates relative to belowground sustainability are difficult to predict. Fauna such as amphibians, reptiles, and rodents, also participate in the formation or alteration of belowground ecosystems and their physical properties. For example, in arid and semi-arid systems, the activity of burrowing mammals creates patches in which plant diversity increases (Thorsten et al, 1997). Accumulation of nutrients, water and seeds trapped in these depressions can be partially attributed to this phenomenon. The direct effects of fire on most soil vertebrates are minimal as they are mobile enough to escape lethal temperature or by feeling on the surface. Indirect effects, such as loss of habitat, exposure of soil burrow openings and increased predation, are persistent for several years following fires (Ream, 1981). In conclusion, for various reasons listed above, fire can be more detrimental to invertebrate than vertebrate populations. However, catastrophic stand–replacing fires can result in significant soil invertebrate and vertebrate mortality. The overall effects of these losses on belowground sustainability may be insignificant compared to other belowground component processes that are lost or significantly altered. Perhaps what is more important following a catastrophic fire is the rate of recruitment of micro- and macro- soil fauna from landscape boundaries (Bell et al, 1997) once other succession processes are underway.

Table 1: Threshold temperatures for biological disruption in soils

Biological components	Temperature threshold (°C)	References
Plant roots	48	Hare (1961)
Small mammals	49	Lyon et al (1978)
Protein coagulation	60	Precht et al (1973)
Fungi (dry soil)	80	Dunn et al (1985)
Seeds (dry soil)	90	Martin et al (1975)
Fungi (wet soil)	60	Dunn et al (1985)
Seeds (wet soil)	70	Martin et al (1975)
Nitrosomonas Spp. (dry soil)	80	Dunn and Debano (1977)
Nitrosomonas Spp. (wet soil)	90	Dunn and Debano (1977)
VAM mycorrhizae	94	Kopatck et al (1988)

Adapted from Debano et al (1998)

2.5- Positive effects of wild land fires (fire as tool for livelihood and ecosystem improvement)

Currently there are several good examples of case studies high lighting the importance and reality of anthropogenic fires in improving livelihood, improving soil conditions, controlling pests and diseases and invasive species and maintaining biodiversity in forest ecosystems. Depending on several fire severity measures, changes in belowground components can either be beneficial or deleterious to the entire ecosystem. Low impact burring can promote an herbaceous flora, increase plant available nutrients and thin-over crowded forests (Daniel et al, 1999). In Africa and Asia, even though in some cases wild fires had been ignited for apparently no valid ecological reasons, the use of fires had been and is still an integral part of land use and livelihood systems. A fire is used for field preparation in slash and burn agriculture on which majority of the rural people depends to meet energy and food needs. During the agricultural activities, the local people use fire to control pest and suppress weeds. In Ghana for instance, fire is also used to prevent the rottenness of the palm trees and to ensure better taste and to increase yield of wine during palm wine processing. To the hunters, fire is a tool for smoking out games (Heikkila et al, 2007).This tells us some of the ways in which communities use fire to cultivate crops, manage pests and disease, hunt and ensure the availability of non-wood products. While the public, particularly those in developing countries may have the option that fires are always harmful to nature due to the devastating effects of wildfire but they do recognize some importance of fires that are connected to their livelihood. They also have different views about wildfires which is important to consider in strategies for community based fire management programs (Heikkila et al, 2007).Prescribed fires are deliberately planned and set by fire management officers for a variety of reasons. Forest managers often set prescribed fires to prepare particular site for the planting, as well as to kill undergrowth to reduce the competition from unwanted vegetation. Prescribed fires are used extensively for wild life habitat management. Prescribed fires are also set and managed to reduce the potential hazard of larger uncontrolled wildfire out breaks. These fires reduce dead vegetation or consume fuel that has accumulated on the forest floor (Bowman, 1988). Early burning is one of the methods adopted in high rain fall savanna wood land. Light fires are started early in the dry season in parts that are just starting to dry while most of grass is still green. Early burning removes the fuel that would start fierce fires later in the dry season. Early burning is conveniently applied in high rainfall wood land where the grasses dry up gradually in patches (Badi et al, 1989). Back firing is one form of the indirect methods. It is normally used against a rapidly spreading fire. Back firing is the process of intentionally starting a fire inside the fire edge or fire barrier in advance of fire-head, or along the forward flanks (Heikkila et al, 2007). In grass land ecosystems, fire is the primary mode of decomposition, making it crucial for returning nutrients to the soil and allowing the grasslands to sustain their high productivity. Research of two uncontrolled burns on organic carbon revealed that the total and available nitrogen, phosphorus and sulfur of surface soils (0-5 cm) of the southern Caldenal region in Argentina (Castelli and Lazzari, 2002) confirmed the general accepted trend that the first controlled burn generally caused beneficial effect on the total elements, either immediately or one to two years after the burn. It has also caused a considerable flush of the available nutrients that were more persistent under the shrubs. This could be explained by the fact that grasslands burn more readily than the shrub ecosystems with fire moving through the stems and leaves of herbaceous plants and only lightly heating the underlying soil even in cases of high intensity (Debano et al, 1998). Thus, releasing nutrients that are locked-up in a slowly decaying woody material into the forest nutrient recycling system. These results indicate that in a fire-prone habitat such as in semiarid ecotones, long-term ecosystem health could rely upon a balance between fire–related nutrient outputs and succession–related nutrient inputs to ecosystem nutrient capital. Research has revealed that fire not only helps to maintain the ecosystem but also helps to ensure the availability of quality forage. For instance, it was found that in South Africa and Namibia, that freshly burnt savanna areas had new plant growth that provided palatable forage compared to unburned areas with older grasses (Heikkila et al, 2007). The threshold level seems to be at 4000 kg/ha of grass sward. Below 4000 kg/ha burning is not required, whereas anything above 4000 kg/ha will require burning to remove unpalatable grass sward. In this part of the world animal keeping is a way of life and domestic animals like sheep, goats and cattle obtain greater than 85% of their nutrition from forage. In addition, wildlife usually intermixes with domestic cattle in grazing in Sub-Saharan Africa. Therefore, pasture created by fire, especially on land that is normally unsuitable for crop production, can be a useful source of forage. More importantly, the fresh forage will encourage large herbivores to move to less preferred areas in order to minimize the overuse of preferred areas which are areas kept short by constant grazing (Archibald et al, 2005), and allow grazing-intolerant grass species to grow in these areas and thus persist within the ecosystem. Fire does not only help to ensure the availability of quality forage, but also certain wildlife species like the ``grass cutter`` and Giant rats do benefit significantly from periodic fires (FORIG, 2003). The fact is that trying to eliminate fire from the wild land is not a practical option, and has adverse effects on regeneration of some species and biodiversity. Fire and ecosystems have been linked in many ways for millennia and that must be recognized for any wild land fire management policy to be effective. More importantly, fire should be well integrated into the practice of forest conservation and management. At least there is sufficient information from these case studies to be sure about the importance of planned burning in ecosystems to maintain biodiversity, ensure regeneration and improve soil fertility and forage production particularly in the savanna areas where biodiversity loss, soil erosion and availability of animal feed are environmental issues of great concern in the future.

2.6- Wildfires' protection

Before onslaught of the industrial revolution almost 50% of the land surface of the world was covered with forest. In 1955 this area had been reduced by half, and in 1980 the original pre-industrial revolution area was estimated to be only 20% of the land surface of today; we can say that every county must be concerned about the threat of fire to their forests (Heikkila et al, 2007). Wildfire protection activities include:

A- Fire prevention procedures

Forest fires prevention is the means of reducing the number of unwanted, uncontrolled or escaped wildfires. Wildfire may occur in any vegetation cover type when conditions are favorable for burning. Every fire requires some spark or flame to start. Fire prevention is one of the most important functions of the fire control service. In addition, prevention activities are very often the most economical way of reducing fire damage and losses. Basically, wildfire prevention means stopping all unwanted man-caused wildfires from starting in the first place (Bayoumi, 2000).

B- Fire suppression activists

They include all the actions that are required in fire fighting for the successful suppression of a fire and to prevent wildfire from spreading from one area to another area (Bayoumi, 2000).

C- Treatment procedures of fires effects

These aim to reducing fire damage and losses by a fforestation or replanting burned forest area (Bayoumi, 2000).

2.7- Forest fire protection methods

The methods for guaranteeing obtaining protection from forest fires may be summarized as:

1- The elimination of the cause from which forest fires originates;

2- The reduction of the fuel (inflammable material) upon which forest fire feeds;

3- Quick detection of started forest fires;

4- Prompt suppression of the discovered forest fires.

Accidental fires do occur naturally, but more than 95% of all forest fires are related to human activities. Consequently therefore, many fire situations may be completely avoided if appropriate training is provided. Additionally, communication, equipment and appropriate tools are required to achieve acceptable levels of preparedness before the annual fire seasons occur. Silivicultrual treatment of the forest assists to ward securing fire protection. Assistance can be rendered in the reduction of the inflammable material available for the fires. Close utilization of defective trees and the disposal of slash will remove an important class of inflammable material. The selection method producing an uneven aged stand with a constantly maintained cover which protects the ground and litter, from excessive drying out, tends to reduce the inflammable material; hence, it is preferable to other reproduction methods. Suppression may be made easier by disposal of slash, in that a forest unencumbered with slash is more readily traversed and fires more effectively fought where slash is lacking. The employment of severance cutting, creating cleared line intervals throughout the forest, also serves to facilitate access and affords vantage points from which fire fighting may be begun. Development (by artificial regeneration) of belts of fire resistant species, parallel to rail road lines or in other locations of high fire hazard, may be used where management can be intensive for preventing the start or spread of forest fires. Without such precautions as have just been given, elimination of the causes, quick detection and prompt suppression of forest fires cannot be influenced to any large extent by silivicultural treatment of the forest (Hawley, 1921).

2.8- Fire effects and protection in the Sudan

Sudan is lacking fire management organizations. However, the traditional system of constructing or maintaining forest fire lines (Firebreaks) is adhered to through an annual program budgeted for, even though necessary funds are always short. Also ground vegetation especially grasses may dry very fast after the end of the rainy season and the firebreak program is never completed in time. Fire lines, which usually form the boundaries of forest reserves, protect government forest reserves by law. The law states that fire lines should be at least 2 m wide but these are inadequate and normally 5 - 8 m wide lines are cleared but still fires may jump over. Cleaning fire lines is an expensive operation. In the colonial time and up to the end of the sixties, the Native Administration under the supervision of the Range and Pasture Department in close collaboration with the Forestry Department maintained a firebreak network, extending North-South over North Kordofan and North Darfur to protect grazing lands and gum gardens. Usually 4 m wide lines are cleaned and spaced parallel to each other and separated by 80 m distance. The middle part of the 80 m is early burned in the dry season before the grasses were fully dry and consequently less likely to burn and at the same time create wide enough firebreaks. This pattern is repeated systematically over the semi-arid lands. Early warning systems, detection and monitoring systems of forest fires are not available. No voluntary fire fighters are available but people and communities are obliged by the forest law to report and help in fighting wild forest fires. Fire research is absent. Prescribed burning is used in natural forests in Western Sudan (Jebel Marra) and used to be practiced as early burning in the Southern Sudan but has stopped due to the war. The method of backfiring for controlling a wildfire is forbidden except for certain conditions and under control of appropriately trained foresters. Early burning is convenient in high rainfall wood land where grasses dry up gradually in patches. It is not suitable in the low rainfall wood land because the grasses dry up immediately after the rains. Very wide fire lines (50 m) have been used to separate blocks of Eucalyptus plantations in the Khartoum Green Belt. Fuel breaks (greenbelts) consisting of teak (*Tectona grandis*) were used in the South to protect fire-prone species. In traditional agricultural areas, people and farmers are guided by extension workers to protect their villages and lands against fires. At present there is no method other than burning to clear forest lands for rain-fed cultivation. The forest law however prevents wasteful burning and obliges cultivators to make use of cleared woody materials (shrubs, trees) by converting them into useful products, e.g. charcoal. The forest policy of 1986 emphasizes the protection of forests against fires. The forest law of 1989 prohibits trespassing of people and their animals into reserved forests and prohibits the carrying of ignited material into the forests, making of fires for cooking or otherwise in or near forest; it also obliges people to help in extinguishing forest fires. Reduction of fires will definitely conserve the natural resources of the country and will improve the growth of many tree species. Needs for fire management can not be detailed here due to the complexity of different environmental conditions and the needs for different management techniques. The very large size of the country, the various local factors and weather conditions, the rapid trends towards repeated severe droughts and desertification, the increase in population and domestic animals, the displacement of rural people towards cities, the expansion of unplanned rain-fed cultivation, the poverty of the people, the unawareness of the decision makers regarding forest conservation - these are all major problems and impediments. Sudan needs extension capabilities to teach the people how to protect their lands. Research is needed to find out safer methods for preparing agriculture or forest lands for cropping or forest plantations. Above all trained personnel and supporting equipment is needed for transport, detecting and fighting forest fires (Bayoumi, 2000).

