Chapter 6
Fire Part I: Introduction and History

6.1 Introduction

Evidence of fire is found first in the Carboniferous age 400 Mya forming fusain or fossilized charcoal in coal deposits, but it was not until the Devonian sufficient fuel may have accumulated for widespread fires, the first trees evolving in the mid-Devonian, and it is not until the late Devonian that there were extensive coastal forests and more charcoal appears in the fossil record. The macrofossil record suggests wild fires in the northern hemisphere then became a regular part of the ecosystem being widespread and frequent (Scott 2000). Some consider the evolution of grasses and their capacity to sprout from leaf bases protected by old leaf sheaths heralded one of the most profound changes of life on earth, enabling them to survive fire this led to the adaptive radiation of large herbivores and their ability to exist at high population densities. The C_4 grassland ecosystems appeared first between 6 and 8 million years ago, one suggestion being that this was due to decreasing atmospheric carbon dioxide (CO_2). But the assumption of the existence of low levels of carbon dioxide in the Miocene has been disputed and it is hard to see how by consuming grass herbivores would promote the spread of grasslands at the expense of forests. Bond and Keely (2005) suggest it was fire which played this role. It is assumed generally that plant distribution, abundance, community composition, structure, and biomass, are determined largely by climate and soils, but fire, rather than herbivores, would have acted on grass fuel to kill trees and open up vast tracts of savannah where grazing mammals could thrive (Bond and van Wilgen 1996). Each habitat fire is a unique event, varying as it does according to the interval between fires, amount of flammable litter, humidity, season, wind currents, age and composition of the vegetation; but is a subject often omitted in ecology despite its extensive and fundamental importance in tropical ecosystems, which Bond and Keely (2005) consider analogous in many ways to herbivory. Hairston et al. (1960) proposed that the properties of ecosystems are determined by regulation of herbivores by predators, or primary consumers by secondary consumers. In the absence of predators herbivores would proliferate, consuming such large quantities of vegetation that plant communities would be transformed

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into those tolerant of herbivory rather than those best able to compete for resources. But critics claimed plants are largely inedible so that herbivores could seldom consume sufficient to transform ecosystems. Both views ignore the effects of fire, much of Africa being classed as 'flammable'- open forests, woodlands, and savannah. Fire, Bond and Keeley pointed out, feeds like herbivores on complex organic molecules, converting them to organic and mineral products, but differs from herbivory in that it consumes both living and dead material. Polis (1999) argued, as had Stuhlmann for Africa in 1894, that vegetation is largely determined by climate, locally modified by soil nutrient status, with "consumer control" by herbivores sometimes occurring but localized in space and time. Bond and Keeley see fire as a consumer in this equation, and one which has much more widespread and much greater control than herbivorous mammals. Bond et al. (2005) pointed to large differences between the climatic potential and the actual vegetation in tropical grasslands, posing the question whether fire was the cause? Low soil nutrients in ancient weathered landscapes may influence the rate of tree invasion into grasslands and shrublands, but do not prevent it.

Hairston et al. considered that herbivores were not limited by food, overlooking that seasonal effects limit availability and/or palatability of vegetation as a source of food. The importance of fire as a consumer depends on the productivity, which is a function of climate and soil nutrient status. Fires are least likely to occur where productivity is either too low because fuel is too sparse, or too high because it is too moist. At intermediate productivity levels high levels of herbivory on nutrient-rich soils remove the fuel for burning, and exclusion of fire would have less effect on primary biomass than would exclusion of herbivores. But low levels of herbivory on nutrient deficient soils allow flammable litter to accumulate and exclusion of herbivores should have less impact on primary biomass than exclusion of fire, also competition between plants should be relatively weak (Bond and van Wilgen 1996).

In Africa we are concerned with three types of fire: annually or quasi-annually set grass fires; fires set to clear woody vegetation to make way for cultivation; and naturally occurring wild fires, although the latter are relatively uncommon in comparison.

6.2 Grasslands

The photosynthesis pathway by which atmospheric carbon is taken up by plants is separated into two types dependent upon the carbon atom isotope: the C_3 pathway of dicotyledons, trees, shrubs, and forbs, and 'sweet' grasses which retain a comparatively high feeding value when dry; and the C_4 pathway of 'sour' grasses, grasses which are more lignified and less edible. C_4 grassy ecosystems first began to form a distinct vegetation type some 6–8 Mya, making them one of the most recently developed biomes on the planet. The C_4 photosynthesis mechanism is favoured by carbon dioxide providing an advantage at low levels and higher growing season temperatures. Thus if atmospheric carbon dioxide had decreased, C_4 grasses would have gained a photosynthesis advantage over C_3 grasses in

equatorial latitudes. But recent studies of palaeoatmospheres do not support the existence of low concentrations of carbon dioxide during the late Miocene. Since the early Miocene, some 24 Mya, atmospheric carbon dioxide appears to have remained at less than 500 ppm, more stable than prior to this era when it was almost seven times higher, while the level in 1999 was some 23% less. But transient intervals of reduced levels may have occurred during rapid cooling of the earth 15 and 3 Mya (Pearson and Palmer 2000). Lyell (1830–1832) referred to an excess of carbonic acid in the air being the cause of the exuberance of the Carboniferous era 340–260 Mya as having long been a favourite theory among geologists, to him the soundness of which appeared most questionable. Arrhenius proposed in 1896 that high levels of atmospheric carbon dioxide were the cause of global warming in the Cenozoic about 60 Mya, and, as Lyell had done, Chamberlin (1898) suggested a variety of geological processes which might affect carbon dioxide concentrations.

Studies in the Niger Delta revealed the presence of bush fires in the Upper Miocene (Morley and Richards 1993) and increased fire frequencies predating anthropogenic burning by millions of years must have been a major factor in the rapid spread of C_4 grasses at the expense of forests, splitting biotas into fire tolerant and intolerant taxa. Thus fire dependent ecosystems are considered not merely an artefact of comparatively recent anthropological fire setting, but have evolved distinct biotas. Isotope evidence from fossil herbivore teeth and palaeosols indicates an abrupt appearance of C_4 grasses in Africa in the Pliocene/Pleistocene, changing the vegetation from C_3 dominated ecosystems. The C_4 grasses underwent a remarkably rapid spread, *T. triandra* spreading to Africa, India, South-east Asia, and Australia, in the course of 7 million years. Whereas there are close phylogenetic relationships among grass taxa on each continent, there are very different phylogenetic affinities between savannah trees.

The Andropogoneae is the key group which constitutes the cover of fire dependent ecosystems throughout the world, exhibiting a number of features which may help promote fire. These are the malate enzyme (NADP-me) for C_4 photosynthesis which has the highest leaf level ratio of photosynthesis carbon gain to photons absorbed. They are highly productive grasses under suitable climatic conditions and therefore able to sustain intense burns on an annual basis under such conditions. A low nutritional value at the end of the growing season reduces decomposition rates and undecomposed litter accumulates, producing a highly flammable fuel. Some of the most common species have an obligate dependence on defoliation, usually by fire, because they produce basal tillers susceptible to shading by litter unless it is removed. *Hyparrhenia* species have been shown to secrete a toxin suppressing the growth of nitrifying bacteria (Boughey et al. 1964) which might thus inhibit other plant growth.

6.3 Atmospheric Chemistry

Fire in African savannahs plays an important role in regional and global atmospheric chemistry, providing an important source of trace gas and aerosol emissions to the atmosphere (Barbosa et al. 1999). Biomass burning produces soot and

vegetation produces the natural hydrocarbon isoprene. Africa has about 66% of the world's savannah regions covering an estimated 10.7 million km^2. These contribute 30% of biomass burned annually in the tropics worldwide, the area exposed to fires amounting to 440 million ha. Massive burning in both Africa and South America causes ozone (O_3) 'smog' formation in plumes which can extend over thousands of kilometres. As a result of high photochemically active ultraviolet irradiation and high humidity, hydroxy radical (OH) formation maximizes in the tropics formed by the photodissociation of ozone in the presence of water. This enhances atmospheric oxidation efficiency so that the tropical atmosphere is a major sink of natural and man produced trace gases. Indications are that the amount of ozone, which is important because it is a strong oxidant which can cause damage to biological tissues and is also an efficient absorber of infra red radiation, has doubled since the late nineteenth century due to industrial causes, but burning in Africa has probably decreased due to droughts reducing available fuel, controls on burning, and increased areas under intensive use, although this might well be replaced with increasing use of fossil fuel. Burning in the tropics and subtropics worldwide contributes about 25% less ozone than that formed from fossil fuel related emissions. Because ultraviolet radiation and water concentration in the tropics is relatively high, chemical ozone destruction in the low latitudes exceeds that in the middle latitudes, resulting in net production south of the equator exceeding that to the north by about a factor of two. Thus the net global mean ozone formation from fossil fuel combustion is about three times greater than that from biomass burning, the latter contributing an increase to the annual average tropospheric ozone column of about 15% (Lelieveld et al. 1997). Complete combustion with minor smouldering, as occurs in drier areas in grassland burning, produces less gases such as carbon monoxide (CO), methane (CH_4) and non-methane hydrocarbons (NMHCs), than fires in woodland and moist savannahs as in West Africa. But nitrogen oxide (NO_x) emissions are relatively high in the former, such that higher specific ozone formation can take place in savannah fire plumes than in forest fire emissions. But the tropospheric ozone concentration depends upon the dispersion of the smoke plume in the atmosphere. Ozone concentrations over the south Atlantic off the west coast of Africa peak during August–October while peak biomass burning, which produces ozone precursors, occurs in southern Africa at the end of the dry season in July–August, earlier than the ozone peak. Soils have been found to be a major source of nitric oxide (NO) in South Africa and could be a significant contributor, thus a combination of biogenic emission in August–October and the pyrogenic emissions which follow, could lead to an increase of ozone off the west African coast from August to October (Scholes et al. 2003). Little is known of the atmospheric chemistry effects of the extensive areas of miombo burning and the grasslands of East Africa, research having concentrated on southern and West Africa, and to what extent herbivorous animals influence the gaseous fluxes by removing potential fuel and the availability of organic substrates for biogenic emissions from soil and litter is also undetermined.

Widespread burning is most prevalent between July and October with about 2,000 million tonnes of dry matter burnt annually in the African tropics, exceeding

that of any other continent and creating one of the largest fire belts in the world, central Africa exhibiting some of the most dynamic yet poorly understood biosphere-atmosphere interactions on earth (Lacaux et al. 1993). In high-grass savannah in Ghana it is estimated that 7–10 tonnes/ha is burnt. It has been estimated that savannah fires contribute between 14% and 27% of global biomass burning emissions of carbon dioxide, non methane hydrocarbons, and cloud condensation nuclei; as much as 40% of nitrogen dioxide (NO_2) and carbonyl sulphide (COS); nearly 20% of carbon monoxide and nitrogen oxide; and 64% of tropospheric ozone produced by biomass burning (Lacaux et al. 1993). One square kilometre of rain forest is estimated to contain 20,000–50,000 tonnes of biomass (all living forms) with 10,000–25,000 tonnes of carbon. Burning converts approximately two-thirds of this into carbon dioxide, but rainforest destruction, as opposed to the dead grass burning of the dry season, removes the principal agent of carbon fixation. However charcoal can provide a carbon sink due to its resistance to microbial decay and long life buried in soils.

Biomass burning worldwide is calculated to produce 20–80 million tonnes of methane/year, but one molecule of methane is 7.5 times more effective in producing global warming than one molecule of carbon, thus burning reduces the effects of methane production considerably. But non-burning adds to the 10–40 million tonnes of methane produced naturally worldwide outside of wetlands (at 115 million tonnes/year the biggest producers).

6.4 Soil Changes

The effects of a burn are to spread large quantities of nutrient ions from the standing vegetation and the litter layer in ash on the soil surface in the form of carbonates, phosphates, and silicates of the cations; but nearly all the nitrogen is lost to the atmosphere as ammonia (NH_4), nitrogen gas, or nitrogen oxide, and the sulphur as sulphur dioxide (SO_2). Sanford and Isichei (1986) however consider there is little if any change in nitrogen content of the soil because a considerable input comes from rain and biological fixation. Most soil carbon appears to be derived from underground biomass and Sanford and Isichei consider that climate through its effect on the rate of mineralization is more important than burning in limiting the concentration of organic matter in the soil.

The presence of allelochemicals in the soil may inhibit seed germination and suppress early seedling growth. The destruction of these allelochemicals by fire may counter their effects. Heating of the immediate soil surface has some direct effect on the physical and chemical properties of the soil colloids, the availability of nutrient ions, and the microbial population. Change in pH and nutrient availability may cause a very different microflora to succeed that present before a burn, the latter being at least partially destroyed. A decrease in the original microbial population may be followed, at least initially, by a higher level than before (Nye and Greenland 1960). Cohen (1949) found in South Africa that burning together

with light grazing produced a soil fungi both richer in species and better balanced than did other treatments, while Fantham (1924) found that post burn cultures yielded almost double the number of soil protozoa than were present before the burn. But Henrard (1939) conducted experiments on soil microfauna and flora in lower DR Congo concluding that microorganisms were negligibly affected by fire. The fires take place when the microorganisms are inactive due to the dry season and it is in the rains after burning has taken place the microfauna and flora undergo a considerable increase.

