FIRE EFFECTS AND MANAGEMENT IN AFRICAN GRASSLANDS AND SAVANNAS

Winston S.W. Trollope and **Lynne A. Trollope**
Working On Fire International Nelspruit, South Africa

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Summary

Africa is referred to as the “Fire Continent” and biomass burning is recognized as a widespread and integral part of the functioning of African grasslands and savannas. Climatic factors are the driving force of fire ecology and Africa has the requisite climate comprising distinct wet and dry periods, lightning as a natural ignition source, and savanna vegetation that is flammable during the dry winter period thus prone to fire during the dormant season of the year. Humans have evolved in a fire environment in Africa hence anthropogenic fires have become more important ignition sources than lightning. With increasing human populations worldwide modern fire regimes that are not affected by anthropogenic fires are extremely rare.

Fire ecology refers to the response of the biotic and abiotic components of the ecosystem to the fire regime i.e. type and intensity of fire and the season and frequency of burning. Based on research on the effects of fire on the vegetation in the grasslands and savanna, manipulation of the fire regime can be used to develop management plans for the use of fire in both domestic and wildlife systems.

1. Introduction

Africa is referred to as the *Fire Continent* due to the widespread occurrence of biomass burning, particularly in the grassland and savanna biomes and it is recognized as a natural and important ecological factor of the environment in these vegetation types. This description is equally applicable to southern Africa where grasslands and savannas are major plant communities in the sub-continent. The early Portuguese explorers, who rounded the Cape of Good Hope in the fifteenth century, referred to the interior of South Africa in their ships logs as "*Terra dos fumos"* - the land of smoke and fire. This capacity of Africa to support fire stems from the fact that climatic factors are the driving force of fire ecology and the main requirement for fire to occur anywhere on earth is to have lightning as the primary ignition source and climatic conditions that will permit the burning of vegetation and the spread of fires caused by lightning strikes. Africa is a continent that is highly prone to lightning storms and has a fire climate comprising distinct dry and wet seasonal periods, during which times the fires burn the plant fuels in the dry flammable period that were produced and accumulated during the wet rainy period.[4]

Research has been conducted since the early period of the twentieth century on the effects of the fire regime on the biotic and abiotic components of grassland and savanna ecosystems. This has led to a greater understanding of the effects of type and intensity of fire and season and frequency of burning on the grass and tree components of the vegetation and has clarified the use of fire as a range management practice in Africa. Viable burning programs have been developed for livestock production, game farming and nature conservation in African grasslands and savannas and its use is best summed up by Phillips who described it as "a bad master but a good servant". The objective of this literature review is to describe and investigate the effect of fires in savannas and grasslands and consider how this information can be used for management purposes.[5] [7]

2. Ignition Sources of Fires in Africa

Africa is where fire and humanity first interacted and the factor that makes fire on this continent distinctive from other regions is the antiquity of anthropogenic fire. If one accepts that *Homo sapiens* originated through evolution in Africa then humans have evolved in a fire environment in Africa and have had to become fire ecologists. The earliest evidence of the use of fire by humans is 1.5 million years B.P. and since then natural fire regimes have been successively altered by humans in response to increases in the human population. For example the majority of the tropical savannas of the world have been shaped and maintained by anthropogenic fires and in most regions of the world humans have become more important than lightning as sources of ignition and modern fire regimes that are not affected by anthropogenic fires are extremely rare.

The dominant role of anthropogenic fires versus lightning ignitions in contemporary Africa is illustrated by the area of savanna that was burnt by different ignition sources in the Kruger National Park in South Africa during the period 1985 to 1992 (see Figure 1) and is generally representative of the ignition sources of fires in African grasslands and savannas. [1] [4].

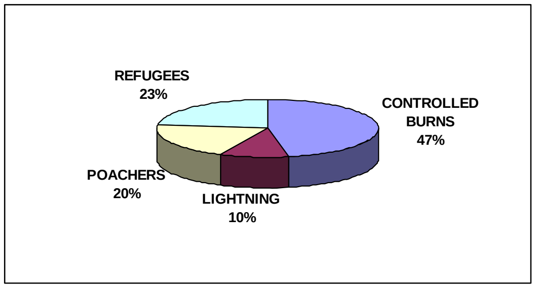

Figure 1. The percentage area burnt in the Kruger National Park in South Africa by fires ignited as controlled burns and by refugees, poachers and lightning during the period 1985 to 1992.