Chapter 3

Materials and Methods

3.1- Study area

The study area covers Albaja region which is located in Al Duem Locality in the White Nile State. According to Harrison and Jackson classification (1958), Albaja grassland area is a major rangeland in White Nile state. Precisely speaking, the area is defined by latitudes 13^{o} 36$^{/}$ - 14^{o} 10$^{/}N$ and longitudes 31^{o} 45$^{/}$ - 32^{o} 23$^{/}E$. Figure 1 shows the location of Albaja area.

The area is dominated by a tropical continental type of climate. The majority of Albaja area lies in the semi desert ecological zone. The fall (autumn) season spans from June to September with a total annual rainfall of 150 to 300 mm. However, little showers are frequently experienced in May. Temperatures are usually high during the summertime with a high record of 43 ^{o}C in mid April. The mean maximum temperature is 38 ^{o}C, whereas the minimum temperature ranges between 16 ^{o}C to 23 ^{o}C seasonally in winter (December-February). Appendices 1a to 1e show the climatic data for the years 2000 to 2007 collected from Alduem meteorological station.

The underlying geology of the area is mainly composed of undifferentiated basement complex, uncomfortably overlain by tertiary and quaternary sedimentary cover. The main outcrops in the research area are represented by two hilly masses (the range of Jebal Abu Rada'a and Arshkoul) with their surrounding pediments (Lotongol, 1976; Vail, 1978). The geology and climate in the area have combined to create two major landscape units, namely: the pediment surfaces and the goz sands. The sandy soil covers the extreme tract of the research area. The process of soil formation under the semi-arid conditions starts with the weathering of the Nubian Sandstone and the Aeolian deposit (FAO and UNESCO, 1974). Vail (1978) noted that in northeast Africa, goz-type sands overlie a wide range of rock types of all ages, susceptible to weathering on the basis of the dune trend patterns; he argues that the ultimate source area of the sand would have been the Sirte Basin in Libya, but the southward-blowing winds would have undoubtedly deposited other suitable sandy materials. It is generally agreed that the goz deposits are Quaternary in age (Vail, 1978). Sandy soil is the dominant type in Albaja and it exists in a form of stretched sand plains or elongated fixed sand dunes. The sandy soil is characterized by its high infiltration rate. Clay and silt soils are confined along the valley banks and in the depressions.

The White Nile and its tributaries dominate the drainage system of the area. The river and the network of the irrigation canals form the main source of water for human and animal consumption. Away from these sources, scoop-holes, water ponds and man-made depressions and shallows (hafir and folas) do exist for use during the dry seasons.

Arboreal, shrubby and grassy covers are all encountered in the area. Short grasses and herbs dominate in the northern sandy portion, whereas shrubs and acacia trees prevail in the southern part of the study area.

It is generally thought by the natives that the area of Albaja was once awash with diverse types of wildlife, both indigenous and drifters. Few of these are rarely seen today. Albaja has been subjected to historical fires, which have affected the niches of the wildlife in different ways (Hashim, 1999). Soil dwelling invertebrates and vertebrates include termites, beetles, and other insects, and amphibians, reptiles and rodents. Some birds are also present.

Albaja region is largely inhabited by sedentary agriculturalists as well as pastoralists, both nomads and semi-nomads. The modes of traditional rain-fed agriculture and animal husbandry (both agro-pastoral and mobile) tower the exercise of land-use practice in Albaja region. The natives customarily follow long-inherited and conventional methods in agricultural production, animal rearing and the management of resources. The main cash crops are sorghum in the clayey plains; sesame, rossell (karkadi), and watermelons in the sand dunes. Albaja is a marginal grass land region with poor growth of *Acacia senegal*, so the production of gum Arabic is low.

Albaja region is endowed with rich natural resources in terms of range-lands. Therefore, it is rich in animal wealth due to the occurrence of lush pastures (texture and productivity). The carrying capacity was estimated as 0.75 ton/ha (AOAD, 1996). The animal populations are estimated to about 107000 heads of camels, cattle, sheep and goats during the rainy season. The area seems to be on the decline because of overpopulation and the irrational use of the resources and these have led to the emergence of: deterioration of range and forest recourses; land degradation; desert encroachment and disappearance or out-migration of certain plant and animal species. The area is subject to current and future hazards due to the following factors:

a) Irrational and continuous grazing in the vicinity of permanent water points and villages deteriorates soil and range resources;
b) Removal of the vegetation covers by virtue of irrational logging and criminal incineration by arsonists;
c) Over-consumption by unauthorized charcoal and log traders. Due to this unwise and illegal activity large areas are affected by desiccation and desertification;
d) Drought which affected and still endangers many trees, scrubs and their seedlings;
e) Shifting cultivation and short fallow periods that don't allow land to restore its fertility;
f) Frequent uncontrolled hazardous fire.

These factors, working individually or in combination have direct bearing on the present-day environment and ecosystem settings and the resultant negative impact on the whole socio-economic patterns of the area. The ignition of thick grass cover following the rainy seasons usually result in the soils enhancing the growth of fire-resistant and unpalatable species that can have detrimental effects on the animal feed resources and biodiversity of the area. The existent hazards due to fire include: extinguishment of the vegetation mantle that protects the underlying soils; scarcity of the palatable plants; encouragement of growth of plants and weeds adaptable to wildfire that in turn lead to drastic change in plants structure and compositions; loss of dry fodder about (30% by volume) and loss of wildlife habitats.

3.2- Experimental design and layout

3.2.1-Fire regime in Albaja

In Albaja extensive wild land fires occur annually, in average 40% of Albaja burns annually. The combined analysis of remote sensing and field surveys suggest that wild fire plays an important role in causing reduction of a number of valuable fire-sensitive species of shrubs and grasses most valuable for animal feed. The fire season was found to possibly start during the first ten days of September and the majority of Albaja area usually burns during October (Elgamri, 2007).

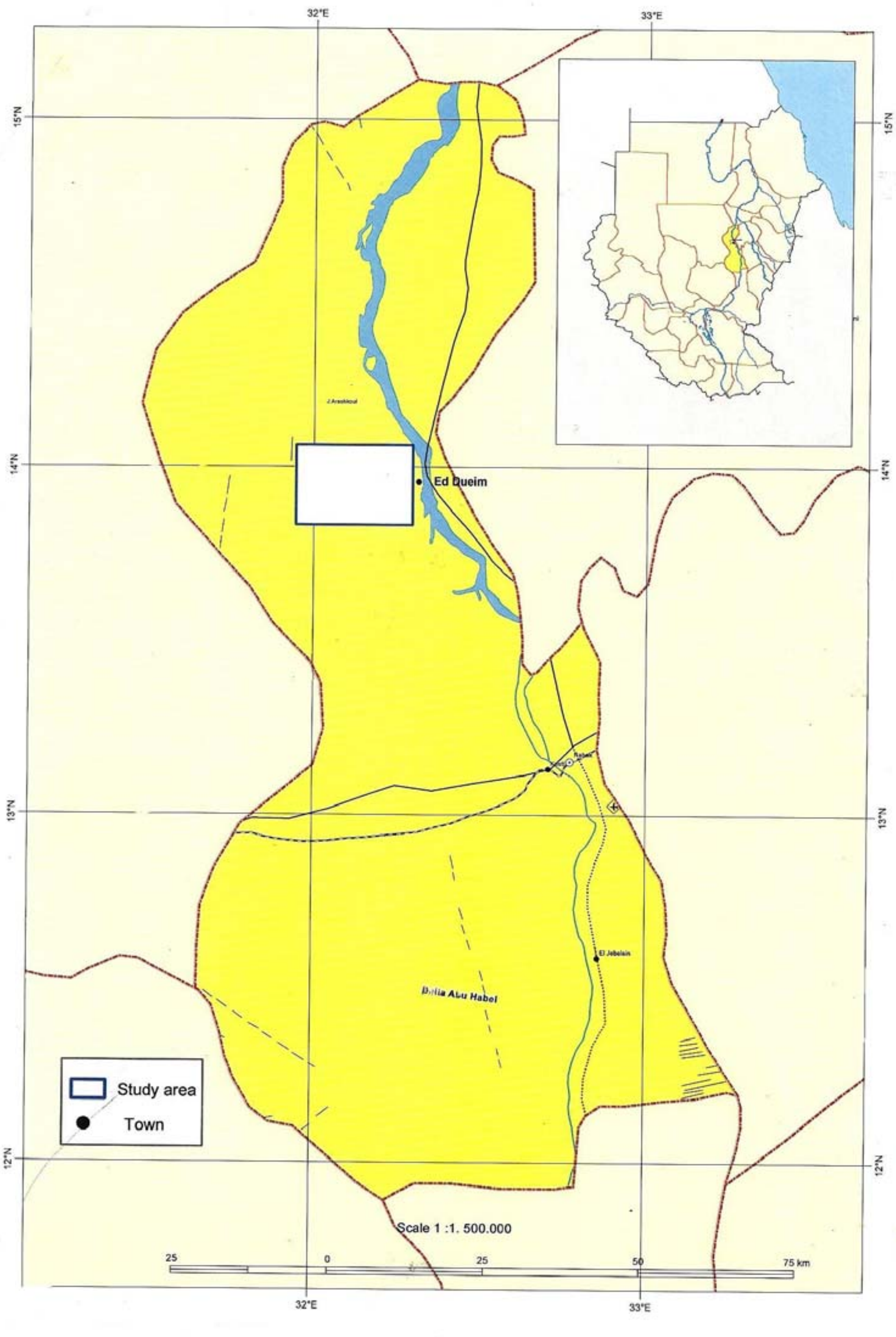

Figure 1: Location map of the study area (source: Sudan geological Research Corporation)