Fire rapidly alters the amount, form, and distribution, of plant nutrients and, compared to normal biological decay, rapidly releases some nutrients into forms available to plants, particularly phosphorous (P), magnesium (Mg), potassium (K) and calcium (Ca). In forest areas acidic surface soils can be changed to alkaline with the removal of humus by fire, but burning can increase the humus layer by inducing leaf fall, although in Nigeria the effect was found to depend upon whether the fires were early season cool fires or late season hot fires, the latter removing humus (Moore 1960). Sawadogo et al. (2009) found in a study of Sudanian savannah woodland in central Burkina Faso that a recurrent annual burn counterbalanced short term increase in soil fertility and plant nutrient concentrations of available nitrogen and other minerals accrued from single or less frequent fires. The standing crop of two tufted annual grass species *A. gayanus*, *Diheteropogon amplectens* [Nees] Clayton, and two annuals *Chasmopodium caudatum* Stapf. and *Rottbellia exaltata* Linn., was found to be lower on burnt plots, which they attributed to the persistence of dead litter in unburnt swards possibly protecting regrowth from herbivorous insects, retention of soil surface moisture by the litter, or recurrent fires exacerbating soil mineral nutrient limitation.

Stromgaard (1985) found the actual concentration of exchangeable cations (base saturation) in the soils of miombo burnt under shifting cultivation was low, but a previous burn ensured a high Cation Exchange Capacity (CEC) detectable up to 16 years later. Necessary to hold the cations mobilized at the next burn normally the CEC is low but increases at 80 cm depth under stable miombo woodland (Stromgaard 1986).

Monro (1906), quoting Lounsbury the Cape Government entomologist, argued that burning the grassland in southern Africa was a wasteful process because the nitrogenous matter drawn by the plants from the soil was entirely wasted, being volatile it was dissipated by the heat and did not remain in the ash after burning. Burning destroyed also the natural mulch of the decaying foliage in which grass seeds would germinate and also large quantities of the seeds themselves. The soil surface was dried out and hardened so there was less moisture available to plants and it exposed the soil to washing by heavy summer rains, which instead of sinking into the ground ran off when on slopes carrying away the best soil. He considered also that burning must weaken individual grass plants by constant exposure during the dry season of the root crowns to the daytime hot sun and night frost, and by shortening the period of rest if there is earlier growth after burning. Phillips (1930) stressed the role of continual fire in causing erosion through removing ground cover, “The literature is filled with references to the influences of fire in increasing

erosion", but emphasized that this depended upon the climatic zone, local physiography, soil type, vegetation community, season of firing as related to season of rainfall, nature and periodicity of rainfall, strength and periodicity of the wind, and the nature and rate of evaporation from the soil surface. Hence in Kenya Edwards (1942) concluded that regular burning of grassland did not cause erosion, and Nye and Greenland (1960) considered this seemed to be true generally in tropical savannah. But fire reduced the water-retaining capacity of the soil and the fluctuation is much wider than in unburned grassland; while the degree of drought in burned areas becomes greater the drier the climate (Daubenmire 1968).

Nye and Geeenland stated that all nitrogen (as well as carbon and sulphur) is lost in combustion but West (1965) was of the opinion nitrogen losses are probably insignificant, other workers agreeing the loss is soon replaced. However Nye and Greenland considered that grasses had a repressive effect upon nitrification and that soil nitrogen status is best under forest, or even under bush, being poor under grassland. Thus, by inference, early burning encouraging bush growth must also encourage soil nitrogen status. But clearly it is at its best when no burning occurs and grassland has been suppressed. Many consider that nitrogen input through rainfall and bacterial fixation compensates for loss through combustion, and in miombo habitat it has been estimated that more than 80% of the species are legumes, many bearing nitrogen fixing root nodules. Thomas (1965) argued that controlled experiments found soils of grassland burnt annually may contain more organic matter than soils of unburnt forests on similar ground. It could be that in unburnt areas termites are more active in carrying humus underground.

6.5 Extent of Burning

From April 1992 to March 1993 satellite imagery showed that globally 50% of active fires were in Africa. In 2006 it showed that the frequency of forest fires was highest in Africa, particularly high in northern Angola, southern DR Congo, southern Sudan, and CAR. The net rate of woodland loss in 2004–2005 totalled more than 4 million ha due to shifting cultivation, fire alone does not destroy woodland. In 1981–1983 and 1985–1991 the frequency of fires was higher north of the equator than it was to the south, with 51% of the area burnt at least every 2 years. Only 9% of the area is burnt every year contrary to suggestions of 75% (Barbosa et al. 1999). More than 50% of the burned area is concentrated in Ethiopian, Sudanien, and North Zambesian Woodland.

Koechlin (1961) recorded that, with rare exceptions, in the southern Congo Republic the entire area of the savannahs was burnt each year, the date and importance of the fires varying according to the regions. Between 1970 and 1973 an average of 13.4% of Uganda's QENP was burnt each year, and 55.3% over three years, the fires not always being uniformly distributed. Menaut et al. (1991) showed in West Africa there was a north-south gradient in terms of area burnt

in the year, increasing from the Sahelian zone, 5–15%, through the Sudanien at 25–50%, to the Guinean at 60–80%; which reflects the density of grassland. Some 20% of the total burned area is accounted for by wetter Zambesian-Miombo Woodland, Somali-Maasai *Acacia-Commiphora* Deciduous Bushland and Thicket, and drier Zambesian-Miombo Woodland. The Sudanien Woodland is characterized by abundant *Isoberlinia*, and a mosaic of Guineo-Congolian Lowland Forest and secondary Grassland. Countries contributing most to this are those with broad savannahs, such as Angola, CAR, Chad, DR Congo, Ethiopia, Mozambique, Niger, Sudan, and Zambia. Most countries which have a low percentage of burned area either have sparse vegetation, such as Namibia, or forest, such as Congo Republic. Exceptions are South Africa, Rwanda, and Burundi, where land management practices may explain the low extent of burning. In South Africa there appears to be a lower frequency in the moist savannah, dependent largely on the rate of fuel accumulation in response to the amount of rainfall and the stocking rate of grazing animals.

The percentage of area burned is high at low human population density because there are large areas of uncultivated grassland, the percentage decreasing with increasing population density until a limit is reached at 15–20 persons/km^2 where land occupation restricts burning (Barbosa et al. 1999).

Bush fires depend on a rather dense cover of grass or shrubs and therefore in the Sahel are more common in the wetter parts. It is considered there is little excuse for burning annual grasses in the Sahel, which does nothing but impoverish and denude the soil. Deshler (1974), studying satellite imagery, found by late February 1973, more than 20% of the Sahel had been burnt from roughly the 400 mm isohyet south to the forest-savannah boundary. The greatest north-south extent was in the Nile valley, where more than 60% of burning occurred in an area extending to eastern CAR, with another burn extending from the Nigerian boundary into Cameroun and western CAR. Such burning occurred also in years of catastrophic starvation and death of cattle north of the zone of maximum burning presumably in a belief that the grass would resprout after burning. The Fulani of northern Nigeria traditionally believed it wrong to burn grass on heavy, seasonally inundated soils, as it brought on the young grass too early which did not continue to grow after emergence and could wither (St. Croix 1945); although Zolotarewsky (1936) recorded that in 1932–1934 the floodplains of the Niger Bend were burnt off completely at the beginning of March up to 2 months before the rains, but these could regenerate before rain due to deep sub-surface moisture.

From a study of aerial photographs Morgan and Moss (1965) claimed there was no evidence in western Nigeria of wholesale destruction of large areas of vegetation in any one season by fires. Burning occurred in scattered small patches and fires once started spread neither rapidly nor far, halting at the edges of forest. The most extensive burned patches occurred principally on shallow, rubbly soils associated with hard laterite pavements, and there was no evidence anywhere along the forest fringe that fires entered the forest. There was little retreat of the forest fringe, even around forest outliers well away from the main forest, and in some areas the forest seemed to be extending into the savannah and increasing in vigour.

6.6 Fire as an Ecological Factor

After climate fire qualifies as the most important factor affecting plant and animal life in Africa.

It is from the advent of man's regular use of fire that 'fire climax' savannahs developed, replacing the drier types of woodland with that of scattered trees among tall grass regularly burnt on an almost annual basis. Büsse (1908) considered the present savannahs were once mostly forest and that perhaps the greater part of East Africa, for example, was once acacia and miombo forest. Where forest was burnt this caused drying of the soil and the forest could not regenerate, becoming savannah. Today 'fire-climax' (the notion of a 'fire climax' was first propounded by Tansley and Chipp in 1926) savannah occupies almost the whole of tropical Africa between the humid forest and the semi-desert regions where grass is too sparse to produce fierce fires. For the latter reason Grove (1973) considered fire was probably not a very important agency in the process of desertification in drier areas.

Fires may well have occurred naturally throughout Earth's post Carboniferous age history but would have been random, sporadic events, and the question arises whether the fire adaptations shown by certain plants, the 'pyrophytes' as Swynnerton (1918) termed them, or fire-tolerant flora, could have evolved in response to these random events, or have they evolved in response to man's more regular recent activities? Has man been a proximate causative factor in the modification of vegetation in response to fire? In the event of the latter being the case, occasional natural random fires seemingly unlikely to exert sufficient selection pressure, then when did this modification by man begin?

Burton suggested in 1863 that much of Africa's grassland and bushed and wooded grassland was fire maintained. Writing of West Africa he considered the development of open savannahs to be the result of "old and yearly burnings". Johnston (1884) noted how fire reduced the forests and that it must have an effect on the phytography, a role stressed later by Büsse (1908). Fitzgerald (1898), describing the country inland of northern Kenya's coast in 1893 noted,

> As to the country, they[1] confirmed my surmise that all this land was originally forest, which was destroyed by the Watiku in making their shambas [cultivated patches]; the annual burning of grass and bush in the dry season forms a constant check on the growth of vegetation. The country to the west and north-west was also originally forest, which still exists to a small extent; thus a strip of forest is followed by open country, with another stretch of forest, and so on....
> The general appearance of the country was park-like, but this is not uniform in all cases: in some places the traces of the original forest were much more apparent. . . Towards the north-west the forest-like appearance is much more marked and noticeable, and the country if left alone would doubtless very soon revert to its original state.. the annual grass fires prevent this.

The view that much of Africa's grassland would be wooded in the absence of disturbance has been upheld by Sankaran et al. (2005) who considered that processes other than mean annual rainfall regulate actual tree cover in many savannahs. If disturbances by fire, browsers, and humans, were absent, then large sections of the African continent would be wooded. Maximum woody cover in savannahs

receiving a mean annual rainfall of less than 650 ± 134 mm is constrained by, and increases linearly with, rainfall. The arid and semi-arid savannahs may therefore be considered as stable grassland systems, while fire, grazing, and soil properties, interact to reduce woody cover below the rainfall-controlled upper limit. Above 650 mm mean annual rainfall savannahs are unstable systems in which rainfall is sufficient for woody canopy closure which excludes grasses and fire, and grazing disturbances are required to promote the coexistence of trees and grass. Below rainfall of about 350 mm soil properties and disturbances such as fire and herbivory rarely regulate woody cover. As mean rainfall increases fire in particular becomes a common factor that reduces woody cover below the rainfall controlled upper limit. Woody cover is higher, on average, where fires are infrequent with less than 10½ years between intervals. In sites with more frequent fires woody cover is typically low, except on very sandy soils, mainly Kalahari sands, which tend to support a higher woody cover. Phillips (1930) considered that savannah in East and South Africa was divided into climax grassland and tree and grass savannah which over the greater part of East Africa was deciduous, but if allowed to develop undisturbed at over 1,500 m altitude became an evergreen scrub climax.

Fire produces communities of pyrophytes such as open grassy plains and savannah woodlands which depend upon periodic burning for their continued existence. Kuhnholtz-Lordat (1939) classified pyrophytes as passive, species which will not burn, or only partially; reactive, those resistant to fire due to their ability to shoot after partial or complete destruction of their aerial parts either by budding or by underground growth; indirect, creating around themselves conditions unfavourable for burning; and social, populations which extend widely after burning through seeding. Fire has produced the 'derived savannah' (Keay 1958) regions of the Southern Guinea Zone and the *Isoberlinia* woodlands of the Northern Guinea Zone. These savannah regions have been referred to as deflected sub-climax communities, but deflected seres would be more appropriate. Rattray (1957) considered that although there were comparatively large areas in Zimbabwe which were very nearly devoid of trees and could be described only as 'grassland', there was, in the strict ecological sense, no true grassland in Zimbabwe, the grassland being a sub-climax maintained by burning. Early accounts of the uplands by such as Baines in1870 (Wallis 1946), and Selous (1893) with his reference to "open rolling downs", gave a misleading impression of the grasslands and savannahs which were fire induced, the early stages of a woodland succession checked by fire. This deceived the first European settlers, encouraging development of cattle ranching in areas where bush encroachment was ecologically inevitable with the reduced incidence of fire, and the early season burns used to stimulate grazing do little damage to woody vegetation. Heavy grazing pressures consume much of the grass which formerly burned and weaken the grasses so that they produce less foliage to burn, thus trees and shrubs thrive, leading to further suppression of grasses. Whereas a climatic change towards wetter conditions would favour trees and shrubs at the expense of grasses, evidence suggests the climate has become drier (Strang 1973). West (1947) stated that nowhere in Zimbabwe was there any area where the climate was such that the climax vegetation should be grass. All of it was seral, a

stage in a natural tendency towards bush and forest. Thus all open grassland was grassland because of some factor or set of factors which prevented or was preventing its invasion by bush, "The most important retarding factor is fire. For ages African vegetation has been subjected to periodical fires which have served to maintain grassland or open woodland in place of the denser bush which almost invariably results when fire is kept out". Of Weenen County, Natal, he concluded also that all of the grassland must be regarded as a sub-climax caused and maintained by fire, "periodic burning maintains the typical 'Undisturbed Veld' while protection induces considerable change in composition and structure leading to the eventual suppression of the grass and its replacement by forbs and woody shrubs seral to bush and forest" (West 1951). But Stuhlmann (1894) considered thickets in East Africa were not the result of forest clearance and savannah fires. The vegetation depended upon moisture and not temperature, and the shortness of the rainy season did not give the plants time to grow bigger. Many of them, he noted, had xerophyllous adaptations such as narrow leaves.