3. Fire Ecology of African Grasslands and Savannas

Fire ecology refers to the response of the biotic and abiotic components of the ecosystem to the fire regime i.e. type and intensity of fire and the season and frequency of burning. West reviewed the topic and found that the first burning plots were established at Groenkloof, Pretoria in South Africa in 1916, at Olokomeji in Nigeria in West Africa in 1929, at Ngong near Nairobi in Kenya in East Africa in 1931, at Ndola in Zambia in Central Africa in 1933 and at the Matopos in Zimbabwe in Southern Africa in 1947. An interesting feature about these early investigations and subsequent research up until 1971 was that it focused on addressing the two key questions of what are the effects of season and frequency of burning on the forage production potential of the grass sward and the ratio of bush to grass in savanna areas. This was undoubtedly in response to requests from mainly agricultural scientists and livestock farmers involved with range management who wanted to know "when is the correct time to burn rangeland and how often should the rangeland be burnt in order to maintain its production potential and to control bush encroachment?"

Until recently fire research in Africa and in particular southern Africa, was conducted with an agricultural objective in mind rather than with the ecological objective of determining the effect of fire on all the biotic and abiotic components of the ecosystem, whereas research in other fire prone habitats like the United States and Australia was focused on controlling wild fires and the emphasis was on studying and quantifying fire behavior. In 1971 a conference was convened in the United States of America by the Tall Timbers Research Station at Tallahassee in Florida on the theme of "Fire in Africa". This congress was attended by fire ecologists from throughout Africa. The major benefit that accrued from this conference was the realization that in Africa the study of fire behavior and its effects on the ecosystem, as described by type and intensity of fire, had been largely ignored in all the fire research that had been conducted up until that time. In contrast detailed knowledge on and models for predicting fire behavior had been developed by the United States Forest Service as a means for controlling wildfires in the extensive forested areas of the country. A similar situation existed in Australia where McArthur, a forest fire researcher in New South Wales, had developed procedures based on fire behavior for decreasing the fire hazard in highly flammable Eucalyptus forests by reducing fuel loads through controlled burning. The outcome of this congress proved to be a turning point in fire research in the savanna and grassland areas in southern Africa and a research program was initiated to determine the effect of all the components of the fire regime on the vegetation. A similar research program was not initiated elsewhere in Africa as far as is known, but the effects of the entire fire regime on the vegetation in the grassland and savanna areas is applicable throughout similar areas of the continent. To follow will be an overview of the known effects of the fire regime on grass and tree and shrub vegetation in African grasslands and savannas based on research results.[2] [12]

3.1. Type of Fire

The most common types of fire in grassland and savanna areas are surface fires burning either as head or back fires. Crown fires do occur in savanna but only under extreme fire conditions. Generally under these conditions they occur as passive crown fires characterized by the "torching" of individual trees rather than as active crown fires that are sustained by more abundant and continuous aerial fuels. The significance of the effect of type of fire on plants is that it determines the vertical level at which heat energy is released in relation to the location of bud tissues from which meristematic sites the plants recover after burning.

Trollope investigated the effects of surface fires, occurring as either head or back fires, on the grass sward in the arid savannas of the Eastern Cape of South Africa. The results showed that back fires significantly ($P \leq 0.01$) depressed the regrowth of grass in comparison to head fires because a critical threshold temperature of approximately 95^{o} C was maintained for 20 seconds longer during back fires than during head fires. It was also found that more heat was released at ground level during the back fires compared to the head fires, therefore the shoot apices of the grass plants were more adversely affected during the back fires than during the head fires.

Bush is very sensitive to various types of fires because of differences in the vertical distribution of the release of heat energy. Field observations in the Kruger National Park and in the Eastern Cape indicate that crown and surface head fires cause the highest topkill of stems and branches as compared with back fires. Unfortunately there are only limited quantitative data to support these observations. Research results were obtained from a burning trial at the University of Fort Hare in the False Thornveld of the Eastern Cape (arid savanna) in South Africa, where a field scale burn was applied to an area of 62 hectares to control bush encroachment. The effect of surface head and back fires on the topkill of stems and branches of bush is presented in Table 1. The data were collected in two meter wide belt transects laid out in the areas burnt as head and back fires.

The majority of the trial area was burnt as a head fire and the results in Table 1 indicate that the phytomass of bush was reduced by 75 per cent in the area burnt as a head fire in comparison to 42 per cent in the area burnt as a back fire. The explanation for this is that the flame height of head fires can be up to three times greater than for back fires resulting in higher temperatures being generated above ground level. Therefore the above ground growing points of these plants, which are located in the canopies of the trees and shrubs, are subjected to greater heat loads and resultant damage during head fires than during back fires. This clearly illustrates the effects different types of fire have on tree and shrub vegetation.