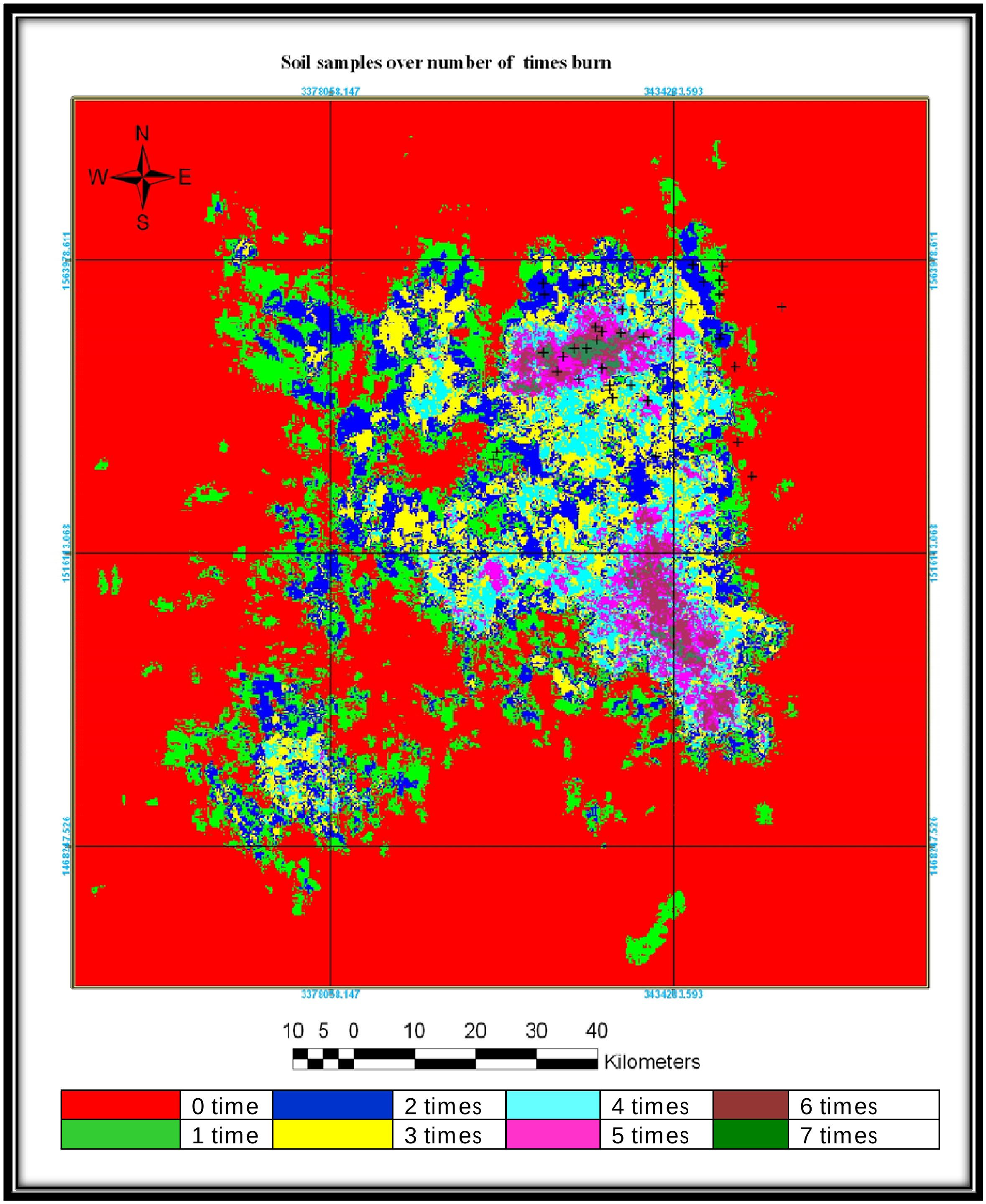

Figure 2: Albaja location map and soil sampling points (Source: Elgamri, 2007)

3.2.2- Methodologies used for the mapping of the arsonized segments in Albaja region

Due to the lack of the previous information on the wildfire occurrences in the study area, Elgamri (2007) has resorted to the application of a number of software techniques in order to reflect the intensity as well as the spatial and temporal distribution of incinerated segments in the wasteland realm of Albaja region that occurred during the period 2000 to 2005 inclusive.

To make for the deficiency and solve the problem in question, the author has utilized the following techniques, namely:

- Global Positioning System (GPS) Device;
- Moderate Resolution Imaging Spectrometer (MODIS);
- Near Infrared (NIR);
- Normalized Difference Vegetation Index (NDVI);
- Arc View Software (AVS).

The GPS readings for the fire events during the successive seasons of 2003, 2004 and 2005 were utilized in interpreting the historical fires in the image time series. Patchy swaths of land affected by consecutive conflagrations that took place in the study area over the six-year timeframe have been singled out by using the MODIS surface reflectance image data, accessible from Land Processing Distributed Active Archive centre (LP DAAC). The aforementioned author has adopted stepwise scenarios in order to ease the analyses of the data and aid the subsequent interpretation, namely:

1/ Selection of cloud and gap free images pertaining to the area of interest with Albaja region enclosed;

2/ The obtained time series map was then windowed to a standard study area that encompasses the whole area as mentioned in (1) above. The aim behind this was to:

2.1/ Trim down the data volume and simultaneously expedite the image processing;

2.2/ Calculate a Normalized Difference Vegetation Index Image (NDVI).

The NDVI is a spectral index susceptible to the presence and abundance of green vegetation. Thus the rate of this index is inversely proportional to the degree and extent of the removal of the vegetation cover. The more burned vegetation areas are the lesser the NDVI is. The burned vegetation appears as pixels where NDVI has reduced significantly over times. Burned areas in Albaja based on difference image were delineated from NDVI time series by means of subtracting earlier images respectively. Burned pixels which NDVI has diminished considerably over times are determined and the changes between sequential NDVI images detected and saved in a new image.

3/ Adoption of interactive threshold for the spotting of scorched areas: The recognition of burned areas was based on the usage of this technique. To mark the gutted areas from each difference image, a color density slice was created by using NDVI difference values from the pixels of minimum and maximum limits of darkness range of the scorched areas. Unaffected areas that resemble the burned ones in their NDVI difference values were technically concealed to generate a new noise free image.

The quoted author went on to interpret that: the consequential burned area images were later transformed from raster- to vector-pattern to assist the preparation of the final burned area maps by way of Arc View Software (AVS). Thereafter, all the burned areas were superimposed in order to come up with one image reflecting the areas that were annually burned. Finally, he concluded that: “The yearly images were then collectively processed to produce a new image on the basis of how often each pixel within Albaja area has burned over the six-year duration of the study in question”.

3.2.3-Burnt area

According to the map that was obtained by remotely sensed satellite imagery as discussed above, the study area was divided into eight classes showing the number of burn times from 2000 to 2006 as:

A- Class I: zero time burn;

B- Class II: one time burn;

C- Class III: two times burn;

D- Class IV: three times burn;

E- Class V: four times burn;

F- Class VI: five times burn;

G- Class VII: six times burn;

H- Class VIII: seven times burn.

3.2.4- Soil sampling

Soil sampling inventory had been undertaken in order to assess the current status of the different properties or components of the soil of the area mostly affected by the seasonal wild land fires. In the year 2007, a total number of 40 plots were located within the study area based on the classes of burn categories, between 10 and 17 May 2007. Five samples from top soil (30 cm depth) were located and taken within each burned area (Figure 1). The profile description was made according to the FAO (1974) guide lines. One profile was located in each site representing the different classes of fire burn frequencies as shown above.

3.2.5- Soil analysis

Soil samples were air-dried and separated into coarse and fine fractions with a 2 mm sieve; coarse fractions were discarded. Sub samples of fine earth were analyzed for physical and chemical properties. All the parameters determination was carried out according to the international procedures of soil analysis (Page, 1982; Klute, 1986).

1/ Procedures for physical parameters analysis

A/ Particle size distribution: The particle size distribution was made using the modified hydrometer method (Day, 1965) and American Society for Testing and Materials (ASTM, 1985 d). The textual classes were determined according to the American system using the USDA classification scheme.

B/ Bulk and particle densities and porosity: The bulk densities were determined using Clod method and the particle density by Pycnometer method. Porosity was calculated according to the following formula:

$$S\% = (1 - D_b/D_p) X100$$

Where: S% = total porosity, D_b and D_p denote bulk density and particle density respectively.

C/ Field capacity, permanent wilting point and available water: The field moisture capacity (FC) and the permanent wilting point (PWP) were determined using the pressure plates and pressure membrane equipment at 33.3 KPa and 1500 KPa pressures using soil clod samples. The available water (AW) was calculated as the difference between Field Capacity and the Permanent Wilting Point (AW = FC-PWP).

D/ Structural stability: Aggregate stability (AS of particles less than 50 microns) was measured in duplicate according to procedures out lined in Hand Book 60 described by Bouyouco (1962).

2/ Procedures for chemical parameters analysis

A/ Soil reaction: A pH meter (model No. 446/1) was used to measure the soil pH in a soil paste and in a soil: water ratio of 1:5.

B/ Electrical conductivity of the saturation extract (ECe): It was measured by an EC meter (model No. CC851).

C/ Soluble cations and anions: Saturated soil pastes were prepared, and the saturation extracts of soil samples were collected using a suction pump. These extracts were saved for chemical analysis. The saturation percentage (SP %) of the soil pastes were determined. Ethylene diamine tetra acetate (EDTA) was used for the determination of calcium plus magnesium. Sodium and potassium were measured using flame photometer. The carbonates were determined by titration against 0.01 *m* sulfuric acid. The chloride was obtained by titration against 0.005 *m* silver nitrate. The sulfate was obtained by difference.

D/ Cation exchange capacity (CEC): The cation exchange capacity was determined by saturating with sodium acetate and the displacement of adsorbed sodium by ammonium acetate.

E/ Organic carbon and organic matter: Weakley and Black (wet oxidation) method was used in the determination of organic carbon (OC). Organic matter was calculated by multiplying OC by 1.72.

F/ Phosphorous: It was determined according to Nelson et al (1953).

G/ Nitrogen: Soil nitrogen was determined using macro Kjeldahl method**.** **Micronutrients (Zn^{2+}, Fe^{2+}, Cu^{2+}, Mn^{2+}):** They were extracted by $CaCl_2$ solution adjusted to pH 7.3 by 6 *N* HCl and analyzed by atomic adsorption spectrophotometer.

3.3- **Soil seed-bank**

Tree seeds were separated from soil by sieving. Seeds were counted for the different fire burn classes and their numbers reported to per hectare unit area. Separation of soil grass seed bank was done using Hayashi et al (1978) standard method.

Seed germination test, for different burn classes, was carried out in Petri dishes in the laboratory and in plastic trays in the nursery. Ten samples from each treatment were replicated and the germination tests were repeated twice. The tests continued for 4 weeks. The soil samples were kept wet through out the germination period by daily watering with a fine shower. Germinated seedlings were counted every 7 days and finally germination percentage was calculated.

3.4- Data analysis

Data from all measurements were statistically tested for significance using a two factor analyses of variance (ANOVA). The two-factor ANOVA was conducted using SAS (1997).

Chapter 4

Results and Discussions

4.1- Vegetation and fires

Albaja region is typified by semi-desert and low-rainfall savanna climatic conditions (150 - 300 mm) in the north and south respectively (Jackson and Harrison, 1958). Arboreal, shrubby and grassy covers are all encountered in the area. Short grasses and taboos dominate in the northern sandy portion, whereas shrubs and acacia trees (*Acacia senegal*, *Leptadenia pyrotechnica*, *Acacia seyal* and *Acacia mellifera*) prevail in the southern part of the study area. *Acacia senegal* and *Leptadenia pyrotechnica* grow in the sand dunes (Qoz land); *Acacia seyal* trees are found both in the beds and fringing the banks and terraces of wadis and other dry streams, while *Acacia mellifera* scrubs dominate in the low-lying areas. Moving progressively southwards, the vegetation cover passes into trees of *Balanites aegyptiaca*, *Ziziphus spina-christi*, *Combretum glutinosun*, and low-density *Acacia nilotica* by the dry streams' sides. Irrational cutting is responsible of this low-density phenomenon. Besides that, grass and shrubs are encountered; they include fine and coarse *Cenchrus biflorus*, *Aristida spp*, *Aristida palida*, *Cymbopogon proximus*, *Cymbopogon nervatus*, *Panicum turgidun*, *Sesamum alatum*, *Cassia senna*…etc.