Although fire may remove species, post burn plant succession is largely determined by the species' composition immediately prior to the fire, but African ecosystems probably differ from the fire resilient ecosystems of Europe, North America, and Australia, as considered for example by Whelan (1995), in their regularity of burning, the quasi-annual burning regime producing a fairly regular response. Walker (1982) pointed to a continuum in the savannah between a minority of species which were highly vulnerable to fire, through to those which are extremely resistant. The relative abundance of the extremes on a particular site provide an indication of its fire history.

Cameron (1877) reported burning in July 1874 in southern DR Congo on the right bank of the Luama, a tributary of the Lualaba River, noting that all the country around was either already burnt or burning. He stated that sometimes the enormous updraft caused the warm air to rush to a cooler level where the moisture was condensed in the form of rain occasioning slight or partial showers. These would fall too soon on the hot earth to be of any benefit. Brown (1887) wrote of South Africa in 1863 that "In some cases the burning of the veldt has been followed immediately by copious rain.... But while cloud or rain may be observed to follow immediately the burning of the bush within a very short period, a few weeks it may be, it may also be found that the streamlets flowing from the place have been dried up in whole or in part". That the heat induced rainfall was disputed by Danckelman (1884). It is now known that the extensive burning in the equatorial regions produces high smoke concentrations which can suppress convective rainfall. This may be why satellites overestimate the region's rainfall by two to three times (Nicholson and Grist 2003) and increasing dryness leading to increased burning may have led to the declines in equatorial precipitation noted by Malhi and Wright (2004).

Annual burning leads to a relatively stable vegetation as regards structure and size-class distribution of trees and general appearance. Species' diversity increases as does species' richness, but evenness decreases. Canopy closure decreases due to high branching and mean tree height is decreased while mean girth increases. Species are selected which have smaller leaves, and pubescent or glaucous leaves

are more common than are compound leaves, and the percentage of woody legumes increases. In Northern Nigeria Ainslie (1934) considered that from a purely forestry point of view early burning markedly improved forest after a few years, improvement being almost as rapid as if the areas had been completely protected from fire. Several reserves showed a regular improvement in growing stock from approximately 2.5 stunted over-mature trees/ha to as many as 20–25 young trees/ha in 4–10 years. Westwards into Ivory Coast several authors have shown forest advance into the savannah despite the presence of fire (Avenard et al. 1974). Morgan and Moss (1965) considered the extent and destructiveness of fires in western Nigeria were rather exaggerated and the idea of an annual burn affecting a large proportion of the area each year was false. It was more likely that some patches, peculiarly susceptible to fire as a result of edaphic or biotic influences, were repeatedly burned, but others were hardly, if ever, affected, "It is also important to note that there is no evidence anywhere along the forest fringe... to suggest that fire sweeps into the forest, effecting notable destruction of forest trees".

Time of burning does not seem to influence the proportion of annual to perennial grasses, grass species' distribution being influenced by soil, mechanical disturbance and shading; but shading is strongly influenced by the burning regime (Sanford and Isichei 1986).

Maley (1996) argued that in the unfavourable climatic phase culminating between 500 and 0 B.C. fire must have been important in affecting forest cover, although fires set by man in the savannah do not penetrate across the forest edges, halted by the low and thick vegetation which remains green in the dry season. However some years are drier than normal and then fires do succeed in penetrating the peripheral semi-deciduous forest. In Ghana a "fire zone" has been defined where fire penetrates forests adjacent to savannahs about every 15 years. In the extremely dry year of 1983 when the dry season was prolonged about 2 months, fires entered the forest in Ghana, Ivory Coast, Cameroun, DR Congo, CAR, and probably other forest regions. Although destruction of forests by fire is almost instantaneous their recovery over wide areas is very slow, but fire within the African forest block is an uncommon phenomenon. If a fire in the forest is not followed by another within a few years then vegetative regeneration is rapid, but pioneer trees are smothered by large monocotyledons dominated by Marantaceae (arrowroot) and Zingiberaceae (ginger) forming a "clear forest" of open canopy and few mature trees. These "clear forests" sometimes cover considerable areas as in Gabon, northern Congo Republic and the extreme east of Cameroun. They may follow forest fires but are also a stage in the colonization of savannah. In Ghana they develop after fires in semi-deciduous forest altering about 30% of it, and Hawthorne (2001) considers that although occasional fires may have occurred throughout history fire now presented a serious challenge to the long term existence of semi-deciduous forest in Ghana. The fires kill most of the smaller plants in "clear forests" but leave the upper canopy trees unharmed. Some herbs colonize the ground layer soon after the passage of fire and grow rapidly into a dense understorey which may impede further regeneration. Swaine (1992) considered that all central African Marantaceae forest was caused by fire while others have suggested that it is a seral stage in the natural succession from savannah to forest which takes place when colonization by forest species is not blocked by fire.

At Lopé in Gabon, long known for its "strange forest-savanna mosaic" (Aubréville 1966) of savannahs dated to *c*9000 B.P. completely enclosed within the Congolian forest block, the forests surrounding the savannahs are predominantly Marantaceae extending up to about 20 km from the savannah edge, at which point they are replaced by open understorey forest. Today the savannahs are maintained by annual fires but where fires do not occur the forest advances into the savannah. White (2001) considers there is good evidence that these Marantaceae forests represent a stage in the development of mature forest following savannah colonization, but this does not explain all types of Marantaceae forest. One of the most common trees in Marantaceae forest *Cola lizae* N. Hallé and the dominant ginger *Aframomum sericeum* Dhetchuvi, are species recently described, in 1987 and 1994 respectively. In Odzala, Congo Republic, *Diospyros whitei* Dowsett-Lemaire and Pannell is also newly described (1996) from Marantaceae forest.

The large areas of peripheral savannahs characterized by a very low density of savannah trees surrounding the central forest block to the north and the south almost without interruption, may reflect successive retreats of the forest block during the arid phase of the late Holocene between *c*3700 and 2000 B.P. The frequent occurrence of fires during this period, especially between 2500 and 2000 B.P. and later in eastern DR Congo and central Gabon, may have destroyed the young regenerating forest dominated by Marantaceae, Zingiberaceae, and pioneer trees, and thus could explain the grass savannahs seen today where typical savannah trees seem to have had difficulty becoming established because of fire frequency (Maley 2001).

6.7 Fire Behaviour

The type of fire varies and hence its effects. An early dry season fire is cool, set before the grasses have completely dried out. It moves close to the ground with temperatures rarely in excess of 250°C and temperature changes in the soil are minimal below 2 cm although soil surface temperatures are considerably hotter than elsewhere. Treetops, denser shrubs, and the green, shaded grasses, are unaffected and dead wood is consumed only slowly. Conversely a hot fire occurs at the end of the dry season when the grasses are completely dry. The fire can move at considerable speeds on a tall front reaching temperatures of 600°C in South Africa, affecting the soil to more than 5 cm below ground. A temperature of 720°C has been recorded in Senegal but the duration of maximum values is always brief. Treetops are scorched and the leaves killed and all shrub and ground layer material is killed down to the ground or main stem level, while dead wood is often consumed. The timing of cool or hot fires is dependent upon latitude. Although a low intensity fire may be patchy in coverage, reducing the importance of seed destruction by fire, it increases that caused by herbivory on post-burn patches.

The heat and effectiveness of a fire depends also upon whether it is a back fire or a head fire. A back fire advances slowly close to the ground and can subject plants to a higher temperature for a longer time than a head fire, which advances rapidly a metre

or more above the ground. It can scorch tree boles and cause fire scars which provide entry points for fungal infection. In American forests a "chimney effect" has been observed, caused by wind blowing the flames around the bole of a tree causing a convection current to rise on the protected side carrying the heat and flames upward, thus bark charring is almost invariably highest on the leeward side. At Ndola a trial plot of 5.7 ha was consumed in 11 min, or an area of 9 × 9 m/s, but experiments showed that temperatures attained in grass fires on a plot of 3 × 3 m were no different to those attained in an area of 16 ha (Daubenmire 1968). In a large area where there are many separate fires wind direction changes rapidly, causing a mosaic of back and head fires and consequently differing effects upon the vegetation. It is dependent also upon climatic conditions, a strong wind makes a fire burn more quickly and a fire reaches its maximum violence during the hottest part of the day, but what constitutes a lethal temperature has little meaning without a time factor.

6.8 Plant Reactions

Plants exhibit a great range of tolerance to fire from bark thickness and composition to growth form and sprouting ability. The growth forms of trees and shrubs subject to repeated burning often display a gnarled and twisted appearance. Sjöstedt (1910) described trees on the plains of northern Tanzania near Mount Kilimanjaro as looking like old apple trees or large-leaved plum trees. The shape of those described as 'orchard-type trees' as seen in *Commiphora fischerei* Engl., *Lannea humilis* (Oliv.) Engl., *Gardenia thunbergia* L.f., *Dichrostachys glomerata* (Forsk.) Chiov., and *Dalbergia melanoxylon* Guill. & Perr., is caused by destruction of the apical buds and stems. But Volkens (1897) considered the growth forms were not induced by fire, "It is also wrong besides to accept that the gnarled stature, the whole habit of the savannah trees and shrubs, derive from the effects of savannah burning. Many desert plants present a similar appearance where there are no fires". Robyns (1936) also considered that burning simply selected for xerophytic types, but Phillips (1965) disagreed. Experimental studies on *Watsonia borbonica* of the South African fynbos, a member of the Iridaceae which flowers after burning, demonstrated that cutting the vegetation caused the same response, but cutting the *Watsonia* alone did not, suggesting it was increased soil temperature after burning which induced the response (Le Maitre and Brown 1992).

Tests on seeds of seven common savannah ligeneous species in South Africa (*Acacia swazica*, *Combretum apiculatum*, *C. hereroense*, *Dichrostachys cinerea*, *Diospyros mespiliformis*, *Euclea natalensis*, *Terminalia sericea*) showed that only one species, *A. swazica*, was stimulated by burning and its germination was lowered in buried seeds, burnt or unburnt. A significant number of all surface seeds was destroyed and germination in four species was reduced. There was no effect on buried seeds. Fire intensity had a variable effect (Schackleton 2007). Perennial grasses generally survive fire because the range of fire intensities is small and the meristems are well protected by the leaf bases.

Grassland is the ultimate product of fire because it is composed of those plants, grasses and forbs, most tolerant of fire, characterized by aerial parts that die off seasonally and dormant buds protected because they are either underground (geophytes), at the soil surface (hemicryptophytes), or just above it (chamaephytes). They also possess storage organs protected from fire, such as leaf bases in tussocks, bulbs, corms, rhizomes, and tubers.

In the woodlands of southern Tanzania a short perennial herb *Cryptosepalum* spp. has a stout rootstock below ground with widely spreading branches, only the tips of which appear above the surface. Dwarfed species of *Combretum* and *Grewia* in this habitat have large underground rootstocks also. Given a lapse in burning the food reserves in such rootstocks allow the plant to shoot up reaching above the level at which fire can destroy the apical buds. But the main difference shown by shrubs and trees compared with grasses and forbs is a lack of aerial parts which die off seasonally.

The many apparent adaptations to fire can thus be seen as characteristics of the life cycle, characteristics which enable survival in the face of fire rather than being specific adaptations to it. If some species have evolved specific adaptations of structure, even these would be limited by the length of exposure to the fire and its degree of temperature. Some plants produce heavy seeds needing a fire to split the testa to allow the seed to germinate, while some seeds are killed by a small rise in temperature, but post burn observations do not support increased germination rates although this can sometimes be achieved experimentally (Trollope 1984). In many temperate zone species a period of exposure to low temperature (vernalization) is necessary to induce germination, the low temperature converting the starch reserve to sugar. Studies on the chemistry of the seed food reserve and its reaction to high temperature seem to be lacking in tropical African species.

6.9 For and Against Burning

Until the 1930s scientific opinion in most areas, particularly in South Africa, was against burning, considering it destructive. This was highlighted by an apparently increasing desiccation. Explaining the drying-up of springs and streams in South Africa Henkel noted (1903), "When the bushes and grasses are eaten or burnt off, the sun bakes the soil, and the rain-water runs off into the rivers, forming new "sluits" as it runs, and is lost in the sea without replenishing the underground supplies.

> On very many Transkeian farms and locations surface springs exist and are utilized, but others have more or less disappeared as the large trees surrounding the outlet of the springs have been cut down or burnt through grass fires.

Kanthack (1907) asserted burning to be one of the causes of erosion in South Africa and that it was a dangerous practice which should be prohibited throughout the country.

Brown (1877) quoted experiments of Blore at the Cape who buried two open jars of water, one in an area partly protected by bush, the other in newly cleared ground

surrounded by bushes at 18 m radius, and found that evaporation from the latter was almost double that of the former. From this he calculated that 405 ha of burnt ground would evaporate in excess of 384 million litres of water more than if the bush or grass had been left unburned. Sim (1916) considered burning to be the first of the "two great causes of desiccation", it killed the tender grasses and produced more bare ground, resulting in a hotter evaporative surface thus repelling more moisture. His conclusion was that although rainfall may have been the same 50 years previously, the results were now very different. The subject was taken up by the Drought Investigation Committee (1923) which considered fires were less prevalent than 75 years previously due to the absence of tall grass. In former days many of the mountain tops and slopes were covered with forests and the fires were accompanied by far greater loss. On the whole grass burning was now on the decrease although still far too prevalent. In sweet veld it was now exceptional, improvement of the veld through grazing control now generally being recognized. But over large areas farmers complained it was still the only method to get rid of the rank grass.