Type of Fire	**Transect**	**Bush Phytomass TE/ha**	**Bush Phytomass TE/ha**		**Reductio n**
	Length (m)	Width (m)	Before	After	**%**
Head Fire	940	2	3525	888	75
Back Fire	560	2	3407	1991	42

Table 1. The effect of surface head and back fires on the topkill of bush in the False Thornveld of the Eastern Cape in South Africa expressed as the reduction in the number of tree equivalents - TE (TE = tree or shrub one and a half meters high).

Similar results were obtained in the Scattered Tree Grassland: *Acacia-Themeda* range type in Kenya by Trollope and Trollope on the effects of head and back fires on the topkill of bush (see Figure 2).

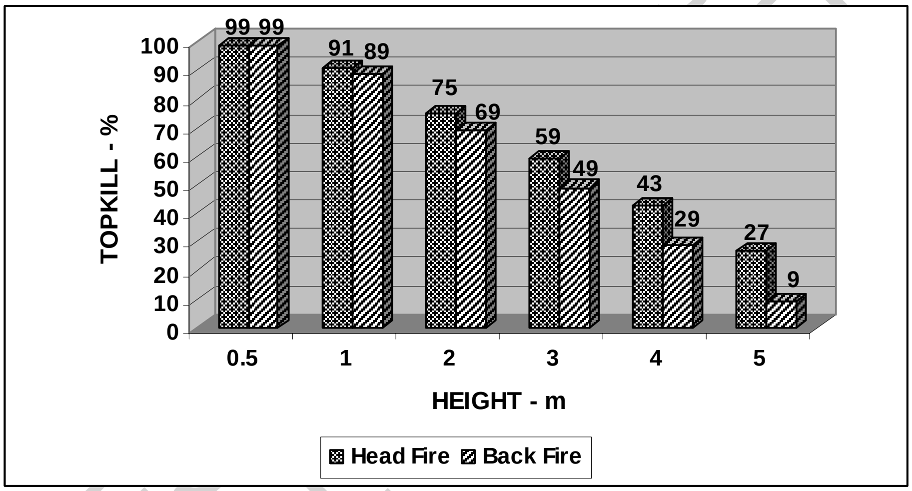

Figure 2. Effect of head and back fires on the topkill of trees and shrubs of all species on the Lewa Wildlife Conservancy and Hopcraft Ranch in the central highlands of Kenya.

Initially both types of fires caused a high topkill of stems and branches in cases where the bush was short but where the trees and shrubs were greater in height the back fires caused a lower topkill compared to head fires. This trend becomes more pronounced with trees greater than two metres in height. The reason for this is that head fires generate greater flame heights than back fires thus resulting in the fire susceptible growing points of taller trees and shrubs being above the flaming zone of combustion during back fires as compared to head fires.

3.2. Fire Intensity

Fire intensity refers to the release of heat energy per unit time per unit length of fire front (kJ s^{-1} m^{-1}). There have been very limited attempts in African grasslands and savannas at quantitatively measuring the intensity of fires and relating fire intensity to the response of herbaceous and woody plants in terms of mortality and changes in physical structure. To date such research appears to be limited to studies conducted in the savanna areas of South Africa. [2]

The effect of fire intensity on the recovery of the grass sward after burning was investigated in the arid savannas of the Eastern Cape Province of South Africa. After a series of fires ranging in intensity from 925 to 3 326 kJ s^{-1} m^{-1} (cool to extremely intense) there were no significant differences in the recovery of the grass sward at the end of the first or second growing seasons after the burns leading to the conclusion that fire intensity has no significant effect on the recovery of the grass sward after a burn. This is a logical result as otherwise intense fires would not favor the development and maintenance of grassland. [10]

The effect of fire intensity on bush has been studied in the arid savannas of the Eastern Cape Province and the Kruger National Park in South Africa. This comprised determining the mortality of plants and secondly the total topkill of stems and branches of bush of different heights. The results indicated that bush is very resistant to fire alone and in the Eastern Cape the mortality of bush after a high intensity fire of 3 875 kJ s^{-1} m^{-1} was only 9.3 per cent. In the Kruger National Park the average mortality of 14 of the most common bush species subjected to 43 fires ranging in fire intensity from 110 to 6 704 kJ s^{-1} m^{-1} was only 1.3 per cent. In both areas the majority of the trees that suffered a topkill of stems and branches coppiced from the collar region of the stem. Therefore it can be concluded that, generally, the main effect of fire on bush in the savanna areas is to cause a topkill of stems and branches forcing the plants to coppice from the collar region of the stem. [10]

The detailed results of this study are illustrated in Figure 3.

The results in Figure 3 show that there was a significantly greater topkill of bush with increasing fire intensities. However, the research also showed that the bush became more resistant to fire as the height of the trees and shrubs increased and this is illustrated in Figure 4.