Fire has probably been an important ecological factor in Africa for many thousands of years. As a result, large areas are occupied by fire-climax vegetation which maintains its existence by the annual fire (Badi et al, 1989). Wild land fires are widespread in the low rain fall savanna zone of the Sudan. Therefore, most of the savanna vegetation of the Sudan is fire-resistant (Bayoumi, 2000). Because the environment in Albaja is highly fire-prone and annually subjected to large scale wild land fires its vegetation is expected to consist of fire-resistant species. The degree of tolerance to wild land fires varies substantially within the fire-resistant species (Elgamri, 2007).

Elgamri (2007) has reported that Albaja is an expanse of grassland with few interspacing trees and shrubs, frequently vulnerable to overgrazing and wildfires which affect around 40% of its total open rangeland. He also maintains that the fire season normally commences around the second week of September. The apex of the raging conflagration is recorded towards mid October. By that time the bulk of Albaja grassland will have been swept over and burned down. Considerable amount of biomass in the area is occasionally removed either by grazing animals or soil consumers, usually termites. As a result, very little organic matter is anticipated to build up remarkably. The average weights of the biomass are estimated to range between zero to 1200 Kg/ha (Elgamri, 2007). Although the area is frequently hit by wildfires, nevertheless, the vegetation cover percentage is insignificantly affected. For instance, *Aristida adscensionis* is species of grass usually attains the highest percentage of coverage density and dormancy as the frequency of fire increases (Elgamri, 2007). On the contrary, *Dactyloctenium aegyptium* shows an inverse relationship, i.e the more the fire frequency increases the more reduced values of the species frequency and dominancy become. Some grasses also exist in low vegetation cover, frequency and dormancy without respect to fire frequency i.e. *Sesamum alatum*. In contrast, some grasses and herbs exist in low vegetation cover, frequency and dormancy**,** but their trend increases as fire frequency increases i.e. *Euphorbia aegyptiaca*. That is to say, the number of fire sensitive species lost by burning is equal to that added to site by fire-resistant species.

Two factors are presumed to have direct bearing on the extent of the burned area namely, the total amount of rain precipitation and the spatial stretch of the land inflicted by the immediately antecedent bout of fire outbreak. It is observed that areas under and close to the trees show no vestiges of burning because they are almost devoid of undergrowths. This is ascribed to the intensive impact of the animal herds that resort there for midday siesta. Elgamri (2007) has noticed and thus reported that areas that are burned at least once tend to occur along the fringes of the rangeland in Albaja region where farming activities are exercised. Once the areas are cultivated they become protected against fires because the farmers opt to take away their harvests, clear the litters and collect the stalks as animal provender in due time before the start of the next farming time. Wild fires under hot arid conditions are triggered and fanned by a number of causative factors; these are, but not limited to, swift winds, low relative humidity, high temperatures and inflammable materials responsible for the flare-up of spontaneous fire. The facilitators of fire flare-up are: exposed terrain, northeast blowing winds and the probable presence of fire-fuel types of grass. From the above mentioned results, we conclude that, the wild land fire is common and spreads rapidly due to the northeast wind and flat terrain of Albaja region. Also due to small amount of fire-fuel (such as grasses) the fires effects are of low severity extend.

Plate 1: General view of vegetation, soil and landscape in Albaja area (Produced by the Author, May 2007)

Plate 2: View of burnt land in Albaja area (Produced by the Author, May 2007)

Plate 3: Close view of burned grasses in Albaja area (Produced by the Author, May 2007)

4.2- Soil characterization

The soils developed on Albaja area are classified as Aridisols (FAO and UNESCO, 1974). Low precipitation limits the development of soil horizons. Although they lack the morphological features of true soils, they are nevertheless very deep and permeable, a characteristic which makes them a good medium for millet growth. Generally they are composed of fine and very fine sands which make up more than 68% of the particle size distribution classes. These sands are mainly fixed by the existing vegetation cover of marakh shrub *(Leptadenia pyrotechnica*) and grasses. Although the physical and chemical properties of these soils indicate infertility, which give them an Aridisols classification (FAO and UNESCO, 1974), they are quite suitable for millet and often for groundnut cultivation even with very low amount of precipitation.

4.2.1- Soil profile description

Soil description in the field was done by digging profiles in the different burning frequency zones. The soil profiles show striking similarities in regard to their measured parameters and characteristics (texture, structure, color, $CaCO_3$, porosity, roots and biological activity). Hence, only one profile (in the zero-burn zone) was selected to represent the whole area.

A- Information on the sampled site

I/ Profile No (zero-burn zone);

II/ Date of examination: 10 - 17 May 2007;

III/ Location: Albaja area, west of White Nile;

IV/ Land forms:

1/ Physiographic position of the site: Plane;

2/ Land form of surrounding country: Flat;

3/ Micro-topography: Nil;

4/ Vegetation: Thorny trees, shrubs, herbs and grasses;

5/ Climate: Semi-arid.

B- General information on the soil

I/ Parent material: Basement complex and Nubian sandstone;

II/ Drainage: Moderately well drained;

III/ Moisture conditions in the soil: Dry;

IV/ Presence of surface stones or rock out crops: Nil;

V/ Evidence of erosion: Erosion by wind has often resulted in the presence of minor barchans which are a common phenomenon these indicating increasing dry conditions (i.e. desertification);

VI/ Presence of salts or alkali: None;

VII/ Human influence: Range and cultivation.

C- Brief general description of the profile

Due to the similarities of the profile features in texture, structure and consistency, it was divided into three layers according to differences in color only.

Top layer: 0 – 20 cm deep; brownish yellow (10 YR 6/8) dry, very dark yellowish brown (10 YR 4/4) moist; sandy loam texture; granular weak fine structure; non-sticky and non-plastic wet, soft dry, friable moist; few small pores; few roots; slightly alkaline; no $CaCO_3$ concretions present.

Middle layer: 20 – 80 cm deep; strong brown (7.5 YR 5/8) dry, dark brown (7.5 YR 3/4) moist; sandy loam texture; granular weak fine structure; non-sticky and non-plastic wet, soft dry, friable moist; few roots; fine pores; slightly alkaline; no $CaCO_3$ concretions present.

Bottom layer: 80 – 150 cm deep; yellowish red (5 YR 5/8) wet, yellowish red (5 YR 5/6) moist; sandy loam texture; granular weak fine structure; soft dry, friable moist, non-sticky and non-plastic; slightly alkaline; no $CaCO_3$ concretions present.

Plate 4: Soil profile in Albaja area (Produced by the Author, May 2007)

4.2.2- Physical properties of Albaja area soils

Result for physical properties of Albaja soils are presented in Table 2. The particle size distribution of Albaja soils is dominated by sand fraction which comprises more than 70%. Clay particles percentage is fairly high (about 17%) but silt fraction is surprising low (about 10%). All fractions of the particle size categories are homogeneously distributed through out the profile. By using the USDA textural triangle, the soil texture falls into a sandy loam class.

The soil bulk density increases slightly with depth. The values represent normal state of bulk densities in most soil types (Hausenbuiller, 2000) i.e they fall in mid–category classes and not in extreme edges such as volcanic soils with values of 0.55 or very strongly compacted soils with values more than 2. Accordingly, the calculated porosity of the soil falls in a mid position but it decreases slightly with depth: 51% at 0 - 20 cm; 47% at 20 - 80 cm and 43% at 80 - 150 cm, and in an inversely proportional sequence to the bulk density values.

The aggregate stability of a soil is the resistance of soil structural units against mechanical or physicochemical destructive forces. Soil structure, soil texture and the type of clay minerals, organic matter content and type, biological activity, cementing agents and cropping history influence the aggregate stability. Determining aggregate stability will give information of the sensitivity of soils to water and wind erosion. In general, there is a decrease in the aggregate stability with increasing soil depth. The values observed are fairly high (> 60%) and are of the same magnitude along the profile depth. It is worth reminding that the study area is semi-arid grassland and there fore plant roots, especially those of grasses spread extensively and deeply into the soil and bind together the particles to form crumb or granular structural units.

The water characteristic values of Albaja soils are found to be in the following order of magnitude (Table 2): field capacity 18 - 20%, wilting point 10% and available water 7 - 10%. Very slight increase with depth in the values of these parameters was noticed.

Table 2: Soil Physical properties of Albaga area

Depth	Particle size distribution			Bulk density	Aggregate stability	Field capacity	Permanent wilting point	Available water
	Sand	Silt	Clay					
(cm)	(%)	(%)	(%)	(g/cc)	(%)	(vol. %)	(vol. %)	(vol. %)
0-20	71.5	10.8	17.7	1.3	67.5	17.5	10.1	7.4
20-80	71.1	10.9	17.9	1.4	63.9	18.9	10.1	8.8
80-150	71.2	10.6	18.2	1.5	62.7	19.9	10.2	9.7

4.2.3- Chemical properties of Albaja area soils

Results for chemical properties of Albaja soils are shown in Table 3. pH values of the soils are about pH 7.4. Its values are identical through out the examined soil profile depth. These pH values fall in the neutrality range of the soil reactivity. The Ece values are typically less than unity (0.3 - 0.9) all along the profile indicating that this soil is free of salinity effects. Likewise, the ESP% and SAR values are low, 4.6 - 7.5% for ESP% and 1.9 - 5.2 for SAR showing that there is no sodium accumulation and its implications on soil structure and plant growth.

Basic nutrient elements contents are low in these soils. Calcium content is about 9 $mmol^{+}$ /100 g soil and magnesium content is about half that of Ca, while Na and K contents are generally less than 1$mmol^{+}$/100 g soil. Distribution of these elements is perfectly homogeneous through out the profile. The CEC of these soils, calculated as sum of the basic cations, is also very low, with magnitudes around 16 $mmol^{+}$/100 g soil. Also the concentrations of secondary elements are very low, really traces for most of the studied elements with values less than 1mg/L, and with the same distribution trend in the profile as out lined for the other parameters.

The levels of organic carbon and hence organic matter in these soils are also very low even in the surface layers with values less than 1%. Corollary, N and C/N and to same extent P contents are negligible in these soils.

In effect, soils of this area constitute part of the desertification front where Aeolian sand deposits are in the process of stabilization. They are composed of coarse mineral material in their integrity. Hence, fertility wise they are very poor (Nimer, 2002; Eltahir et al, 2004). Even though, they may be physically good yet their water retention capacity is very low. So, it is not astonishing that these soils will support only poor scattered vegetation (mostly grasses and shrubs) which flourishes only in the short rainy season and is quickly deteriorated and vanishes soon after the rain seizes, through the impact of many factors: drought stress, over grazing, fire burning, dust storms and wind erosion impaction …etc. Concerning agriculture, working of these soils is very easy even with local hand made implements but due to their extreme poor chemical fertility, they are not supposed to sustain any intensive durable cultivation except through shifting cultivation and raising nutrient non exigent crops such as sorghum, millet, ground nuts, water melon, sesame…etc.