Sim pointed out that where grass grew so vigorously it could not be grazed down by full stocking the country would be naturally wooded and should be used for timber production. At a symposium held on veld burning in 1924, Marloth (1924) considered that fire in the fynbos of the winter rainfall area of the South-west Cape had caused the extinction of species, increased runoff, diminished water supplies, and reduced the ability of the mountains to capture moisture, stressing his remarks applied to that area only,

> Centuries ago, before white colonists required the hills and slopes for grazing purposes, these parts were covered with thick evergreen scrub, termed maquis by the botanists. This maquis consisted of many hundreds of shrublets, shrubs and small trees... Between the shrubs the ground was entirely occupied by perennial herbaceous plants.. Now all this is changed. Only here and there... one may find the original shrubby vegetation or even trees as relics of the past... an infinitesimal fraction of the hundreds of square miles of luxuriant maquis which have been devoured by the flames during a century or two of reckless burning....

Levyns (1924) declared fire menaced the future of the country, this view being taken up by other delegates who condemned burning generally in the Cape, Orange Free State, and Transvaal.

Wildeman (1940) was typical of the condemnation, "Being a survival of ancestral destructive methods of cultivation and hunting, it is our obligation to fight against these current methods and seek to replace them as soon as possible with more rational methods". But Thomson in1910 had noted the presence of grass in any large quantity in tropical Africa was synonymous with the occurrence in the dry season of fires and should be looked upon as one of the established natural conditions against which the vegetation had to contend. Trees in such areas possessed an extra thick bark out of all proportion to the rest of the stem tissues and some had enormously thickened roots due to the aerial growth being cut back each year, until the emergent stems eventually reached a height which enabled the crown to escape the direct action of the fire (Plate 6.1).

Reichard, writing of East Africa in 1892, considered fire a "blessing for all creatures", contrary to West Africa where because of the continuous, denser, and

Plate 6.1 Cool fire advancing in grassland close to the ground Akagera National Park July 1969. Absence of lower branches on the acacia trees and lack of regeneration indicate frequent fires (C. A. Spinage)

much taller grass, the fire often burnt antelopes. Büsse (1908) argued that conflicting opinions about the adverse or otherwise effects of fires reflected observations in different countries, denser and taller grass growing in those with high rainfall. Thus the tall grass of Togo produced much fiercer fires than did the relatively short grass savannahs of East Africa. Phillips (1930) noted that in Zimbabwe and South Africa frost killed back the greater portion of the above ground growth resulting in hotter burns than was the case in most parts of East Africa.

Jeffreys (1945), whose concern was Nigeria, argued the statements condemning grass burning were not based on facts, quoting generalizations offered by authorities such as Tansley and Chipp (1926), Aubréville (1957), and others. He considered there was no evidence the practice had a deleterious effect on the soil. As a means of range management Phillips argued in 1965 that where the control of grass through normal agencies of management was not possible then fire was absolutely essential to prevent a steady deterioration of grazing. Komarek (1971) argued burning of grassland by Africans for attracting game and improving pasture was often done with knowledge, especially by the Maasai in Kenya and Tanzania, "To one not versed in fire ecology, some of this may appear haphazard or careless, but if the pastoralist had burned off too great an area, particularly at the wrong time, he and his grazing would have suffered".

In more recent years opinion has recognized fire as a useful tool in the management of bush and grassland, but this is in respect of management for husbandry or some specialized objective, such as game viewing. It must still be regarded as a very destructive agency for forest and unmanaged grasslands, its signs remained in the burnt cedarwood forests of Kenya for more than a century after the event.

In 1937 the forest on the Chyulu Hills was reported burnt from end to end and the charred trunks were still present 40 years later (Plate 6.2). The "Burnt Forest" of Uasin Gishu north of Eldoret in Kenya dates from much earlier and its traces are still evident. Jeannel (n.d.) remarked upon its immense area and sad appearance in 1932, the local people allegedly having fired it 100 years before. Von Höhnel recorded in 1888 that in the Gilgil area the district was called by the Maasai *angata elgek* or 'firewood plain' because nearly all of the trees were dead, "their bleached branches sticking stiffly out, whilst the ground is strewn with stems and twigs". Leleshwa shrub *Tarchonanthus camphoratus* L. was the only vegetation, "The whole Angata Elgek district bore unmistakable traces of a great conflagration" (von Höhnel 1894). Thomson had passed through in 1885 and referred to the "marvellous numbers of dead trees". To him they seemed to have died from natural causes, but what he could not say, ".. probably the strange effect is due to either a change of temperature or alteration of the rainfall". Von Höhnel relates they were quite at a loss to understand why Thomson assigned quite a different reason to fire for the deaths of the trees. Both may have been right. The fire may have occurred in the apparent dry years of the early 1800s, that there had not been a more recent fire is demonstrated by the unburnt litter which von Höhnel recorded.

Troup (1922) found that fire in *Juniperus procera* forest in Kenya probably caused wounds which allowed the Cedar fungus *Fomes juniperinus* Schrenk to attack the tree destroying the heartwood. But this posed an economic rather than an ecological problem.

Plate 6.2 The Chyulu Hills Kenya December 1972 showing retreating forest edge due to burning (C. A. Spinage)

6.10 Naturally Occurring Fires

Fires can occur naturally due to spontaneous combustion, falling rocks striking sparks, and lightning. Bond and van Wilgen (1996) state that lightning is the chief cause of fires in natural vegetation. An instance is reported of a 40 m tall *Pterocarpus soyauxii* Taub. in the middle of a forest in central Gabon struck by lightning and burnt (Tutin et al. 1994). Koechlin (1961) records that in southern DR Congo fires were set deliberately partly to prevent wild fires caused by lightning. Lightning tends to occur at the end of long dry spells at the beginning of the rains created by storms which herald the rain, and fires ignited by lightning often are soon extinguished by the ensuing rain. In most cases their occurrence would be spasmodic and rare but Harroy (1949) reported that such fires occurred several times each year in the plains south of Lake Edward and were perhaps less exceptional than one might imagine, but were followed by rain which extinguished them. Records showed that in 1957 a total of 423 ha were burnt following ignition by lightning. In 1958 the total area was 13,783 ha, and in 1959 it was 4,410 ha (Delvingt 1978). In Zimbabwe lightning fires are recorded as not uncommon and at Inyanga two strikes about 5 min apart were witnessed in the rainy season when conditions were wet, the strikes producing clean burns of some 20 ha each before they were extinguished by staff (West 1971).

In Southern Africa lightning accounts for 1–10% of fires but is rare in the dry months, although in the fynbos of the western Cape it can cause fires even although the density of strikes in the region is far lower than in the montane grasslands of the Drakensberg and accounts for about half of all recorded fires there. In Kruger NP a strike burned nearly 480 ha and shortly afterwards another 100 ha nearby. Between 1957 and 1996, 21.6% of the area burned during that period was caused by lightning. In forest plantations, between 1957 and 1970 the number of fires started by lightning averaged 29/year in the range 13–46 (Komarek 1971). In Natal multiple fires from lightning were recorded from one storm but in the Natal Drakensberg less than 1% of fires in periods ranging between 12 and 73 years were lightning caused. In the Hluhluwe-Umfolozi region of Zululand also lightning was the cause of only 1% of fires in 24 years. Hence it was concluded lightning was unimportant and insufficient to maintain fire-induced communities (Edwards 1984).

Johnston (1906), presumably referring to Liberia although he had a wide African experience, wrote, “They [the Negroes] may have only known the effects of fire through the lightning constantly setting the bush aflame in the Tornado season... The present writer has so frequently witnessed the ignition of the African bush by flashes of lightning that he can well realise how the Negro may have even been led into the use of fire by keeping alive and feeding the remains of a conflagration..”.

Spinage and Guinness (1971) showed that in Akagera NP, lying within the 180 thunderstorm days/year belt, the effects of lightning on trees appeared extensive. After one storm in which trees were affected over a wide area, 42 were counted

struck in 34 ha, or 1.2/ha, damage comprising the lopping off of crowns or side branches and complete felling (Plate 6.3); but lightning as a factor starting fires appeared unimportant. Phillips (1930) quotes German records kept for central Tanzania over a period of years prior to 1918 showing that while there were frequent occurrences of forked lightning during the moist season when vegetation was kindled with difficulty, there were very few occasions on which this took place in the dry season.

Although East Africa lies within one of the highest thunderstorm regions of the world, between the 20 and 140 thunderstorm days/year belt rising to 240 days/year at Kampala, Uganda (a "thunderstorm day" is a day upon which thunder is heard and does not necessarily imply rain, wind, or air to ground lightning), and the frequency of lightning in equatorial Africa is by far the greatest in the world (Nicholson and Grist 2003), these storms are most frequent when the ground is fairly wet, dry seasons being the periods of least thunderstorm days. In America the converse is true, thunderstorms occur most frequently in the dry summer months, and although lightning in eastern Africa is unlikely to be an important agent in igniting fires it is of importance in southern Africa and in America (Komarek 1964).

Fires caused by volcanic eruptions are exceptional, occurring in the dry season only and as irregular, rare events. But that of the DR Congo's Nyamuragira volcano in January 1938 destroyed 10,000 ha of forest north of Lake Kivu.

Plate 6.3 Acacia trees showing branches broken by lightning, Akagera National Park 1969 (C. A. Spinage)

6.11 Ancient Fire History

The use of burning to clear vegetation is not peculiarly African. Known as swaling in Europe, burning was used traditionally to clear forest and bush for cultivation. Kuhnholtz-Lordat (1939) has shown this was worldwide dating in Europe to at least Celtic times, and there is evidence of ancient periodic burning of forests in southern France to improve pastures 2600 B.P. (Le Houèrou 1973). A more destructive method which seems to have been more thorough than the Zimbabwean *chitimene* method was devonshiring or denshering, in which the turf with its vegetation was pared off and heaped into smothered fires, the ash then scattered back over the ground. This was believed to have been practised in Spain as early as the sixth century and in Europe until at least the seventeenth, but in France regarded in the sixteenth as an unusual practice employed in the Ardennes every 16 years to fertilize the soil. Both this latter practice and slash and burn were carried on in the Ardennes until "not so very long ago" (Parain 1940). Forest clearance by burning for cultivation in Finland differed from that in Africa in that in the former country the burnt roots were pulled out. Planting millet in forest clearings was practised in Poland, among American Indians (although fire is believed to have formed much of the prairies some prairie land was not of secondary origin having succeeded the glacial tundra), and in Australia.

Literary allusions in Homer's Iliad indicate forest fires were known in ancient Greece about the eighth century B.C. Hector was as mad "as a conflagration in some thick forest upon the mountains", and Achilles went on "as a devouring conflagration rages through the valleys of a parched mountain height, and the thick forest blazes, while the wind rolls the flames to all sides in riotous confusion..". About four centuries later in Israel the prophet Joel referred to a noise "like the noise of a flame of fire that devours the stubble", indicating burning was used in Israel at this period (Joel 2.5). Wild fire in times of drought was also known, Joel lamenting, ".. the fire has devoured the pastures of the wilderness, and the flame has burned all the trees of the field. The beasts of the field cry also to you: for the rivers of waters are dried up, and the fire has devoured the pastures of the wilderness" (Joel 1.19–20). Perhaps a one hundred years earlier the prophet Isaiah wrote in analogy, ".. it shall devour the briers and thorns, and shall kindle in the thickets of the forest.." (Isaiah 9.18). There are several other allegorical references to the burning of thorns and stubble, thus ".. as the fire devours the stubble and the flame consumes the chaff.." (Isaiah 6.24). An indication of forest fires is given in Psalms (83.14), "As the fire burns a wood, and as the flame sets the mountains on fire".

In Greece Xenophon *c*350 B.C. wrote, "I imagine that the stubble may be burnt with advantage to the land.."; and Cassianus Bassus in *Geoponica* a sixth to seventh century A.D. compilation of ancient Greek texts, records, "The best manure for all vegetables is ash, and being most fine and naturally warm, it will kill the fleas and worms and other small beasts". And ".. instead of nitre, some people use ash to also kill caterpillars" (Liacos 1973).

Practised in ancient Rome, Virgil in the *Georgics* (30 B.C.) wrote,

> Some thankless soils will swains by burning tame,
> And give the stubble to the crackling flame;
> Fresh powers unknown the altered soil receives,
> Rank weeds are killed, superfluous moisture leaves
> The finer surface, and its pores imbibe
> More healthful juices for the cereal tribe (King 1882).

Writing of Rome in 20 B.C. in the *Aeneid* he referred to shepherds setting heathland alight,

> Just as, in summer-time, when the winds he has prayed for have risen,
> A shepherd may light fires at intervals over the heathland;
> All of a sudden the interspaces catch fire, an unbroken
> Line of crackling flame is spread across the broad acres (Lewis 1952).

In western Europe clearing of forest for cultivation began in the fifth century on the plains, in valleys and on the terraces of mountain slopes, but on the steep slopes and high places difficult of access temporary cultivation of burnt ground was practised, as it was still in Corsica and in the forest of Ardenne in 1940 where as a rule only one crop was taken off. Clearing by burning was still practised near Paris in the twelfth century and was widespread in the Alps in the eighteenth. In 1447 the men of Diois in the Haut Dauphiné explained that they were forced to adopt the practice instead of regularly clearing parts of the forest because they had not enough manure for an extension of permanent cultivation. The method had been forbidden in the Oisans from about 1350 as it often turned forest into increasingly unproductive moorland (Parain 1940). But as late as 1793 it was reported from the district of Gard in France that people burnt the forest down to plant wheat, "one sees already how the fires have destroyed the wood" (Becquerel 1853). After the mid-fifteenth century burning was practised by shepherds and goatherds in Mediterranean countries following the invasion of Arab Bedouin pastoralists from the desert.