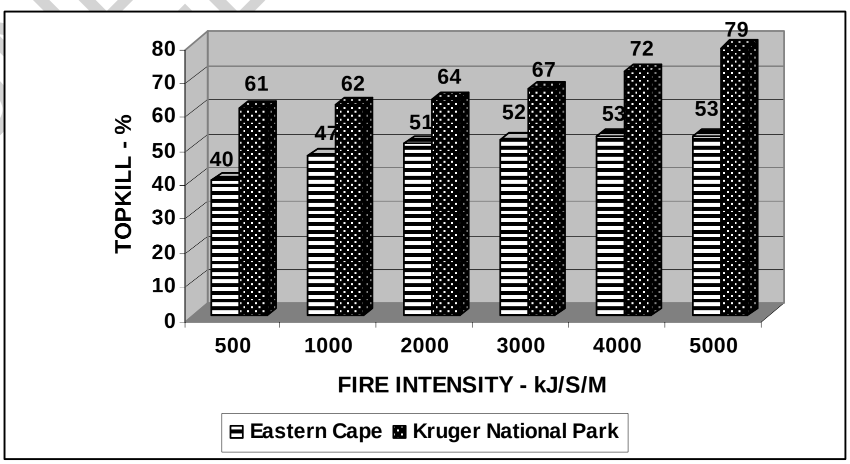

Figure 3. Effect of fire intensity on the topkill of bush two meters high in the Eastern Cape Province and Kruger National Park in South Africa.

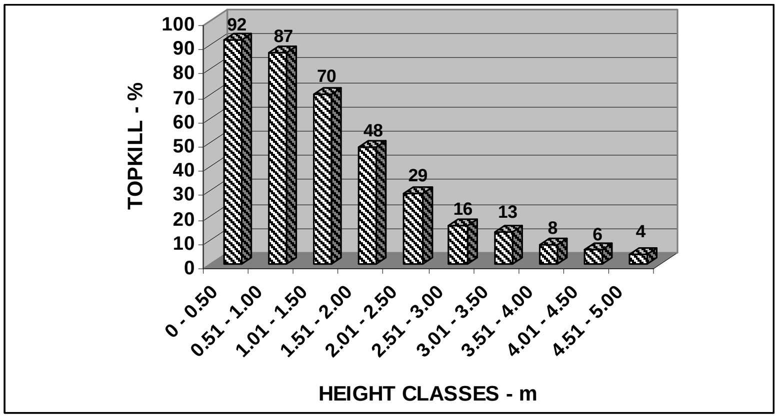

Figure 4. Effect of height on the topkill of bush subjected to a fire intensity of 3 000 kJ s^{-1} m^{-1} in the Kruger National Park in South Africa.

Similar responses in topkill of bush to increasing fire intensities were obtained in the Scattered Tree Grassland: *Acacia-Themeda* savanna in the central highlands of Kenya.

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Biographical Sketches

Professor Winston Trollope was born in 1940 and grew up on a farm in the Komga district in the Eastern Cape Province of South Africa. He obtained a BSc Agric. (1962), MSc Agric. (1971) and PhD (1984) majoring in Rangeland Science at the University of Natal in Pietermaritzburg, South Africa. His interest in fire ecology was kindled by Professor J.D. Scott at the University of Natal, who was one of the pioneers in fire research in South Africa. As Pasture Officer in the Ciskei region of South Africa, he identified the encroachment of undesirable plant species into natural rangeland as one of the main problems facing the livestock industry in this region. This focus formed part of his MSc project where he studied the encroachment and control of macchia vegetation in the mountainous areas of the Eastern Cape Province. He concluded that fire was the most effective, practical and economic method of controlling macchia vegetation and he was able to formulate burning programs that have been and are continuing to be successfully applied throughout the mountain ranges of this region And received international recognition for this work by being invited to deliver a paper at the Tall Timbers Fire Ecology Congress on "Fire in Africa" held in Tallahassee, Florida, in 1971. Attending this conference proved to be a turning point in both his research career and fire ecology in South Africa, as it became apparent to him that we in Africa had completely ignored the effects of type and intensity of fire on the vegetation, having focused only on the effects of season and frequency of burning. His PhD addressed the effects of type and intensity of fire on the grass and tree components of the vegetation in African savannas. This research has resulted in a greater understanding of the role of fire in savanna ecosystems and a significant improvement in the use of fire as a range management practice for both domestic livestock systems and wildlife management.

He is currently a Fire Ecology Consultant (2006 to date) –He has published 50 peer reviewed publications, 22 non-peer reviewed publications, 23 chapters in books, 26 scientific reports and 14 posters.