Table 3: Soil chemical properties of Albaga area

Depth (cm)	pH	ECe (dS/m)	Exchangeable elements				Cu (mg/L)	Zn (mg/L)	Mn (mg/L)	Fe (mg/L)	CEC*	P (mg/L)	ESP (%)	SAR	N (%)	OC (%)	OM (%)	C/N
			Na *	K*	Ca*	Mg*												
0-20	7.4	0.8	0.9	0.5	9.0	4.5	0.17	0.5	0.6	0.04	15.9	4.39	6.1	3.7	0.03	0.06	0.1	2.25
20-80	7.4	0.3	0.7	0.4	9.3	4.8	0.14	0.3	0.5	0.04	16.1	4.04	4.6	1.9	0.03	0.04	0.02	1.85
80-150	7.5	0.9	1.3	0.6	8.9	4.6	0.15	0.5	0.5	0.04	16.4	3.76	7.5	5.2	0.02	0.03	0.1	1.38

* mmol+/100g

4.3- Effects of fires on the soil properties of Albaja area

4.3.1- Effects on the soil physical properties

Results of wildfires on the soil physical properties in Albaja area are shown in Table 4. Statistical analysis of the data showed that for all the measured physical variables, no significant differences were found between the different fire burned plots; however, the aggregate stability of these soils is the only physical variable that exhibited significant difference, between some fire burnt category plots. It is worth to mention that, values for textural fractions (sand, silt, clay) and bulk density for the different plots of fire burnt frequencies are strikingly identical with no or very little variation and also no discernable trend could be out lined within a number of fire burning frequencies. Analysis of aggregate stability gave significant differences between the control (zero burn areas) and some recurrently burned plots. Also significant differences were detected between the various fire burned categories (Table 4). The aggregate stability values do not show a definite ascending or descending trend, particularly with respect to fire burning frequencies. The soil is unlikely to be affected by the kind of low grass fires prevailing in Albaja area, because for the soil particles to be disintegrated, high temperatures (> 500 ^{0}C) lasting for long period (Giovannini et al, 1983; Hunerford et al, 1990) are needed. Bulk density and soil aggregation depend largely on soil structure and to a lesser extend on particles size distribution. Hence fire conditions that affect soil structure will produce the maximum effects on these parameters. The likely soil structure components to be affected by fire are particles size and nature and cementing materials (clay, oxides and organic matter). So the light grass fires prevailing in the study area are not likely to generate high temperatures to cause damage to these factors.

Table 4: Effects of fire on the soil physical properties per number of times burn frequency

Fire burn frequency	Soil texture			Bulk density (g/cm^3)	Aggregate stability (%)	Structure
	Sand (%)	Silt (%)	Clay (%)			
0 times	70a	10a	20a	1.5a	61.8c	Granular
1 times	70a	12a	18a	1.4a	72.7a	Granular
2 times	71a	12a	17a	1.4a	63.9bc	Granular
3 times	70a	11a	19a	1.5a	67.5abc	Granular
4 times	68a	11a	21a	1.5a	73.6a	Granular
5times	70a	11a	19a	1.5a	67.8abc	Granular
6 times	70a	11a	19a	1.5a	71.3ab	Granular
7 times	68a	11a	21a	1.4a	72.4a	Granular

Values in the column with the same letter (s) are not significantly different at $P \leq 0.05$.

The irregular results of aggregate stability run contrary to our expectations and to the general hypothesis due to fire's ability to consume the plant roots and further reducing soil aggregate stability. Therefore, the significant difference in value of aggregate stability may be due to the variability present in the plots and not due to fire effects. This variability may be due to secondary factors such as animal grazing, agricultural practices and wind erosion that can potentially impair soil aggregate stability. The highly the effects of these factors present on the plot, the lower the value of the aggregate stability becomes. This is especially true in the soils of control plots which tend to occur on the outer boundary of Albaja area which is subjected to farming encroachment, grazing and wind erosion more than other plots (Elgamri, 2007). On the other hand, this suggests that the low number of samples and the deeper depth of Auger samples (30 cm) with observed signs of animal grazing, agricultural practices and wind erosion, affected the results. This may have resulted in obscuring the impacts of the fires effects. In contrast, Garren (1943) found that while single prescribed burns may have not significant effects on soil, the high frequency of fires in the southern USA can have cumulative effects on the soil physical properties. Soil organic matter is usually lower in soils that are repeatedly burned and he noted that burned soils were harder, denser and less permeable than unburned soils. In general, fire may alter several physical soil properties such as soil structure, texture, porosity, wetability, infiltration rates and water holding capacity. The extent of fire effects on these soil physical properties varies considerably depending on fire intensity, fire severity, and fire frequency and duration. In general, most fires don’t cause enough heating to produce significant changes to the soil physical properties (Hungerford et al, 1990). This is particular true for low intensity fires. Even where fires do cause direct change to the soil physical properties, their indirect effects on soil hydrology and erosion will vary greatly depending on the conditions of soil, forest floor, topography and climate.

4.3.2- Effects on the soil chemical properties

Results for fire effects on Albaja soil chemical properties are presented in Table 5. The statistical analysis showed no significant difference between the control and the other fire burning frequencies for all the studied parameters and also no significant difference was found among the various fire burning frequencies. In addition, no trend could be outlined concerning the magnitude order of the values of the studied parameters within the fire burning categories. The difference in values of these parameters could be attributed to existing natural variability in the field. The fact that no effects were introduced in Albaja soil physicochemical properties by the different burning intensity rates may be ascribed to: weak non aggressive fires produced by grassland fuel; changes may have been occurred some times during the fire burning event but have faded away because being of reversible nature; soil sampling depth (30 cm) may have obscured possible variation in the soil burning frequencies; human intervention through a number of management practices such as cultivation, grazing, wood and grass collection…etc.

It is generally expected that pH will increase in the range land of Albaja after fire and decrease with time, the rate at which it does is being dependent on precipitation (Woodmansee and Wallach, 1981). Precipitation in this semi-arid area is low so the rate at which pH returns to base line levels would be relatively slower. Average pHs of the control and 5- times burn soils of this study average 7.6 in the top (0-30 cm), 7.4 in the 1- and 6- time burn soils, 7.4 in the 4- times burn soils and 7.7 in 3- and 7- times burn soils. Soil pH was lowest in the 1- and 6- time burn areas, while the 3- and 7- time burn had the highest pH. This patterns runs contrary to our expectations due to fire's ability to raise pH of the soil shortly after fire (DeBano et al, 1998). This suggests that the low number of samples, as well as time of taking samples from the site with deep depth 0 - 30 cm, affected the results. On the other hand these fires were of low severity and may not have caused a measurable change. Increase in pH has been attributed to ash accretion (Smith, 1970). The response depends on the amount of ash and buffering capacity of the soil and is considered negligible in grasslands (Nye, 1959).

Organic carbon is added to the soil by plant residual or ash remains alter burning. The level of organic carbon and hence organic matter was found not affected with fire frequency. This means that the quantity of organic carbon and organic matter added to the soil with burning is equal to that added by plant resides in unburned (control) area. Results presented in Table 5 showed that the lowest level of organic carbon and organic matter was found in 7- time burn area, and this is highly consistent with expectation that organic carbon and hence organic matter are usually lower in soils that are repeatedly burn (Garren, 1943). While the 5- time burn burned area had the highest level of organic carbon and organic matter. The levels were steady in the 6-, 3- and 2- times burn areas with averages of 0.09% for organic matter and 0.05% for organic carbon. These results run contrary to our expectations due to fire’s ability to reduce amount of organic matter and organic carbon and their levels tend to decrease as the frequency of fire increases (Garren, 1943). On the other hand under natural conditions the humus content of a virgin soil is usually higher than in adjacent burnt areas. This is caused by a higher rate of addition of organic matter by natural vegetation accompanied by a lower rate of biological activity and lower temperatures (Broadbent, 1954). These irregular results may be due to secondary factors such animal grazing, agricultural practices and surface erosion that might have greater effect on the soils more than the direct effects from low severity grass fires. These above mentioned factors remove organic material from the surface and subsequently reduce the amount of organic matter in the soil. Generally, the wild land fires in Albaja are of low severity and don’t cause significant changes. In these areas, the organic stock is mostly confined to belowground zones and the grasses are mostly fire-adapted. Thus, we suggest that the secondary effects, such as grazing, cultivation and wind erosion may be stronger factors that create the variability rather than the direct effects from fires.

No difference in nitrogen among the burned and unburned areas was found. All the plots had similar values of N. The content of nitrogen ranged between 0.02 and 0.03%. The nitrogen percent was lowest in 3-, 6- and 7- time burn areas while the control, 1-, 2-, 4-, and five times burn areas had the highest N content. This is not consistent with expectation that fire's ability to increase or decrease nitrogen levels in the soil is dependent on fire intensity (Raison, 1979). Nitrogen stock in the soil is mostly organically bound and is lost into the air from combustion of organic material. Studies showed that available nitrogen in the soil is usually increased following burning (Davis,1959) because of low volatilization temperatures of nitrogen and subsequent temperature accelerated mineralization and nitrification rates after the soil surface exposure to fire (Wells, 1971; Raison, 1979) especially in light intensity fires (Blank et al, 1994). Likewise, results showed that extractable P in the surface horizon was not significantly different among all plots. Indicating that, fires had no effect on P levels. P was highest in the 2- time burn areas, although, it was under the critical level, about 5.4 ppm and the critical level for the grasses is 15 ppm (Little and Mccutcheon, 2004) . The lowest level of P was in the 7- and 3- times burn areas. P levels in the soil are affected by many factors like organic matter stock, degree of weathering, climate conditions, erosion and crop removal (Alkhateeb, 1998). Schripsema (1977) found that the availability of P varied with sites. White and Gartner (1975) found an increase in available P only if temperatures do not exceed 200 °C. In this case study, the irregular results may be due to the grasses consumption which have higher requirement for phosphorus (Spikes, 2004; Little and Mccutcheon, 2004). Kraemer and Hermann (1979) found no difference in P among burned and unburned areas, 25 years after cut and broadcast burning on the west side of the Cascade mountains of Washington State. Also, Wagle and Kitchen (1972) found no difference in extractable P among a 3-year-old burn, 14-year-old burn and control in ponderosa pine forest in Northern Arizona.

The cation exchange capacity of these soils, calculated as sum of basic cation averaged 15 between 19 $mmol^+$/100 g in the surface horizons of all sampled soils, Table 5. The interaction between plot and presence or absence of fire was not significant for the CEC of all plots in Albaja area. This may be due to low severity fire that didn't affect the soil colloids. Hatten et al (2005) found that, the presence of fire and site characteristics such as vegetation cover, and slope and erosion can combine to cause secondary effects on CEC. Mineral elements were expected to increase or decrease after fire and return to control levels with time. No significant differences were found with either presence or absence of fire. All plots had similar low levels of elements. Ohr and Bragg (1985) found that iron and manganese decreased after fire. However, they also found that if the plot was burned in consecutive years, then copper, iron and zinc availability increased. This was attributed to different rates of plant uptake for each nutrient. In this study, this may be due to the low intensity of fires which were unlikely to cause significant changes in elements either by convection or volatilization (Raison, 1979). Moreover, fire had no effects on the electrical conductivity (ECe), exchangeable sodium percentage (ESP) and sodium adsorption Radio (SAR) in the soils of Albaja area. In general, soil moisture and heat determine the extent of change in these parameters, and the soluble salts occur in very low portions in these soils, which add to obscure the impact of low intensity fire.