Schleiden (1849), in an early discussion of the production of carbonic acid into the atmosphere, noted, "In the whole of Northern Germany, the burning of moors is a very common practice; below Ems it is annually done on the largest scale. So in Corsica, the *makis*, or evergreen shrubs, are cut down once in 3 years, and burned upon the soil. In North and South America the breaking up of new land always commences with the burning of the aboriginal wood, which is occasionally done also in the Old World, especially in Russia. Amongst the various burnings is also that of the Steppes, so frequent in the Pampas and the prairies of North and South America". He seemed unaware of the contribution which Africa made.

Pechuël-Loesche (1882) describing the climate of Loango based on his expedition there in 1873–1876, was the first to stress the influence of the smoke of grass fires on the clouds and on the weather in general on the south-west coast of Africa. He noted smoke of the moor-fires of northern Germany, although it tarnished the atmosphere from the North Sea to Vienna and Krakow, was however marginal in comparison to that of the African grass fires, which consumed great quantities of vegetation and sent out correspondingly equal and important masses of smoke into

the atmosphere. Barbosa et al. (1999) estimated that up to 1.8 million tonnes of particulate matter may have been produced into the atmosphere in 1989–1990, but a century before we may suppose that the emissions would have been greater due to more uncontrolled burning and less settlement.

6.12 African History

Fire has a long history of regular occurrence in Africa possibly extending back almost 2 million years. Gowlett et al. (1981) suggested man may have been using fire deliberately for domestic use at least 1.42 Mya in Africa, but later work dated the first association of fire and hominids in South Africa at about 1.8 Mya (Brain and Sillen 1988), with regular domestic use probably around 100,000 years B.P. (Deacon and Deacon 1999). Further work revised the former back to 1.5 Mya (Bellomo 1994), compared with suggestions of 500,000 in China and 300,000 years ago in France. Analysis of marine cores covering a 1 million year period from off the African west coast suggests a marked increase in charcoal for the last 200,000 years of the record, but interpretation of carbon in marine sediments is controversial (Bond et al. 2003).

Clark (1959) stated earliest evidence of the use of fire in Africa was associated with the African Stone Age Chelles-Acheul, and perhaps the Fauresmith industries, which according to C_{14} dating of charred wood from hearths at Kalambo in Zambia flourished about 60000 B.P. Hamilton and Faden (1974) considered that fire had been used for domestic purposes in south-west Tanzania for at least 60,000 years. On Mount Kilimanjaro charcoal horizons in the soil indicate fires occurring before 10000 B.P., while Salzmann (2000) found from pollen core samples in north-east Nigeria that grass fires were frequent there throughout the Holocene (10000 to less than 3800 B.P.). But Sanford and Isichei (1986) consider that before and for considerably after 10000 B.P., burning must have been very rare as it was only then that man's transition from hunting and gathering to farming took place, overlooking that burning was probably regularly used as a hunting device before this. Linseele (2007) speculates burning for hunting may have been used by Late Stone Age people *c*3000–2000 B.P. in West Africa. There is evidence of vegetation change caused by fire but it is impossible to determine between natural and anthropogenic fires. Natural fires however would be relatively rare events, so the latter is more plausible.

In a layer beginning 25 cm below the surface of mature mahogany forest in Okumi, south-west Nigeria, extensive remains of pottery and charcoal, the latter mostly oil palm *Elaeis guineensis* kernels, have been dated to 750–700 B.P., indicating forest establishment since then. In northern DR Congo similar layers of carbonized oil palm kernels have been found also under mahogany forests over a wide area, dating from 2400 to 900 B.P., peaking between 1800 and 1700 B.P. Boulvert (1990) found a carbon layer dating to 1580 $\pm$ 70 B.P. at 80 cm depth at

Gadzi on the border of the CAR (4°17′30′N, 14°48′E), and a layer in the Lobaye forest, western CAR, which dated to A.D. 380 ± 220.

West (1965) points out the maintenance of fire sub-climax vegetation types probably could not have occurred until man used fire frequently, and it is unlikely that present pyrophytes date from an era which predates the extensive pluvial periods as these could well have negated any major trends.

The Ituri forest of north-eastern DR Congo comprises about 70,000 km^2 of tropical lowland forest characterized by three main forest types: *G. dewevrei* forest in which this species can comprise more than 75% of tree species; mixed forest; and secondary forest of shifting cultivation bordering roads. Soil pits reveal charcoal is widespread at depths of up to 80 cm dating from 4190 to 130 B.P., mostly from the past 2,000 years (Hart 2001). These charcoal layers show a former different forest composition. Some of the species most represented in the charcoal are no longer present although existing elsewhere, and others are rare. *G. dewevrei* now monodominant over much of the southern Ituri was not found before 500 years ago, but other species such as *C. alexandri* are still common. Hart concluded there had been significant species' replacement which could not be explained by directional change in the regional climate, rather it suggested numerous small fires burning forest which was structurally similar to the present forest. This may have resulted from increasing occupation of the forest as well as climatic fluctuation.

At the Cape periodic grass burning has been a contentious issue since concerns about its effects were expressed in the seventeenth century. The first governor, Van Riebeeck, in December 1652 gave the local people some tobacco in exchange for extinguishing a grass fire they had started (Thom 1952–1958). Concerned by the damage caused by uncontrolled fires, the settlers having adopted the indigenous practice of annual burning, he issued laws against it in November 1658 and again in December 1661, appointing "veld watchers" to enforce them. The repetition of the laws would suggest that enforcement was not very effective and after a particularly destructive fire in February 1687 the then governor Simon van der Stel issued a law for which punishment for a first offence was a severe scourging, and for the second "the cord until death do follow"; re-enacted in 1740 and 1741. These laws were intended to protect wood supplies and property and were not for conservation. Contrary to South Africa, in America's North Carolina a law of 1731 stipulated an annual March burning of pastures.

Fire was traditionally used in grassland for hunting to drive game, to encircle it, and to provide a fresh flush to attract it. Even in the absence of big game it was and is used to hunt rats. Bushmen in eastern Namibia have been seen to set as many as eight fires at once. Honey hunters were an important accidental cause of fire in the Kenya forests, lighting fires in trees to smoke out bees. Some authors consider this burning to have usually been late burning, such as Swynnerton (1918) noted was used by the Zulus for hunting, and he observed it had a greater effect than early burning. Burchell (1822–1824) referred to its use to produce a fresh flush to attract game for hunting in 1822. An example from Zimbabwe is given by Broderick (1962, quoted in West 1971), who recorded that a chief used to send out word in August and September to his people near Bindura Hill, about 65 km north-east of

Harare, to burn the grass. This would be done for miles around in such a manner as to leave the hill untouched, game taking refuge in the unburnt area surrounding it where on a given date the chief then organized a hunt. The Ndebele chiefs of Matabeleland apparently had special areas where only they could hunt by burning. Hunting fires were usually late dry season and thus hot fires. Also recorded in Zimbabwe was the practice of burning all unburned areas throughout the country prior to the rains in the belief that it would ensure a good season. West (1971) describes several areas in Zimbabwe where it had been tribal custom to burn the sward to improve grazing. In Tanzania's Lake Rukwa area Lea and Webb (1939) reported it was customary for a particular date for burning to be set by the local chief, although this practice may have been instituted by the German occupation. However many fires were started much earlier by Wanyika hunters to provide fresh flushes to attract game, such sporadic fires being an almost daily occurrence from the beginning of August.

Jeffreys (1945) records that in West Africa some people had set times for burning. One tribe timed it when a certain insect came out of the ground, presumably referring to winged termites emerging before rains; with another it was when the trees *uko*, *amba*, *mbun*, and *ifirdin* flowered. In Cameroun some chiefs produced laws on burning, punishing those who contravened them.

Most traditional burning took place at the end of the dry season when it is most effective for depressing woody vegetation and encouraging grass, but observations of Baker in Uganda and Cameron in Tanzania suggest early burning. In central and western Africa, where the higher rainfall produces grassland 3 m tall, hemming in the people on all sides for 6 months of the year, burning is practised as early as possible.

In Uganda, Masefield (1948) noted that "in the old days" papyrus swamps were sometimes fired to obtain ash for soap-making, extract salt, or to promote an even growth of young stems for making rope, thatching, etc., but the fires were now almost always accidental.

The Gbaya of west CAR name certain months of their traditional year according to burning. The first month at the beginning of the dry season is translated as "the fire crackling in the grass", the time when children begin to burn the grass bordering the village. This is followed by "smoke rising everywhere" when the grass is burnt for hunting; and then "the fire has devoured wide spaces" when almost all the savannah is burnt. This is followed by "the grass is completely finished" (Roulon-Doko 1996).

The earliest written record comes from Hanno who sailed down the west coast in the sixth century B.C. and noted fire inland. Two thousand years after Hanno, Bartolomeu Dias rounding the Cape about 1488 named Cape St. Francis *Ponta des Queimadas* on account of the bush fires inland.[2] Persistent and frequent burning probably started with the introduction of the safety match about 1856, although the use of a fire-making tool, consisting of twirling a hardwood stick on a piece of softwood, was widespread before this and burning as a regular practice seems to have been extant in Africa since at least historical times.

6.13 West Africa

6.13.1 Hanno's Account

There have been several interpretations of Hanno's account (see for example Oikonomides and Miller 1995) but it does seem that he witnessed grass burning at several points along the western coast. Burton (1863) interpreted the account as extending to Cameroun and this has been adopted by some present-day writers, but Müller's (1855) interpretation seems more likely, that the month-long voyage extended as far as Sierra Leone only.

Passing what all scholars agree was the River Senegal, "full of crocodiles and hippopotamuses", after 12 days' sailing he came to some high and wooded mountains of which the wood of the trees was fragrant and of various kinds. This was probably Cape Verde. Rounding these mountains, after another 2 days he arrived at an immense opening of the sea, probably the mouth of the River Gambia, on either side of which was low-lying land "from which we saw at night fire rising up everywhere at intervals, one time higher, one time lower". Five days later, on a forested island in a lake on an island (the Bijagos Islands?), he saw many fires at night but these could have been those of villagers as they heard drums beating, music, and much uproar, "We took off and sailed in haste and we coasted along a land burning full of fragrance [Portuguese Guinea], from which streams of fire poured down into the sea. The soil was so hot, that we could not walk on it". Sailing another 4 days "we saw the land by night full of flames, in the middle of this one flame towered above the others, which seemed to reach the stars. Where this flame was in daylight we could see a very high mountain called the Chariot of the Gods", which Müller identified as Mount Kakulima in Guinea, but Purchas (1625) considered was Sierra Leone the continual thunder and lightning at some times of the year presenting the spectacle which Hanno reported. Continuing for another 3 days Hanno bypassed some "streams of fire" and arrived at a bay with another island, where he encountered "gorillas".[3] This has been suggested to be Sherbro Island off the coast of Sierra Leone. He then returned. An alternative, promoted by Burton, is that he reached 3 days east of Mount Cameroun and the island would therefore be Bioko (Fernando Pô), a journey about a third longer. It is argued that Mount Kakulima is an extinct volcano, whereas Allen and Thomson (1848) were informed by a European resident of Cameroun of many years that the latter had seen flames near the summit of Mount Cameroun. They suggested this might be accounted for by the practice of the natives burning the grass in the dry season for the purpose of catching wild animals. But several natives declared that about 1838 "fire came out of the ground", thus suggesting the volcano was active, and now we know that it erupted as recently as 1922. However Burton noted also that on the mountain the best sites [for settlement] were occupied by clearings and plantations. These sites were probably subjected to slash and burn techniques. Rouch (1925) exploring the coast of Senegal in 1912 recorded,

> Every evening, in order to clear the ground, the natives set fire to the bush, and gave us the impressive spectacle of a conflagration of the mountain. Starting from the base of Mount Kakulima, the fire climbed the slopes and gave them a head of flames. One could say that

> streams of fire were ascending to their source. Then Mount Dixime was similarly set ablaze, and other summits yet further away. In the far distance one could see the flames twisting, hurling themselves to seize the least clump of trees, sometimes, great showers of sparks mounted in the sky, pushed by a sudden explosion, at other times the fire appeared to calm down, to go out, not finding fuel, but this appearance was only momentary, abruptly the whole body of the hillside was again in flames.

This account shows that we do not have to explain Hanno's fires in terms of volcanic eruptions.

Owen (1833) noted in 1753 that Fogo, one of the Cape Verde islands, burnt continually at the summit and was "very dreddfull in the night to saylors". In 1757 the fire was extinguished by an earthquake, the peak being wholly "carried away". Valdez (1861) refers to eruptions in 1680, 1785 (elsewhere he gives this as 1795), 1799, 1817, and 1857. Referring to the 1799 eruption it was reported that during the night the whole island appeared as if illuminated. So if Hanno did see a volcano it may have been nowhere near Cameroun.

6.13.2 Other Early West African Records

Leo Africanus wrote in 1526 that the country lying east of Bornu was much subject to burning and the people had great abundance of cattle (Brown 1896). In an early description of slash and burn De Bry described in 1600 how the people of Guinea burnt the woods, trees, roots, and shrubs, with all the rubbish, down to the ground, then scraped it into piles and left it for 8–10 days before planting (Purchas 1625). Fryer (1698) described the mountains in the south-west of the Cape Verde island of St. Tiago [St. Jago] in January 1673 as "very high and burnt". In November 1749 on the north bank of the Niger near Podor, Adanson (1759) set fire to the wood "in the manner practised by the negroes". He had to throw in fuel to get the fire going, spreading it "for several leagues through this vast desert.... Eight days afterwards I heard, that it was still burning, and had laid the country open for several leagues". He referred to it as "a desert country, that had never been cultivated, over-run with wood, as ancient as the country itself, and the thickness of which, independently of the wild beasts that lurk there, ought naturally to have filled me with horror".