Table 5: Effects of fire on the soil chemical properties per number of times burn frequency

Fire burn frequency	pH	OC (%)	OM (%)	N (%)	P mg/L	CEC*	Exch. Na*	Exch. K*	Exch. Ca*	Exch. Mg*	Mn mg/L	Fe mg/L	Cu mg/L	Zn mg/L	ESP (%)	SAR	ECe dS/m
0 time	7.6a	0.051a	0.085a	0.028a	3.70a	17.80a	0.97ab	0.25a	10.30a	4.95a	0.235a	0.026b	0.026a	0.064a	5.30a	2.65a	0.35a
1 time	7.4a	0.057a	0.100a	0.033a	3.95a	16.95a	1.20ab	0.60a	8.75a	4.60a	0.175a	0.028b	0.237a	0.789a	7.30a	5.05a	0.75a
2 times	7.5a	0.050a	0.085a	0.029a	5.40a	15.95a	1.36ab	0.82a	9.15a	4.30a	0.442a	0.019b	0.174a	0.283a	9.30a	6.92a	1.25a
3 times	7.7a	0.045a	0.075a	0.024a	3.50a	17.35a	0.53ab	0.65a	10.20a	5.20a	0.710a	0.024b	0.060a	0.781a	3.05a	0.39a	0.20a
4 times	7.5a	0.052a	0.090a	0.031a	3.95a	18.55a	0.76ab	0.25a	10.40a	5.10a	0.741a	0.023b	0105a	1.465a	3.95a	1.66a	0.35a
5 times	7.6a	0.048a	0.85a	0.025a	4.05a	16.95a	1.49ab	1.00a	9.55a	4.85a	0.466a	0.105a	0.096a	0.050a	9.20a	7.32a	1.20a
6 times	7.4a	0.049a	0.090a	0.023a	4.15a	17.25a	0.77ab	0.20a	11.05a	5.25a	0.550a	0.026b	0.259a	0.711a	4.35a	2.12a	0.35a
7 times	7.7a	0.033a	0.060a	0.023a	3.40a	19.10a	2.72ab	0.30a	11.70a	5.60a	0.440a	0.100a	0.014a	0.090a	14.20a	12.12a	1.20a

Values in the column with same letter are not significantly different at $p \leq 0.05$

* mmol+/100g

4.4- Impacts of fires on the soil seed-bank

Soil seed banks are important components of vegetation dynamics, affecting both ecosystem resistance and resilience (Pugmaire and Lazaro, 2000). Assessment of the soil seed banks is very valuable in determining the restoration power of the communities, through examining the number of seeds and longevity of viability in the soil. Table 6 shows the numbers of soil seed banks in the different fire burning frequencies.

Assessment of the numbers of the seeds (dead and viable) showed that there were no significant differences in the different fire burning category areas. No trend could be out lined concerning the quantity of seeds in the plots in relation to fire burning frequencies, as the number of seeds is highly variable between the different treatments. On the other hand, the number of dead seeds exceeds those of viable seeds by more than 4 folds in many burning category plots. In general, different grass species accumulate very high soil seed bank stock, which ranges between 95.4 and 477 million seeds/ha for the sound and 349.8 and 572.4 million seeds/ha for the dead seeds respectively. Annual weed species ecosystems have very large seed bank, especially under grazing, this may be due to opening habitat by light grazing that allows annuals with seed production to thrive and produce many seeds. Trampling may create conditions in which seeds retain greater viability in the soil (Swaine, 2001).

Table 6: Average number of soil seed bank per number of times burn category.

Fire burn frequency	Number of dead seeds/250g soil	Number of sound seeds/250g soil	Number of sound seeds/ha (in millions)	Number of dead seeds/ha (in millions)
Zero time	13ab	3a	95.4	413.4
1 time	11b	3a	95.4	349.8
2 times	16ab	15a	477	508.8
3 times	18a	3a	95.4	572.4
4 times	15ab	3a	95.4	477
5 times	14ab	3a	95.4	445.2
6 times	13ab	15a	477	413.4
7 times	13ab	2a	63.6	413.4

Values in the row with same letter are not significantly different at $P \leq 0.05$.

The areas of 2- and 6- time burn have a highest accumulation of soil seed bank, which decrease in the areas of 7- time burn but seed stock amounts were variable in the control, 1-, 3-, 4- and 5- times burn areas. This pattern runs contrary to the general hypothesis and to our expectation due to fire's ability to reduce the number of soil seed bank (Fox and Fox, 1994). These irregular results may be attributed to many factors such as animals, humans and winds which may concur to affect the soil seed bank through many mechanisms. In addition the vegetation is not homogenous and that may affect the distribution of the seeds. Furthermore, fire usually burns after the plants produced and shed the seeds which are incorporated in the soil and are less susceptible to damage by the low temperatures from the surface fires. This is facilitated by the sandy soil coarse texture and structure allowing deep penetration of the seeds into the spore-spaces and hence provides effective protection against wild land fire. These results are similar to the findings reported by Fox and Fox (1994) and Hassan (2004). They reported that in ElNour forest at Blue Nile State, fire has no effect on *Cymbobogon nervatus* soil seed bank accumulation. Fox and Fox (1994) noted that this character is produced by long-term effect of fire which allows species to be considered as a fire- specialist. Also, Elgamri (2007) found that fires of different frequencies have no effect on vegetation cover percentage in Albaja area. Another factor involved in this mechanism is the nature and deep penetration of grasses root systems that helps in maintaining their regeneration after fires or prolonged drought periods. For the individual species, there is an increase or decrease of some of them as fire frequency increases, while other species appear to be unchanged in the face of low severity fires. Collectively, this suggests that the quantity of soil seed bank lost with burning from fire sensitive species is equal to that added by fire resistant species. We conclude that, no change in vegetation cover with regard to wild land fire in Albaja area is expected, because there is no change in the soil seed bank stock.

Chapter 5

Conclusions and Recommendations

5.1-Conclusions

The present study underscores the following findings:

1) The soils in Albaja region are infertile sandy loam types. Albeit the soils possess good physical characteristics, yet their chemistry is too poor to support the growth of dense vegetation mantle. Hence, the present-day scenario features a landscape of sparse trees with intervening thin cover of seasonal grasses.

2) The main factor responsible for soil aggregate stability is the grass-roots. The chemical and physical properties of these soils indicate infertility, which gives them an Aridisol classification (FAO and UNESCO, 1974), in spite of this; they are quite suitable for millet and often for ground nut cultivation even with very low amount of precipitation.

3) The seasonally recurring wildfires have no pronounced bearing on the soils; this is true for both their natural characteristics and seed-bank at 30 cm depths where the samples originate. This observation is attributable to the interplay of the following reasons:

A) The wildfires are of low intensity, superficial and short-lived, producing very little impacts on the soils' properties. Only few centimeters on the surface are presumed to have been affected;

B) The samples were taken 6 months after the active season of burning has begun, which usually commences in September and attains its zenith in the mid of October (Elgamri, 2007), implying that any effects produced on the soil properties might have been obscured by many factors such as wind erosion, animal grazing and traction, human activities…etc;

C) The soil might have a reversible nature after such a long period since the fire incidence in September-October.

4) Experiments were conducted in the laboratory and the nursery to examine the nature and germination of the seeds. The seed content of the soil is considerable. The proportion of the dead seeds to the live ones is observed to be four folds. Seeds failed to germinate and this could be ascribed to one or any combination of the following factors:

A) The lengthy dormancy period of the seeds; thought to be extending over 20 years;

B) The unfavourable physical conditions in both the laboratory and the nursery, for the seeds need special conditions (humidity, temperature, stimulator…etc) to germinate;

C) Unknown reasons.

5. 2- Recommendations

Because else where in Sudan, research results are insufficient, lacking, or contradictory in regard to the effects of wild land fires on below ground systems, particularly soil properties and soil seed-bank, similar research is needed in all areas affected by wild land fires to elucidate the impacts of fire on these systems including the implementation of the known fire protection procedures and techniques.

References

Abdel Mageed, A. (1998). Sudan Industrial Minerals and Rock; Center for Strategic Studies, Khartoum, Sudan.

Aguiar, M.R., Soriano, A., Sala, 0. (1997). Seed distribution, Constraints. The Dynamics of the Patagonian steppe. Journal of Applied Ecology (78): 93-100.

Ali, M.M and Bayoumi, A., M.S. (1999). Assessment and mapping of desertification in western Sudan using Rremote sensing techegiques and GIS. Sudan Silva No 28 Vol. Vlll 1999. Sudanese society and forest national corporation, Khartoum.

Allen, M.F. (1991). The Ecology of Mycorrhizae. Cambridge Univ. press, Cambridge. pp.189.

Anderson, H.G., Bailey, A.W. (1980). Effects of annual burning on grassland in the aspen parkland of east-central Alberta. Can J Bot 58: 985-996.

Anderson, J.M. (1991). The effects of climate changes on decomposition processes in grassland and coniferous forests. Ecol. App l. 1, 326- 347.

Archibald, S., Bond, W.J., Stock, W.D. (2005). Shaping the landscape: fire-grazer interactions in an Africa savanna. Ecological Applications 15: 96-109.

Arefyera, Z.N., Kolesnikov, B.P. (1964).Dynamics of ammonia and nitrate nitrogen in forest soils of the transurals at high and low temperatures. Sov. Soil Sci. 3: 246-260.

ASTM (1985, d). American Society for testing and materials, 1985 Annual Book of A. S. T. M standard 04. 08. 117-123 Am. Soc. Tes. Msat Philadelphia.

Auld, T.D., Connell, O. (1991). Predict patterns of post fire germination in 35 Australian fabacease. Australian Journal of Ecology, 13:1, 11-15.

Badi, k., El Houri, A. Bayoumi, A. (1989). The forests of the Sudan. Sudan, Khartoum. PP.16-18, 49-51.

Badi, K.H. (1999). Protection against Fire in Low Rainfall savanna Region of the Sudan. Sudan Silva No. 28 Vol. Vlll 1999. Sudanese Forestry Society and Forests National Corporation, Khartoum.

Bailey, A.W. (1982). Ecology: United States and Southern Canada. John Wiley and Sons, Inc. New York, 501pp.

Baskin, A.A., Baskin, J.M. (1998). Seeds: Ecology, Biogeography and Evaluation of Dormancy and Germination. San Diego Academic Press.

Bauyoucos, G.J. (1962). Hydrometer method improved for making particle–size analysis of soils. Agron.J.53:464-465.

Bayoumi, A. (2000). Fire situation in Sudan. IFFN No. 25, July 2000, pp. 115-117.

Bell, S., Fonseca, M.S. and Motten, L.B. (1997). Linking restoration and Landscape ecology. Soc. Ecol. Rest. 5, 318 – 32.

Biederback, V.O., Campbell, C.A., Brow REU, K.E., Schnitzler, M. and Mclver, R.N. (1980). Effects of burning cereal straw on soil physical properties in and grain yields in Saskatchewan. Soil Sci. soc. Am. J. 44: 103 – 111.

Blair, J. (1997). Fire, N availability and plant responses in grass land: a test of the transient maxima hypothesis. Ecology 78: 2359-2368.

Blank, R.R., Allen, F., Young, J.A. (1994). Growth and elemental content of several Saga Brush- Steppe species in unburned and post- wildfire and plant effects on soil attributes. Journal of plant and soil (164): 35 -41.

Brits, G.J., Calitz, F. J., Brown, N.A. (1993). Desiccation as the active principle in heat – stimulated seed germination of Leocosermum r – br (Predecease) in fynbos. New- phytologist, 125:2, 397-403.

Broadbent, F.E. (1957). Organic Matter. In: soil, year book of agriculture, pp 151-157 Washington, D.C: Governmental Printing Office, 1957.

Burns, P.Y. (1952). Effects of fire on forest soils in the pine Barren region of New Jersey. Yale University School of Forestry Bull 75, 50 pp. 45-70.

Campbell, A.J., Tanton, M.T. (1981). Effects of fire on the invertebrate fauna of soil and litter of a eucalypt forest. Australian Academy of Science, Canberra, Australia. pp. 215-241.

Campbell, R.E., Baker, M.B.Jr., Ffolliott, P.F., Larson, F.R., Arrery, C.C. (1977). Wild fire effects on a ponderosa pine ecosystem Arizona case study. USDA For. Serv. Res. Pap. RM-191. pp. 12.

Castelli, L.M., and Lazzari, M.A. (2002). Impact of Fire on Soil Nutrients in Central Semiarid Argentina, Arid land Research and Management, Volume 16, Number 4, 349- 364 (16).

Chandler, C., Chency, P., Thomas, P., Trabaud, L., Williams, D. (1983). Fire in Forestry volume I: Forest Fire Behavior and Effects. John Wiley and Sons, Inc., New York.

Chrisrensen, N.L. (1976). Short–term effects of mowing and burning on soil nutrients in big meadows, Shenandooh National park .J Range manage 29:508-509.

Conrad, C.E. (1978). Effects of fire on Ecosystems. Ecology 59:4.089-497.

Coults, J.R.H. (1945). Effect of veld burning on the base exchange capacity of a soil. South Africa. J. Sci. 41, 218 – 224.

Daniel, G.N., Klopatek, C.C., Debano, L.F., Ffolliott, P.F. (1999). Fire effects on belowground Sustainability: a review and Synthesis. Forest Ecology and Management 122: 51-71.

Daubenmire, R. (1968). Ecology of fire in grass lands. pp. 209-266 in J. B. Cragg (ed), Advances in ecological research, Vol. 5, Academic press, New York.

Davis, K.P. (1965). Forest fire: control and use. Mc Graw – Hill book company, INK.

Day, P.R. (1965). Particles fractionation and particle size analysis. In C.A. Black (ed), Methods of Soil Analysis, Agron. No. G. Part I: Physical and Mineralogical Method, Am. Soc. Agron., Madison, WI, USA. pp. 545-565.

DeBano, L.F. (1971). The effect of hydrophobic substances on water movement in Soil During infiltration. In: Soil Science Society of America Proceedings. 340-343.

DeBano, L.F., Dunn, P.H., Conard, C.E. (1977). Fire’s effect on physical and chemical properties of chaparral soils. Serv. Gen. Tech. Rep. wo-3, Washington, D-C. pp. 65-74.

DeBano, L.F., Klopatek, J.M. (1987). Effect of management on nutrient dynamics in south – western pinyin- juniper woodlands. USDA for. Serv. Gen. Tech. Rep. RM – 149. pp. 157 – 160.

DeBano, L.F. (1969). The relationship between heat treatment and water repellency in Soils. In: DeBano, L.F. Letey. J. water repellent soils. Riverside: University of California: 265-279.

DeBano, L.F., Neary, D.G., Ffolliott, P.F. (1998). Fire effects on ecosystems. John Wiley and Sons, inc., New York, New York, USA.

DeByle, D.C. (1981). Clear Cutting and fire in the larch Douglas- fir forests of Western- Montana- a multifaceted research summary. General Technical Report, INT-99. U.S.D.A. Forest Service Intermountain Forest and Range Experimental Station, Ogden, UT: None.

DeByle, N.V. (1976). Soil fertility as affected by broadcast burning following clear cutting in Northern Rocky Mountain Larch /fire forests. Proc, Tall Timbers Fire Ecol Conf 14:447-464.

Delmas, R.A., Loudjani, P., Podaire, A. and Menaut, J. (1991). Biomass burning in Africa: an assessment of annually burned biomass. Global Biomass Burning: Atomospheric, Climatic and Implication. Cambridge, Massaclusetts: MIT Press. Pp. 126-132.

Dhillion, S.S., Anderson, R.C., Literta, A.E. (1988). Effect of Fire on the ecology of little bluestem (*schizachyrium scoparium*). Can. J. Bot. 66, 706-713.

Dicosty, R.J. (2000). Fire Effects on soil organic Matter. Forest Encyclopedia 1D PP. 680.

Dunn, P.H. and DeBano, L.F. (1977). Fire's effect on biological and chemical properties of chaparral soils. Palo Alto, CA. Washington, D. C. USDA For. Serv. Wo-3. pp.75-84.

Dunn, P.H., Barro, S.C. and Poth, M. (1985).Soil moisture affects survival of micro-organisms in heated chaparral fire. Soil Boil. Biochem. 17, 143-148.

Dwyer, E., Pinnock, S. and Gregoire, J.M. (2000). Global spatial and temporal distribution of vegetation fire as determined from satellite observations. International Journal of Remote Sensing, Vol.21, No. 7, pp. 1289-1302.

Dyrness, C.T. and Youngberg, C.T. (1957). The effects of logging a slash burning on soil structure. Soil Science Society of America, 21:440-447.

Elgamri, M. (2007). The Use of Remote Sensing Technology in Defining and Assessing the Wild Land Fire Regime and its Impacts on Range and Forest Management. PhD Thesis, Sudan University of Science and Technology, Sudan.

Eltahir, B.A. (2006). Nutrient Balance in Traditional farming systems Involving *Acacia senegal* (L) Wild. in Semi-arid Sandy Soils of Northern Kordofan, Sudan. PhD Thesis, Faculty of Forestry, University of Khartoum, 210p.

Enright, N.J., Kintrup, A. (2002). Effects of smoke, heat and charred wood on the germination of dormant soil stored seeds form *Eucalyptus baxteri* in Victoria, SE Australia. Record (1). CAB abstracts.

FAO and UNESCO (1974). Soil Map of the world. VOL.1 Legend. UNESCO, Paris.

FAO. (1974). Guide line for soil description. FAO, Rome.

FAO. (1974). The Euphrates Pilot Irrigation project. method of soil analysis, Gadeb soil laboratory (A laboratory manual). Food and Agricultural Organization. Rome. Italy.

FAO. (1999). FAO Meeting on public Policies Affecting Forest Fires, FAO Forestry Paper 138, Rome, Italy.

FORIG. (2003). Forest Fire Management in Ghana, Final Technical Report PD. 32/98 Rev (F). Forestry Research Institute of Ghana. Kumasi. pp. 39.

Fox, M.D.and Fox, B.J. (1994). The Role of Fire in the Scleromorphic Forest and Shrub Land of Eastern Australia. SPB Academic Press.

Friese, C.F.and Allen, M.F. (1993). The interaction of harvester ants and vesicular- arbuscular Mycorrhizae fungi in a patchy semi arid environment: The effects of mound structure of fungi despersion and establishment. Functional Ecol. 7, 81 – 88.

Frost, P.and G., H. (1999). Fire in Southern Africa woodlands: Origins, impacts effects, and control. In proceedings of an FAO Meeting on Public Policies Affecting Forest Fires, FAO Forestry Paper 138, pp. 181-205.

Garren, K.H. (1943). Effects of Fire on Vegetation of the Southeastern United States. Bot. Rev. 9: 617-654.

Gartner, F.R. (1975). Immediate effects of prairie fire on the soil nitrate, ammonium, available phosphorous and total N content. Proc, SD Acad Sic 54. 188-193.

Gashaw, M.and Michelsen, A. (2002). Influence of heat shock on seed germination of plant, from regularly burnt Savanna woodlands and grasslands in Ethiopia. Plant Ecology, 159:1, 83-93.

Gentry, J.B.and Striritz, K.L. (1972). The role of Florida harvester ant, *pogonomyrmex badius*, in old field mineral nutrient relationship. Environ. Entomol. 1, 39- 41.

Gerard, C.J., P. Sexton, and G. Shaw. (1982). Physica l factors influencing soil strength and root growth. Agronomy journal. 74: 875- 879.

Giovannini, G., Lucchesti, S., Giachelti, M. (1988). Effects of heating on some physical and chemical parameters related to soil aggregation and erodibility. Soil Sci. 146,255-262.

Gough, L.P., McNeal, J.M. and Severson, R. C. (1980). Predicting native plant copper, iron, manganese, and zinc level using DTAP and EDTA soil extractants, Northern Great Plain Soil Sci. Am. J. 44 (5): 130-135.

Gressel, N. (1995). Forest soil organic matter: Characterization and modern method of analysis. Forest soils, chap.2. Soil Science Society of America, Madison, Wl . PP-13-32.

Gwarazimba, V.E.E. (1987). Seed testing problems of forest seeds in Zimbabwe. Proceedings of the international symposium in forest seed problems in Africa, Harare- Zimbabwe, August 23-Septeber 2, 1987.

Hare, R.C. (1961). Heat effect on living plants. USDA For. Serv., Paper 183, New Orleans, LA.

Harrison, M.N., Jackson, J.K. (1958). Ecological classification of the vegetation of the Sudan. Forest Bulletins. New Series No.2, Forest Department, Khartoum.

Hartford, R.A., Frandsen, W.H. (1992). When it’s hot, it’s hot- or may be it’s hot (surface flaming may not portend extensive soil heating). Int. J. Wild Fire 2, pp. 139-144.

Harvey, A.E. Jargenen, M.F.and Larsen, M.J. (1976). Intensive timber utilization and Prescribed Fire: Effects on the microbial ecology of forest.

U. S. For Serv, intermit for and Range Exp. stn Gen Tech. Rep. INT -28, 46 PP.

Hashim, I.M. (1999). Management and Development of Wildlife in Albaja. Wild life Research Center, Shambat, Khartoum, Sudan.

Hassan, M.M. (2004). Effects of Fire on Soil Seed Bank, Vegetation Cover and Some Soil properties in Elnour Forest at Blue Nile State. M.Sc Thesis, University of Khartoum, Sudan.

Hatten, J., Zabowski, D., Scherer, G. and Dolan, E. (2005). A Comparison of soil properties after contemporary wild fire and fire suppression. Forest Ecology and Management 220(2005) 227-241.

Hausenbuiller, R.I. (2000). Soil science fundamentals and Applica tions.

Hawley, R.C. (1921). The practice of Siliviculture. John Wiley and Sons, Inc. New York. pp. 241 -251.

Hayashi, I., Panache, J.V., Sastoroutom, S.S. (1978). Preliminary report on the Buried seed of floating Islands and Bottom of lake Rawapening, central Java. Japanese journal of ecology. 28: 235-330.

Heikkila, T., Gronqvist, R.and Jurvelius, M. (2007). Wild land fire Management, Hand book for Trainers, Ministry of foreign affairs of Finland.

Heyward, F. (1938). Soil temperatures during forest fires in the long leaf pine region. Journal of Forestry. 36: 478-491.

Hulbert, L.C. (1969). Fire and litter effects in undisturbed blue stem prairie in Kansas. Ecology 50:874-877.

Hungerford, R.D., Harringtox, M.G., Fran dsen, W.H., Ryan, R.C. and Niehoff, J.G. (1990). Influence of the fire on factors that affect site productivity. Symposium on Management and Productivity of Western- Montana Forest Soils. pp.677.

Isaac, L.A., Hopkins, H.G. (1937). Forest soil of the Douglas-fire region, and changes wrought upon it by logging and slash burning. Ecology 18:264-279.

James, S.W. (1982). Effects of Fire and soil type on earthworm population in tall grass prairie. Pedobiologia 24, 37-40.

Jenny, H. (1980). The Soil Resource. Springer – Verlag, New York.

Jorgensen, M.F., Larsen, M.J., Harvey, A.E. (1979). Forest soil biology – timber harvesting relation ships. U.S. For Serv, Intermt For and Range Exp. Stn, Ger Tech, Rep . INT -69-12 pp. Kariuki, E. M. (1987).

Kariuki, E.M. (1987). Effects of Browsing Treatments of four important tree species in Kenya. Proceeding of the international symposium in forest seed problems in Africa, Harare – Zimbabwe, August 23- September 2, 1987.

Kettredge, J. (1938). Comparative in filtration in the forest and open. Journal of Forestry. 36: 1156-1157.

Klopatek, C.C., DeBano, L.F., Klopatex, J.M. (1990). Impact of fire on the microbial processes in pinyon – juniper wood lands. USDA. For Serv. Gen. Tech. Rep. RM-191. pp. 197-205.

Klopatek, C.C., DeBano, L.F., Klopatex, J.M. (1988). Effects of simulated fire on vesicular – arbuscular Mycorrhizae in pinon-juniper woodland soil. Plant and Soil. 109, 245-249.

Klopatek, J.M. (1987). Nitrogen mineralization and nitrification in mineral soils of pinyon – Juniper ecosystem. Soil Sci- soc. Am J. 51. 453 – 457.

Klute, A. (1986). Methods of soil analysis, Agron. 9, part I: Physical and Mineralogical Methods, AM. Soc. Agron., Madison, WI, USA.