Dobson (1780) referred to annual burning in Ghana to remove cover for enemies. Park (1799) provided an early description in Senegambia,

> Whenever the grass is sufficiently dry, the Negroes set it on fire; but in Ludamar [the southern region of Mali], and other Moorish countries, this practice is not allowed; for it is upon the withered stubble that the Moors feed their cattle, until the return of the rains. The burning of the grass in Manding exhibits a scene of terrific grandeur. In the middle of the night, I could see the plains and mountains as far as my eye could reach, variegated with lines of fire. . . In the day time, pillars of smoke were seen in every direction. . . This annual burning is soon followed by a fresh flush and sweet verdure, and the country is thereby rendered more healthful and pleasant.

At Loango in 1766 it was noted people burnt off the dry grass in the long dry season, everyone being informed beforehand of the day burning would start so that they could protect their huts (Proyart 1776). Robertson (1819) describing Mayumba, inland of Loango, noted the grass of the extensive plains was commonly burnt each autumn to destroy reptiles and other vermin, its only usage being for thatch. The observation was repeated by Pechuël-Loesche (1907) in Loango where burning took place in December 1875. He noted the fires never penetrated thickets, at most singeing the edges.

Rankin (1836) during a visit to Sierra Leone in 1834 recorded,

> A very limited portion of the Peninsula between Cape Sierra Leone and York is cleared. As we lay at sea, districts of forest on fire, wrapping the land in a mantle of smoke during the day, and glowing in streams of flame by night, denoted that cultivation was contemplated on many a wild spot. This method of preparing ground for husbandry is useful; not merely on account of the rapidity of the process... but because the soil, either sandy, or sour with a damp covering of fallen and decayed herbage... is much improved by the fall of wood-ashes.

Later he wrote that the surface of wild bush was annually diminished by conflagration.

Barth (1856–1857) in October 1850 north of Lake Chad entered a "well-wooded district, where all the grass had recently been burned, or was still burning..... This burning of the grass seems to be a general practice all over Negroland". Later, south of Lake Chad in April 1852, he noted the bushes and trunks of trees had been burned "in order to render the soil more productive by means of the fertilizing power of the ashes". Du Chaillu (1861) noted in Gabon in the dry season people removed from their villages to the plantations, "they burn the dry brush, cut down trees, and clear the ground for agricultural purposes". Barret (1888) also described burning in Gabon, "It is this big pioneer that he sends before to probe the thick forest, which he does not care much to break in upon the darkness". Towards the end of the dry season the flames lit up the sky clearing the plantations. The bush was burnt during the dry season to cultivate manioc, the trunks shorn of leaves by the flames being cut down; "Sometimes fire devours it [the forest], the fire lit for his plantations by the native, or falling from the sky, uncovers wide spaces encumbered with burnt trunks. But the rains come and restore that which the fire has consumed; the seeds stored in the humus germinate anew under the ashes; the leaves revive on the blackened twigs; the ruin turns green, and soon the fecundity of nature has effaced all trace of an ephemeral destruction". Burton (1863) noted signs on Mount Cameroun at about 2,200 m "of a late firing". Later, camping in the Black Crater his servants brought fuel "from the lately charred trees". He noted that in the lower regions the 'smokes' or hazy season, lasted from early December to the end of January, the haze seeming to extend gradually up the mountain.

Johnston (1884) referred to the "smokes" of the Guinea Coast describing them as morning and evening mists characteristic of the rainy season but appears to be confusing the name with the dry season smoke haze. Clarke (1860) described the fogs or "smokes" setting in on the Ghana coast shortly after the end of the rains

towards the end of July, continuing until the middle of August. Monteiro (1875) described them thus in Angola[4],

> Shortly after the rains cease in May, the grass, having flowered and attained its full growth, rapidly dries up under the hot sun, and is then set on fire by the blacks, forming the wonderful "Queimadas", literally "burnings", of the Portuguese, and "smokes" of the English in the Bights. If only the leaves are sufficiently dry to catch fire, the stems are left green, with a black ring at every joint or base of the leaf....
> .. the flames.. rapidly destroying the enormous extent of the dense, nearly impenetrable mass of vegetation covering the surface of the country, leaving it perfectly bare with the exception of a few charred root stumps of grasses, and a few stunted, scorched shrubs and trees. . .
> No trees or shrubs are consumed by the burning of the grasses, everything of a larger growth being too green to take fire; a whitening or drying of the leaves is generally the only effect even where the light annual creepers growing on them have been consumed. Forest or jungle in Angola, unlike other countries, never burns.....

Danckelman (1884) described the effects of fire on climate at some length. From 150 to above 200 m the horizon was an almost continuous veil of vapour and smoke,

> This veil is due to the smoke of these vast savannah fires which appear every year during the dry season in the whole of tropical Africa. They produce such quantities of smoke that one has difficulty in forming an idea of it, compared with which all the smoke of our steam machines, fires and peat bogs, etc., appears insignificant.
> In lower Congo, these fires begin with a weak intensity immediately after the rainy season, in May, and last until November. They reach their maximum in September and at the beginning of October. . .
> In 1883 the first smokes appeared at Vivi the 9 May, and the 10th one could see indistinct cumulus [clouds] which characterize the dry season..
> The savannah fires constitute a particular characteristic of tropical Africa. The reports of the last travellers who have visited these countries, Cameron, Buchner ["Hardly has the first half of May begun with a prodigiously swift return to the dry season with its sharp East wind, when the patters of little fires soon begin here and there. The first big fires appear in July and August" (1883)], Pogge, Wissmann, often make mention and speak of their influence on the appearance of the vegetation and the country. . . This phenomenon is as frequent in west Africa as it is in the east of this continent and in the wide regions of the Soudan.
> I saw myself in June 1883, on the plateau of Huila, Mossamedes province, at the 16th degree of latitude S, wide fires, devastating the grass which had reached 20–25 cm in height. These fires are produced equally much more in the south, in the Ovambo [according to Büttner (1883) the vegetation in south-west Africa was already very sparse due to repeated fires which often stretched for acres] and the Herero.
> From the agreed evaluations of various travellers, seven-tenths of the soil surface in lower Congo are thus destroyed by fire.
> M. Buchner has written to me that, in his opinion, at least 50% of the soil of the African countries he has crossed are burnt each year; around Malange, where the population is not as dense as in the country of Lunda, this proportion rises up to 80%.
> From the reports of Pogge and of Wissmann, we know that central Africa, to the east of the Kasai or of Lulua, is equally covered with wide savannahs, and one would not have to tax exaggeration in admitting that at least one-fifth of the African territory comprising that between the equator and the Tropic of Capricorn is burnt during the period from May to October.
> After repeated tests, I have found that grasses of 2–4 m height, covering a surface of one square metre, if one weighs them towards the end of the dry season, weigh an average of 0.8 kg. Thus would burn about 560,000 kg or 560 tonnes of straw per km^2 around Vivi. But as in many countries in Africa the grasses do not reach as great a height as in the Congo, one could reduce the weight per m^2 to 0.4 kg. Admitting the destruction of a fifth of the country

by fires, one obtains a figure of 80,000 kg/km^2 of grass burnt, or 609 million tonnes for all that part of the continent between the equator and the Tropic,[5] of which the area is about 7,612,000 km^2.

If one reduces the proportion of the surface burnt by one-sixth, because of forests, swamps, lakes and rivers, etc., one would still have a loss of 507 million tonnes of straw, without taking into account dead trees and the large stretches of thickets, which also sometimes become prey to the flames. By comparison, we recall that the amount of coal used annually in the whole world is around 300 million tonnes according to Neumann-Spallart.[6] The masses of smoke produced by this quantity of grass still more or less damp, without doubt play a role of some importance in the cloudiness of the dry season in Africa. Do we not verify this influence in Europe, where the fires of the peat bogs of north-west Germany are however without importance compared to those of which we speak? .....

We cannot however admit to the theory that the burning of the tall grass could be the immediate cause of rainfalls. . . If this theory was exact, one would see sudden downpours of large drops and not this humid fog, the form under which rain is actually presented and almost exclusively, in all these regions, during the dry season. This rain, or this damp fog, which falls gently and in small drops, almost exclusively during the night or the early morning, has the greatest resemblance to the kind of rain or fog well known from the west coast of middle America, called "Garrua", and which is not evidently produced by fires, considering there is nothing to burn in these regions.

On the other hand, it could, as the theory holds of Coulier, Mascart and Aitken on the influence of dust in the air in the formation of clouds and fog, that this immense quantity of smoke particles produced by the fires exerts an influence on the cloudiness, not only by the large quantity of smoke itself, but by the influence of these particles on the water vapour and its condensation in little liquid globules.

The smoke is sometimes so thick at Vivi, even when the fire is not in the neighbourhood of the station, that it is impossible to see the heights to the south-west.., the air impregnated with the smell of burning a veritable rain of cinders and debris of burnt grass falls.

Above these fires form great grey-white cumulus clouds in balls, to which the atmosphere full of smoke takes blurred outlines; these clouds could become the seat of electrical manifestations, as the German expedition to Loango has stated.

I saw myself the 30 October 1882, at sunset, some glimmers and some clearings in a cushion of cumulus which had taken birth and was constantly held above a violent savannah fire to the east of the station.

These clouds are maintained in the higher beds of the atmosphere as long as the water vapour produced by the fire feeds them. They dissolve when the fire is extinct, or lose their cumulus form and cover the sky with a uniform grey veil. The grey day sky covers of the dry season could well be due to this cause. .....

These fires could be considered as a hygienic measure applied on a grand scale. They relieve the natural habitat of an enormous quantity of substances which decompose during the wet season and they only injure to cure the nests of birds or insects. The snakes, small rodents, etc., generally have time to hide themselves in holes during the rapid passage of the scourge.

In 1884 Johnston described burning in Angola. Writing of "the constant presence" of euphorbias in native towns and the presence of large trees and luxuriant vegetation around villages, he wondered if the reason was that all the uninhabited country was periodically set on fire by the native, and only in those places where the bush fires could not reach did rich vegetation and forest trees exist; as had been observed by Stanley and Schweinfurth. Approaching Stanley Pool in DR Congo he referred to a gnarled and stunted tree which was spread in a sparse manner on the hillsides,

This difference in richness of vegetation that exists between hills and valleys in this part of Africa is not due so much to the relative abundance of moisture as to the

prevailing grass fires in the dry season. These sweep over the hills at times, destroying all the finer trees, so that only these stunted shrubs and the rank grass spring up from their roots anew and flourish for a season. Therefore it is that around the villages whose plantations are protected from the ravages of the flames... rich forest invariably exists, and their presence may be infallibly detected in this country by the groups of fine trees and patches of purple forest growing isolated on the many hill-tops. Again, in all shut-in valleys and river-courses, where the fires are choked, there vegetation of the most wonderful character riots....

Not far from Boma at the end of April he referred to "the great grass fires" which covered the distant hills with flame, and writing generally of the forest,

> The reason this forest belt does not extend more fully over Africa is that, where there is a continuous dry season of 4, 5, or 6 months, there is time for the long grass to become thoroughly tindered by the sun, and the natives can then more easily set going the great bush-fires... which clear the ground for their plantations, and at the same time sweep the forest from the hills.

Büsse (1908) believed that southern Togo was formerly covered with rain forest removed by the agency of man and fire. Early legislation against burning enacted by the Germans led to a rebellion as it affected traditional hunting.

6.14 East Africa

In Ethiopia Bruce recorded in 1769 that sometimes the wheat straw in Taranta was burnt after harvest, and in Tigré they did this to try to control rats and mice. Referring to a journey in February 1770 along the side of a hill through thick wood and high grass he observed the sides of a valley had been shaded by high trees, "but in burning the grass the trees were consumed likewise; and the shoots from the roots were some of them above eight feet high since the tree had thus suffered that same year". But the causes of burning are obscured by the continual wars which were waged, thus he later records near lake Dembea that being in an enemy's country the king "began to proceed in his usual manner, by giving orders to lay waste the whole adjacent territory with fire and sword. The whole line of March, 2 day's journey in breadth from the lake, was set on fire..". In March 1771 in Atbara he reported,

> The mountains at a distance towards the banks of the Tacazzé, all Debra Haria, and the mountains towards Kuara, were in a violent bright flame of fire.
> The Arabs feed all their flocks upon the branches of trees; no beast in this country eats grass. When therefore the water is dried up, and they can no longer stay, they set fire to the woods, and to the dry grass below it. The flame runs under the trees, scorches the leaves and new wood, without consuming the body of the tree. After the tropical rains begin, the vegetation immediately returns... All sorts of verdure being now in the greatest luxuriancy, the Arabs revisit their former stations. The conflagration is performed at two seasons; the first, by the Shangalla and hunters on the southern parts of this woody country, begins in the month of October, on the return of the sun... the latter, which happens in March, and lasts

> all April, besides providing future sustenance for their stocks, is likewise intended to prevent, at least to diminish, the ravages of the [tabanid] fly.....
> The extensive, and very thick forest, which had reached without interruption all the way from Tcherkin, ended here at Imgellalib.... The forest, however, though thick, afforded no sort of shade; the hunters, for the sake of their sport, and the Arabs, for destroying the flies, having set fire to all the dry grass and shrubs, which, passing with great rapidity, in the direction of the wood from east to west, though it had not time to destroy the trees, did yet wither, and occasion every leaf that was upon them to fall, unless in those spaces where villages had been, and where water was (Bruce 1790).

In Kordofan in the 1830s Pallme (1844) recorded that as soon as the harvest was gathered and the stubble dry, the latter was burnt causing thousands of locusts to fly up out of the grass.