KolesniKov, B.P. (1964). Dynamics of ammonia and Nitrate, nitrogen in forest soils of the transural at high and low temperatures. SOV soils sci 3:246-260, Finland, Helsinki.

Kraemer.,J.F., Hermann, R.K. (1979). Broadcast burning: 25 year effects on forest soils in the western flanks of the cascade mountains. For Sci.25,427-439.

Little, C., Mccutcheon, J. (2004). Fertility, management of meadows. Ohio State University, Extenion Fact sheet- ANR-5-99.

Lotogol, A.C.I. (1976). Some Remarks on the physical landscape of the ED Duiem Kosti area under graduate dissertation. (unpublished).University of Khartoum. Khartoum.

Lyon, J.L., Crawford, H.S., Pearson, H.A. (1978). Effects of fire on funa: a state-of-knowledge review. USDA. For. Serv. Gen. Tech. Rep. WO-6.

Martin, R.E., Miller, R.L., Cushwa, C.T. (1975). Germination response of legume seeds subjected to moist and dry heat. Ecology 56, 1441-1445.

Maruyma, E., Yokoyama, T., Mighita, K. (1989). Effect of temperature are preheating on Germination on *Guazuma criita* mart and *G ulmifollia*. Journal of Japanese Forestry society, 714:2, 65-68.

Mayland, H.F. (1967). Nitrogen availability on fall –burned oak –mountain Mahogany Chaparral Range Manage 20:33-35.

Metz, L.J., Lotti, T. and Klawitter, R.A. (1961). Some effects on prescribed burning on Coastal Plain forest soils. U.S. for serv, southeastern for Exp stn, Res Pap SE -133, 10PP.

Middleton, A.B. (2003). Soil seed banks and potential restoration of forested wetlands after farming. Journal of Applied Ecology (406) pp 1023.

Moore, P.D. (1996). Fire damage soils our forests. Nature. 384: 312 – 313.

Nearly, D.G., Klopatek, C.C., DeBano, L.F., and Folliott, P.F. (1999). Fire effects on belowground sustainability: a review and synthesis. Forest Ecology and Management. 122:

Neary, D.G., Jokela, E.G., Comerford, N.B., Colbert, S.R., Cooksey, T.E. (1990). Understanding competition for soil nutrients: the key to the productivity on southeastern coastal plain spodosols. University of British Columbia, faculty of forestry Pub., Vancouver, B.C. Canda. Pp.432-450.

Nelson, W.L., Mehlich, A. and Winters, E. (1953). The development, evaluation and use of the soil tests for phosphorous availability. Argon 4:153-188.

Nimer, A.M. (2000). Effects of *Acacia senegal* (L. Wild) on sandy soil and assessment of its foliage nutrient content: Case study of Damokeya forest. Northern Kordofan State. Msc. Thesis, Faculty of forestry, University of Khartoum, 66p.

Noordwjik, M.V. (1984). Ecology text book for the Sudan. Khartoum University Press, First edition, pp. 23-31.

Nye, P.H. (1959). Some effects of natural vegetation on the soils of West Africa and their development under cultivation. UNESCO, Abidijan Symposium, tropical Soils and vegetation, pp 59-63.

Nye, P.H. and P.B. Tinker. (1977). Solute Movement in the soil – root system. Landon: Black well Scientific Publications.

Ohr, K.M., and Bragg .T.B. (1985). Effects of fire on nutrient and Energy concentration of fire Praire grass species. Prairie Nat 17:113-126.

Okoro, O.O. (1978). Forest seed problems of Nigeria. Proceedings of the international symposium in Forest seed problems in Africa, Harare-Zimbabwe, August 23-September 2, 1987.

Owensby, C.E., and Wgrill, J.B. (1973). Effects of range burning on Kansas Flints Hills soils, J Rang Mange 26-185-188.

Page, A.I., Miller, R.H. and Ceaney, D.R. (1986). Method of soil analysis, par II. Chemical and microbiological properties, (2nd ed). American Society of Soil Science.

Page. A.L. (ed). (1982). Method of soil analysis, Agron., G, Part 2: ,USA.

Parr, C.L. and Brockett, B.H. (1999). Patch mosaic burning: Anew paradigm for savanna fire management in protected areas. Koedoe, 42, pp.

Perry, D.A., Amaranthus, M.P., Borchers, J.D., Bochers, S.L., Brainerd, R.E. (1989). Bootstrapping in ecosystems. Bioscience 39, 230 – 237.

Precht, J.J., Chripherson, H.H., Larcher, W. (1973). Temperature and life. Springer-Veriag, New York, NY.

Pugnaire, F.I., Haase, P., Puigfafabregas, J. (1996). Facilitation and Succession under the Canopy of *Retama sphaeroearpa* (L) Boiss in semi-arid environments in southeast Spain. Oikos.

Pugnaire, F.L., lazaro, R. (2000). Seed Bank Under story Species Composition in a Semi–Arid Environment: The Effect of shrub Age and Rainfall. Annals of Botany 86: 807 -813.

Raison, R.J. (1979). Modifications of soil environment by vegetation fires, with particular reference to Nitrogen transformations: a review. Plant and soil 51: 73-108.

Rajas, S., Herrera, J. (1989). Effect of physical and chemical treatments on seed dormancy of *Desmodium ovalifolium*, Agronomai – costorricence, 13:1, 11-15.

Ralston, CW. and Hatcher, G. E. (1971). Effects of prescribed burning on physical properties of soil. In: prescribed burning symposium proceedings, April 14-16, 1971. Rawapening, Center Java. Japanese journal of Ecology. 28: 235-330.

Read, D., Francis, R., Finlay, R.D. (1985). Mycorrhizal mycelia and nutrient cycling in plant communities. Black well Sci. Publs., Oxford pp. 131-217.

Ream, C.H. (1981). The effects of fire and other disturbances on small mammals and their predators: An annotated bibliography. USDA For. Serv. Gen. Tech. Rep. INT-106.

Richard, D.W., Milton, S. (1997). Simulated plants disturbances to small- scale. Disturbances in semiarid shrub- lands. J. Veg. Sci. 8, 163-176.

Richards, L.A. (1956). Diagnosis and improvement of saline and alkali soils. USDA Agric. Hand book 60.washington, D.C.

Roy D.P., Frost P.G.H., Justice C.O., Landmann T., Le Roux J. L., Gumbo K., Makungwa S., Dunham K., Du Toit R., Mhwandagarii K., Zacarias A.B., Dube T.O.P., Pereira J.M.C, Mushove P., Morisette J.T., Santhana S.k., Vannan and Davies, D. (2005). The southern Africa Fire Network (SAF Net) regional burned- area product- validation protocol- Interaction Journal of Remote Sensing VOL.26, No. 19, pp. 4265-4292.

Sabuti, E.N., Wein, R.W., Saigusa, M. (1987). Fire and acacia seeds: A hypothesis of colonization successes. Journal of Ecology. 74,937-946.

SAS (1997). Statistical Analysis System for linear Methods (3^{rd} Edition), SAS Institute, Nc, USA.

Schripsema, D.R. (1977). Ecological changes on pine – grass land burned in spring, late spring, and winter, MS thesis, south Dakota state, univ, Brookings, 99 pp.

Scottor, G.W. (1963). Effects of forest fires on soil properties in northern Saskatchewan. For Chron. 39:412-421.

Sgardelis, S.P., Pantis, J.D., Argyropulou, M.D. (1995). Effects of fire on soil macro invertebrate in a Mediterranean Phrygianic ecosystem. Intl. J. Wild fire 5, 113 – 121.

Smith, D.M. (1970). Concentrations of soil Nutrients before and after fire. Can J soil Sci 50: 17-29.

Spikes, M. (2004). Pasture grasses always contend with natural requirements and pests. Country world. The rural news paper of Texas.

Springett, J.A. (1976). The effect of prescribed burning on the soil fauna and litter decomposition in Western Australian Forests. Aus. J. Ecology. 1, 77-82.

Stark, N.M. (1979). Nutrient losses from timber harvesting in a Larch/Douglas fire forest. U. S. For Serv, intermit for and Rang Exp stn Res paper INT - 231,41pp.

Stehling, H., Heyde, B., Saile, P. (2000). International forest fire news. Geneva: UN- ECE Trade Division.

Swaine, M. (2001). Protocol for Assay of soil seed Banks. Euro Workshop on Functional Groups in Tropical Forests Trees (10-12 December).

Thorsten, W.

Trigg, S. (2002). Towards improving the use of remote sensing for monitoring burnt vegetation in Africa savannah. PhD Thesis, University of Greenwich, England.

Tryon, E.H. (1948). Effects of charcoal on certain physical, chemical and biological properties of forest soils. Ecol. Monger 18:81-115.

Tyler, C.M. (1995). Factor contributing to the post fire seedlings establishment in chaparral: Direct and indirect effects of fire. Journalof Ecology (83) 1009-1020.

Vail, J.R. (1978). Outline of the Geology and Mineral Deposits of the Democratic Republic of the Sudan and Adjacent Areas. Overseas Geology and Mineral Resources, 49 .HMSO, London.

Vilarino, A., Arines, J. (1991). Number and viability of Vascular- arbuscular frugal propgules in field soil samples after a wild fire. Soil Biol Biochem. 23, 1083-1087.

Vlamis, J., Biswell, H.H., Schults, A.M. (1973). Effects of prescribed burning on soil fertility in Second growth young ponderosa pine .J for 11: 905-909.

Vogl, R.J. (1974). Effects of Fires on grass land. Pp 193- 194 In T.T. Kozolowski and C.E. Ahlgren (eds), Fire and Ecosystem, Academic Press, New York.

Wagle, R.F., Kitchen, J.H. (1972). Influence of fire on soil nutrients in a ponderosa pine type. Ecology 53, 118-125.

Wagner, D. (1997). The influence of ant nests on acacia seed production, herbivory and soil nutrients. J. Ecology 85: 83- 93.

Watanabe, H., Kusagaya, Y., Saigusa, M. (2002). Environmental factors affecting germination of apple of Peru weed science CAB abstracts.

Weast, R.C. (1988). Hand book of Chemistry and physics. CRC press, Boca Raton, FL.

Wells, C.G. (1971). Prescribed burning on soil chemical properties and nutrient availability. In: Proc. Preceribed burning symposium. Charleston, South Carolina, USDA, for expt stn publ: 86-99.

Wells, C.G., Compell, R.E, DeBano, L.F. (1979). Effects of fire on soils: a state of the Knowledge review. USDA For. Serv. Gen. Rep. Wo-7, 34

White, C.S. (1991). The Role of Monoterpenes in Soil Nitrogen Cycling Processes in Ponderosa Pine. Biogeochemical 12, 43- 68.

White, E.M., W. Gartner, F.R. (1975). Immediate effects of prairie fire on the soil nitrate, ammonium, available phosphorousand total N content-proc,

White, E.M., W. Thompson and F.R. Grather (1973). Heat effect on nutrient release from soils under ponderosa pine. J Range 26:22- 24.

Whitford, W.G. (1987). Soil fauna as regulators of decomposition and Nitrogen cycling in pingon – juniper ecosystem. USDA For. Serv. Gen. Tech. Rep. INT- 215. pp. 365- 368.

Woodmanse, R.G., Wallach, L.S. (1981). Effects of fire regimes on biogeochemical cycles. Ecological Bulletin (Stockholm) Vol 33 pp 649-669.

Wright, H, A. (1977). Effects of fire ash, litter on soil nitrate, temperature, moisture and tobasa grass production in the Rolling plains. J Range Manage 30:266/270.

Wright, H, A., Bailey, A. W. (1982). Fire ecology: United States and Southern Canada. John and Willey and Sons, Inc. NY, 501pp.