Burton on the way to Harar recorded a fire in December 1855 which swept down a hill on the Marar plains in Ethiopia, according to his companions threatening the whole plain although it does not appear to have burnt into it. He attributed the bush fires to accidents, "These accidents are common: a huntsman burns a tree for honey, or cooks his food in the dry grass, the wind rises and the flames spread far and wide. On this occasion.. the hills. . . smoaked for 2 days" (Burton 1856).

Lejean (1862) described burning on the Atbara plains in 1860, "each evening the fires lit up the immense cover of tall yellow grass". The herdsmen burnt the *ghech* a little like the same reasons for which the Breton peasants denshered their fields, the ash was a strong manure intended to fertilize the soil and prepare it for the rainy season, "which would cover it with a green mantle, hope for the starving beasts".

Baker (1866) described hunting elephants in 1863 by Baggara Arabs in Latuka country, east of Juba in the extreme south of Sudan, using ring-firing. In the long grass the fire raged to heights of 6–9 m and buffaloes and antelopes were also killed, such a destructive method making antelopes so scarce that in a days' journey a dozen head were seldom seen in the open savannah.

Describing the country of the south-western Sudan Schweinfurth (1873) in November 1869 observed that because of the repeated burning of the savannah almost all of the vegetation was blighted and impoverished,

> in particular the higher districts presented an appearance of wretched desolation.....
> Incalculable in its effect upon the vegetation of Central Africa must be the influence of the annual steppe-burning, which is favoured by the dryness of the seasons. The ordinary soil becomes replaced by charcoal and ashes, which the rain, when it returns, as well as the wind, sweeps right away into the valleys.

The distinction was very marked between the savannah vegetation,

> and vegetation as it displays itself by the banks of rivers, where the abundant grass resists the progress of the fire..... But even more than the impregnation of the soil with alkalies, does the violence of the flames act upon the configuration of plants in general. Trees with immense stems, taking fire at the parts where they are lifeless through age, will die entirely; and, where the grass is exceptionally heavy, the fresh after-growth will perish at the roots, or in other places will be either crippled or stunted. Hence arises the want of those richly-foliaged and erect-stemmed specimens which are the pride of our own forests; hence the scarcity of trees, which are either old or well-developed; and hence, too, the abnormal irregularity of form which is witnessed at the base of so many a stem and the projection of so many a shoot.

Emin encountered burning in southern Sudan's Lado province near the river Yalo in 1881 in country which had been cleared for cultivation, "A broad grassy steppe stretched far away when we had left the corn-fields of Rumbek; it was bare of wood, but for some distance abounded in fine butter-trees (Bassias), which had been spared.... The country hereabout, with its solitary trees and scattered pile-dwellings, has a very different aspect from the countries of the south" (Schweinfurth et al. 1888). Casati (1891) writing of the same region noted it was a general custom in the Sudan to burn dried grass in order to clear the ground and manure it as a preparatory step to sowing. Bòttego (1895) found on 10th January 1893 the high ground over the Uelmal valley, a tributary of the Dorya in Somalia, was covered with fire, observing the inhabitants burnt the grass because it revived sooner. Along the Baro or Sobat river in January 1900 Austin (1902) commented the natives had recently burnt the rank growth of grass.

Vidal-Hall (1952) considered fire seemed to be causing a continuous retreat of the forest margin, the closed forest in Equatoria and Bahr el Ghazal provinces retreating due to frequent fires and that more open savannah had increased. The Baggara Arabs in the Sudan moved southwards with their herds in December–January setting up camps along the Bahr el Arab, the use of this area during the early part of the dry season resulting in the loss by fire of much grazing. Harrison wrote in 1955,

> Fires are started by various causes. Some sweep across from *qoz* areas to the north, where fires do not matter and there are vast uninhabited areas that cannot be controlled. Some come back from swamp country and areas of sour perennials in the south, which are deliberately burnt for their regrowth. Some are started by honey gatherers and hunters, and by travellers generally, who wish to clear the country. Yet the vast majority are started by the carelessness of the animal owners themselves. The herdsmen who are moving elsewhere do not bother about fires started behind them. . .
>
> . . . every year over 80% of the potential grazing is lost by fire.

In DR Congo near the Bomakandi River at Kubbi bush fires were mentioned by Junker in 1882 (Junker 1890–1892). Exploring up the valley of the Kwango in 1892 Grenfell reported the vegetation "evidently suffered severely from each successive annual bush fire" and they were "impoverishing vast areas" ruining the country. Johnston added, "These fires, together with the wasteful native system of destroying the virgin forest for manioc plantations were gradually turning the country into a semi-desert, for the soil without the constant supply of leaf manure (from the trees) was poor and sandy, and fit for little but the cultivation of maize. Moreover, the game, at one time abundant in this region, was driven far away by the ravages of the bush fires" (Johnston 1908). Of Uganda Johnston (1902) had written,

> These Nile countries are further ravaged annually during the protracted dry season by bush fires.... by far the most normal cause is the hand of man. . . As soon as the grass is withered by the commencement of the drought, it is set fire to, and these grass fires, sweeping over the wide plains, burn up all the vegetation they encounter. They thus make it impossible for large trees to subsist in unsheltered places. Scrubby trachylobiums, bauhinias, proteas, and such-like gnarled and twisted trees can apparently stand an annual singeing without dying; but any tree of handsome appearance must of course be killed the first year and burnt the second. . ..

Oral tradition concerning the Kiziba and Rwanda drought sometime between 1741 and 1768 relates, "During those years the country was very hot. Fire started in Kyamutwara and burnt it all and crossed into Kiziba. It burnt forests and grass for almost 2 months and even reached Buganda...." (Webster 1979).

Phillips (1930) noted in east African grasslands the proportion of direct sunlight was much decreased during the months of May to October as the skies are "for appreciable periods overcast by dun palls of smoke arising from the great fires that sweep the country from end to end", a feature of burning to which attention was drawn by Spinage (1969) in western Uganda where the Western Rift acts as a trap for the smoke pall so that insolation can be completely blocked out and visibility reduced to as little as half a kilometre. That this is of long standing is borne out by Stanley (1890) who, visiting the area in June 1889 noted, ".. obtaining a view beyond the headland of Kaiyura [Mweya Peninsula] into the chaotic and formless void. The haze was as thick as a fog, and nothing could be distinguished further than 3 miles". With a visibility of almost 5 km the annual burning was probably just beginning. It was reported from the Serengeti in January 1968 that an unusual westerly wind brought smoke and smog from Uganda and DR Congo for days on end.

Brenner in 1866 made a brief reference to a grass fire in November inland of the coast in present-day southern Kenya near Jombo Hill, north-east of Lunglunga (Kersten 1871).

The Teleki expedition encountered a fire in Kenya in February 1888 in the Loroghi hills,

> .. we came to traces of the destructive hand of man, a fire, lit by some of the Wandorobbo who frequent the Loroghi chain for hunting expeditions, having evidently raged for weeks, for whole tracts were burnt or burning, trunks and branches were scattered on every side, and the ground was covered with a layer of ashes from which smoke and steam were rising in clouds" (von Höhnel 1894).

Wimbush (1929) wrote that just as there was formerly a far greater area of forest on the southern slopes of Mount Kenya, so to a less extent had there been destruction in the past to the cedar forests of the western and northern slopes caused by fire as opposed to shifting cultivation in the south. Up to comparatively recent times the Maasai inhabited the plains to the west and north of Mount Kenya and periodically fired the grass in the dry weather to encourage fresh growth. The appearance of the north and west forests of the mountain showed clearly the results of fires of the past century, "The lower edge of the forest is a series of tongues running out from the main forest, each tongue following a river valley, while on the tops of the intervening ridges, once dense forest, open grass glades penetrate far up the mountain side, often reaching the lower fringe of the bamboos. The head of each glade is crowned with a fringe of the white skeletons of cedar trees into which fire has penetrated, not often enough to transform the forest into an open glade, but frequently enough to leave the dead trees standing". In the ascent of Mount Kenya in August 1899 Mackinder's party set fire to the moorland grassland (Barbour 1991). The description of the burning of the forest and the large trees which were destroyed, as well as the manner in which the giant groundsels *Senecio*

battiscombei R. E. & Th. Fries and *S. keniodendron* R. E. & Th. Fries, burnt, suggests fires were not frequent at that altitude.

A great forest fire was reported in oral tradition from northern Tanzania occurring sometime between about 1587 and 1589 (Webster 1978). In June 1858 in the Malagarasi River valley of western Tanzania, Burton observed that land on the higher levels was already drying up, and a sheet of flame, beginning with the size of a spark, overspread the hill-side (Burton 1860). Becker (1887) travelling to Tabora in 1878, at the end of July reported people cleaned their fields by firing the straw and weeds which otherwise would form dense tangles. Blown by the wind in a few hours the flames denuded immense areas of ground and the soil, already so fertile, was further improved by the ashes covering the burnt plain. According to local tradition the north-east portion of the Magamba camphor forest of the West Usambaras was destroyed by fire about 1880, which would coincide with the drought period. Böhm (1888) encountered a fire west of the Uluguru Mountains about July 1880, "Now all the grass was withered and yellow, or the fire had left nothing but a coal-black surface, with here and there fallen trees in the middle of piles of snow-white wood ashes glowing and smoking, while in the evening the sky was red with forest fires, and one saw flickering lines of flame through the backwoods on the mountain tops". Later at Gonda between Lake Tanganyika and Tabora on 11th June 1882 he recorded, "We should note how the water vapour issuing from the black smoke produced by the savannah fires condenses into veritable clouds, which cover the sky, after some days, with a uniform veil". In July 1882 he wrote, "As soon as the dry condition of the grass allows, we estimate in all the favourable places the vegetation will be fired, the burning down of the old has the effect of new young grass immediately sprouting up, which otherwise is for a long time only weak, its nutrition exerts a big magnet on the game". Reichard (1892), who had accompanied Böhm, gave a generalized account of fire in Tanzania, noting that by mid-June the grass had dried out completely and the fires, which had already begun, were much greater "..a blessing for travellers, the natives and the wild animals". But the fires were not like the depictions of American prairie fires as there were never large continuous areas of grass except in the river valleys, and the stems reached only to one's middle, rarely chest-high. Game animals quietly moved from one position to another to avoid the fires. In West Africa it was different, because the grass was continuous and both taller and denser, and antelopes were frequently burnt. Despite the dryness and heat the grass sprouted again immediately, and in 5–6 days there was already a green sward.

Coulbois (1901) who lived mostly at Lake Tanganyika between 1883 and 1900, recorded the local people fired the dry grass in July to remove the tall grass which obstructed them and provided a refuge for carnivores and bandits.

Stuhlmann (1894) encountered a fire west of Mpwapwa in Tanzania in 1890, everywhere was already dry and the natives had begun to clear the grass for cultivation. Volkens (1897) stated he had seen the savannah burning in all possible places for months at a time, especially in August and September, and again in January and February, but it was wrong to think that all of the savannah was burnt each year. Büsse (n.d.) encountered burning in miombo inland of Dar es Salaam in

1900, the fire apparently started by honey hunters. After the valley had been burnt out the fire ascended the hills either side continuing down the other sides. Between Msanga and Isala he marched through countless charred stumps beyond which were wide stretches of mostly burnt grassland. He concluded the wooded savannah of Ugogo was not a natural plant formation but a consequence of recurring fire leaving only certain fire resistant trees which had escaped destruction, either as individuals or as compact clumps. The destruction was a consequence of the method of indigenous cultivation and not of colonization, the area he presumed being formerly covered with thick masses of trees, some at least being Burseraceae, and more open miombo such as he encountered on a plateau near Ilindi.

Büsse (1908) noted that in Tanzania a law against burning in Meru enacted in 1903 was ignored and there were insufficient officials to enforce it. Sjöstedt (1910) described the plains between Mounts Kilimanjaro and Meru in 1905, already at the end of August the grass which had been burnt on the routes of the Maasai was beginning to sprout again. In the first week of September extensive burning by the Maasai was still continuing, the fires spreading a red appearance over the plains and over the "huge mass of Meru mountain". At night the fires were always becoming bigger, colouring the sky red, and in the daytime, "The fires of the steppe have always become bigger..". From 1908 to 1910 particularly destructive fires raged through the forests of Mount Meru started by honey-hunters as well as Boer settlers who used fires to flush out rhinoceros when hunting them (Schabel 1990).

Siebenlist (1914) considered fire the most frequent injury threatening wooded areas in Tanzania, mainly in densely populated regions, often completely destroying the forest and replacing it with small shrubs, thin dry forest, or sterile savannah grasslands. Most fires were due to negligence and lack of understanding caused by abandoned camp fires, cigar ends, etc., but some were set deliberately for hunting both by Africans and Europeans. Table 6.1 shows the number and area of fires recorded between 1909 and 1913.

Bent (1936), travelling between Kasunga and Sumbawanga west of Lake Rukwa in south-east Tanzania in 1934, noted that burning of the grasslands took place every year in August to improve visibility for hunting and to concentrate game on the following fresh flush. Further north at Isangwa he found the country partly burnt over also.

Above 4,300 m on Mount Kilimanjaro, and in the Afroalpine belt on Mount Meru, tussock grassland is the most extensive vegetation type, on both mountains being very open and widespread. Burning, encouraging the spread of grassland at the expense of such fire-sensitive communities as *Alchemilla* scrub and Ericaceous thicket, is probably the cause of the extensive presence of this tussock grassland at high altitudes on the Aberdares and Mount Kenya also (Plate 6.4).

Table 6.1 Fires recorded in Tanzania for the year April 1st–March 31st from 1909 to 1913

Year	1909–1910	1910–1911	1911–1912	1912–1913
Number	19	35	21	19
Area burnt (ha)	2,084	6,200	5,405	11,620

Source: From Siebenlist (1914)

Plate 6.4 Aberdare moorland, Kenya, showing fire maintained tussock grass and ericaceous thicket patches 1975 (C. A. Spinage)

6.15 Central and South Africa

Lacerda encountered grass fires in northern Zambia on 4th and 20th September 1798. The first occasion was west of the Muchinga Mountains near 32°E 12°S. On the second occasion, near Luwingu north of Lake Bangweulu, he camped to take astronomical observations noting the bush burnings which began at from nine to ten in the morning left the air clear at night. He recorded, "This [morning] chill is followed by an intense heat, the effect of the sun and grass-smoke, and at 11 A.M. it is at its height. To-day we suffered from the smoke which was all round us, and, fortunately for us, the dried herbage was not very high" (Burton 1873). On 29th June1860 in southern Zambia Livingstone noted near the confluence of the Chongwe river with the Kafue that grass burning had begun, ".. and is producing the blue hazy atmosphere of the American Indian summer, which in Western Africa is called the "smokes". Miles of fire burn the mountain-sides in the evenings, but go out during the night. . ." (Livingstone and Livingstone 1865).

A number of early writers on the Cape referred to burning following van Riebeeck's encountering the practice in 1652. Kolben (1731) in 1727 stated that when the natives found the grass was too old and rank, they burnt it on the ground and departed, returning by the time it grew up again, which was very soon,

> .. the ashes of the grass exceedingly enriching the soil, which rarely wants refreshments of rain. The grass grows very thick and high; and by this practice of burning it the country is sometimes seen in a blaze for several miles about. In this the Hottentots are imitated by the Europeans at the Cape, with this difference only, that the Europeans make ditches round the grass they would burn, to stop the course of the fire, whereas the Hottentots give themselves no such trouble.

Sparrman in 1775 referring to locusts wrote, ".. perhaps, the use of these creatures is the same as with that of fire, which latter is applied by the colonists

and Hottentots to the purpose of clearing their fields from weeds. The ground is, indeed, by this means, in both cases, stripped quite bare; but merely in order that it may shortly afterwards appear in a much more beautiful dress..” (Sparrman 1785). Thunberg (1793–1795) describing a journey into Kaffraria in October 1772, noted that in many places the land had been set on fire for the purpose of clearing it,

> though in a very different manner from what is done in the north [i.e. in Europe]. Divers plains here, produce a very high sort of grass, which being of too coarse a nature, and unfit food for cattle, is not consumed, and thus prevents fresh verdure from shooting up. . . Such a piece of land as this, therefore, is set on fire, to the end that new grass may spring up from the roots. Now if any of these places were overgrown with bushes, these latter were burned quite black. . .

Barrow (1801–1804) encountered a fire near the mouth of the Great Fish River in September 1797, “On approaching the sea-coast we observed a long train of fires. . . supposing them to have been made by a party of Kaffirs stationed there..... The flames ran in all directions among the long dry grass and healthy plants with incredible celerity. The face of the country for several miles was a sheet of fire, and the air was obscured with a cloud of smoke. . .”.

Between the Camtoos River and Algoa Bay the country was “Like a gentleman’s park, or pleasure-grounds, in England, the surface is diversified with thickets and knots of stately trees.. The knolls are covered with thick grass, which, for want of cattle to eat it off, is suffered to rot upon the ground, or is partially burnt off towards the end of summer to make room for the young blades to shoot up with the earliest rains of winter”.

Lichtenstein (1812–1815) noted in 1803 that it was common to burn the lands each year but care had to be taken that it did not ignite the bush and spread to the forests. Burchell (1822–1824) visiting Genadendal in 1811, recorded that firewood was very scarce in the vicinity of Hottentot settlements, “and, in all the grazing parts of he colony, it is rendered much more so by the wasteful and destructive practice of annually setting fire to the old withered grass, as the means of clearing the pastures. The flames, spreading rapidly, scorch and destroy every shrub and plant in their way, and pervade the whole farm, unless stopped by a river, or a beaten road. In ascending the Dunkerhoek (Dark Corner) mountains. . . the devastation occasioned by this custom was very striking, in the fatal havoc it had lately made amongst the finest plants of proteas, heaths, and the richest variety of shrubs we had passed in our ride. That delicate and beautiful heath, *Erica vestita*. . . discoverable by one large plant which had escaped the conflagration. *Antholyza lucidor*, and *Aulex umbellata*, were recognised, although quite scorched up. Every thing was nearly consumed or destroyed. . .”.

In November at the banks of the Ky-gariep in some parts of the plain the Bushmen had burnt away the old grass for the purpose of attracting the game, “In places which had not in this manner been cleared by burning, the green blades were concealed by the old withered grass; a circumstance which ever gives to the plains of Africa a more pale and arid appearance than they would present if the wild animals were able to graze off the yearly crop as closely as the cattle do in the pastures of Europe”.

Prior, sailing off the south-east coast in September 1811 saw a large fire to the southward of Cape Delgado, "These are frequent on the whole of the eastern coast, and seem intended either to frighten wild beasts, or to open the country by destroying the woods (Prior 1819). Godlonton (1835) wrote of Natal in 1832, "The growth of the grass is so rapid that what was burned in September and October is now eight feet high". Holden (1850) quoted an observer in Natal who stated that nearly the whole surface of the country was burnt over once or twice a year,

> . . . not all at once, but in sections, so that at all seasons the flocks and herds may have abundance of fresh grass.... long lines of fire sweeping over the plains, descending into some deep valley. . . or gathering round some lofty hill, whose precipitous sides they climb, dance a moment or two on its summit, and then expire. In 2 or 3 days after. . . countless numbers of a little leafless flower (one of the *amaryllaceæ*) shoot up. . . In 2 weeks the under-grass puts forth its leaves, and the earth is spread with a flowery carpet of richest green.

Brooks (1876) noted in Natal ".. the old colonists secure a constant source of tender young grass by continually burning the grass in large patches as soon as it gets dry and unduly coarse. This leads to the 'grass fires' which are regular and frequent accompaniments of the 'dry season' throughout the colony, and which occasionally, under bad management or accidentally adverse conditions, become dangerous and destructive conflagrations".

In the Orange Free State, Zeyher and Burke (1845) referred to burning by local people in 1836,

> In every direction rose clouds of smoke caused by the custom which the natives have of firing the dry grass. This they do partly to encourage a new growth in the following summer, but principally because they thus ensure an easy course over the plains. . . the practice of burning the dried vegetation, which is adopted by all the sub-tribes of the Betchuana nation so far as we have been amongst them to the remote distance near the tropics of Capricorn, may also have a beneficial effect on the health of the people living in those parts, where the putrid matter of a rich vegetation during the hot and moist season would undoubtedly generate miasma destructive to man as is the case along the east coast about Delagoa Bay (Hall 1934).

Moffat (1842) writing of the Bechuanas noted they had the yearly custom of burning the dry grass, "which on some occasions destroys shrubs and trees even to the very summit of the mountains". Andersson (1861) in eastern Namibia in April 1857 noted it was customary with the tribes of South Africa to fire the grass when it had arrived at a certain state of maturity and dryness, fires being set apparently by those accompanying him. But here they seemed to do considerable damage for near Okwa he saw groves of "huge giraffe thorns – all in a blaze.."; and once a "huge trunk, in flames from top to bottom, fell athwart our path..".

Oates (1881) writing of the area near Pretoria in June 1873 noted, ".. this part of Africa is no timber country. On the high veldt there is nothing but parched grass, in many places burnt for a whole day's trek, as fires are of everyday occurrence". In September, travelling north through Botswana he encountered a bush fire near Shoshani, ".. a dusky haze hung over the horizon. As the flames devoured the yellow grass, they left a blackened track behind. The trees, however, seem to

escape; some in blossom, some in autumnal tints, but the greater portion leafless". Near Tati in July 1874 he encountered another fire, "one tree in particular, showing all its twigs red-hot or in flame..".

By this time burning was customary among the colonists and writing of the Transvaal in 1877 Jeppe noted,

> In the Southern districts, and along the highveldt, the habit exists of burning off the grass during the dry winter season, in order to improve the pasturage. Whether this object is attained or not, is still an open question, but so much is certain, that the habit is most injurious to the growth of trees and shrubs. This may be one of the reasons that these are very scarce in the Southern parts of the country, and that nothing but small patches of bush, consisting of the different acacia species... are met with travelling through these parts (Jeppe 1976).

Kerr (1886) in Zimbabwe in June 1884 encountered "an immense prairie fire. Far away, stretching for many miles, nothing could be seen but a vast chain of lurid fire..". North of the Zambesi near Tete in September he passed a "sun-parched forest in which large sycamore trees were scattered, and where prairie fires had swept away "with an irresistible strength the thick undergrowth of rank grass". Not long afterwards he encountered another "immense" grass fire.

Around the Amatola forests in 1884 extensive grass fires occurred during the winter but fire did not enter the forest. On the tops of the mountains where the forest was more scattered the danger was greater. The whole of the upper portion of the Perie range, including the Evelyn valley to the west of Mount Kemp, was burnt as it had been each year for many years past. Beginning at the end of July it lasted for 2 weeks, originating on the north and west of the range from Africans burning grass for their cattle. But on the Hogsback and the upper Amatolas generally the grass fires were yearly becoming less fierce as the grass was more grazed by stock. In the large blocks of dense evergreen forest numerous fires were lit during the winter, mostly by African hunters, but in no instance did these spread, not more than the single tree lighted being destroyed, "In Stockenstrom, where the forests are in an over-worked, open, and dangerous condition... rain fell just in time to prevent another of those terrible fires which have wrought such ruin in the Katberg forests.." (Hutchins 1883 in Brown 1887).

Brown (1887) dealt at some length with the destructive effects of fire. In the Colony of the Cape of Good Hope, as in many other places, it was customary to destroy old, withered dry vegetation by fire, a practice he believed was detrimental as well as conducive to the prosperity of the Colony, the latter more so, but it was necessary to counteract the evil. One of the evil effects was the desiccation of soil and climate which might be partly counteracted by planting extensive forests.

Selous (1893) observed in the Transvaal, Bechuanaland, and Matabele country (western Zimbabwe), the long grass was burnt off about June or July, the ground remaining black until the next rains. But in the moist valleys of the Mashona uplands in central Zimbabwe, after being burnt off a fresh flush of sweet grass appeared at once.

The law against burning first enacted at the Cape in 1658, by 1741 impossible to enforce due to the scattered population, by 1806 had apparently died out

(West 1965), replaced by the *Forest and Herbage Preservation Act* in 1859. Although "stringent" the latter was reported in 1865 to be a dead letter "from the absence of any wish to bring offenders against it to justice". In 1870 a revised law was passed which essentially gave anyone the right to burn on his own land provided that any damage to others was compensated for. Legislation controlling burning was enacted in Namibia by a German concession company in 1888 followed by a general law in 1894 making burning a criminal offence. In 1923 the South African Drought Investigation Commission pointed out that although it was a criminal offence to set fire to the veld (tree steppe or grassland) of which one was not the owner (in South Africa), prosecutions were very few compared with the large amount of arson taking place, but more stringent legislation would be unlikely to be of advantage being impossible to enforce, accused persons alleging "spontaneous combustion"; while making an owner legally responsible for all fires on one's property would be contrary to principles of equity and justice. What could be done would be to prohibit grazing in mountain catchment areas which were particularly valuable for irrigation below, for where the right to graze is removed the desire to burn automatically ceased.

6.16 Notes

1. Fitzgerald (1898) describes "they" as slaves of the Watiku who mostly originated from the Wa-Teita but had no recollection of when.
2. No firsthand account of Dias's voyage survives and the reference to fires is usually wrongly attributed to Vasco da Gama rounding the Cape in 1497 allegedly naming the bay *Terra de Fume,* but there is no such reference in the anonymous account of da Gama's voyage, no account by da Gama himself surviving. The country inland of Cape St. Lucia, Zululand, was denoted on a map as *Terra dos Fumos* which Ravenstein (1898) stated meant "land of petty chiefs", more correctly *Mfumos*, explicitly stating it had nothing to do with smoke. The reference in the account of the voyage simply states "There are many chiefs". Prior (1819) repeats the error the land was called *Fumas* "from the quantity of smoke first observed on its shores".
3. This has exercised men's imaginations ever since. The gorilla *Gorilla gorilla gorilla* (Savage and Wyman) was not described until 1847, and it was then so named using Hanno's name, although Battell provided the first account, published by Purchas in 1613 (Ravenstein 1900), in which he called it Pongo, a corruption of its native name *Mpungu*, which probably related to Mpongwe where it occurred. Hanno described what he found as "wild savages", which his interpreters, probably from the region of Morocco, called "gorillas". "The biggest number of them were females, with hairy bodies... Chasing them we could not catch any of the males, because all of them escaped by being able to climb steep cliffs and defending themselves with whatever was available, but we caught three females...". The latter they had to kill to subdue

them, and they then skinned them returning with the skins. Although many argue for these having been gorillas, gorillas do not climb steep cliffs and defend themselves with objects, and even female gorillas are most unlikely to have been caught by men on foot. The same would apply to chimpanzees. Although the baboon is a possible candidate, baboons must surely have been known to the Carthaginians. The social structure, most being females, accords with primate social organization, but the mostly likely interpretation is that this was a native population clothed in animal skins. Du Chaillu (1861) concluded Hanno could not have met gorillas as the male advances to confront the danger and would not run away leaving the females behind.

4. Sanford and Isichei (1986) refer to the "smokes" as being caused by the dust of the harmattan wind, but although this obstructs insolation also there is no doubt the "smokes" are caused by burning, occurring as they do in much of Africa where there is no harmattan.
5. Barbosa et al. (1999) estimated the average burned biomass for Africa during 1985–1991 as 704–2168 million tonnes, varying according to the amount of area burnt each year.
6. Neumann-Spallart, F. X. von. 1884. Uebersichten der Weltwirtschaft. Stuttgart, Julius Maier.