Forum Article

Personal Perspectives on Commercial versus Communal African Fire Paradigms when Using Fire to Manage Rangelands for Domestic Livestock and Wildlife in Southern and East African Ecosystems

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ABSTRACT

Africa is often referred to as the Fire Continent, and fire is recognised as a natural factor of the environment due to the prevalence of lightning storms and an ideal fire climate in the less arid regions with seasonal drought. On a global scale, the most extensive areas of tropical savanna, characterized by grassy under stories that become extremely flammable during the dry season, occur in Africa. The use of fire in Africa to manage vegetation for domestic livestock and indigenous wildlife is widely recognized by both commercial and communal land users. Research on the effects of fire has been conducted throughout the grassland and savanna areas since the early twentieth century, resulting in the development of effective and practical guidelines for prescribed burning for domestic livestock and wildlife management systems. Generally, the reasons for prescribed burning in Africa are similar for both commercial and communal land users, namely, to remove moribund and or unacceptable plant material and to control the encroachment of undesirable plants negatively affecting domestic livestock and wildlife. In addition, commercial operators use fire to manage wildlife conservation areas. Prescribed burning to control ticks is also widely used in communal communities but is generally not recognised in commercial livestock enterprises. However, research has shown that tick populations can be reduced using fire to alter the micro-habitat for these organisms. Until recently, commercial and communal land users held differing views on the appropriate season for prescribed burning, with the former igniting fires shortly after the first spring rains and the latter burning throughout the dry winter period. Subsequent research has shown that both seasons of burn have similar effects; the key requirement being that the grass sward is dormant at the time of burning to minimise the negative effects on the vegetation. A valuable tentative comparison has been made between fire management practices applied by commercial land users and communal land users, and provides an exciting opportunity for further and essential research to be conducted to gain greater insight into how communal African communities use fire. Based on extensive experience, my aim is to provide a personal perspective on the use of fire by commercial and communal land users for managing rangelands in southern and east African regions of the continent.

Keywords: east Africa, fire, fire paradigms, indigenous people, southern Africa

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INTRODUCTION

Africa is often referred to as the Fire Continent (Komarek 1965), and fire is recognised as a natural factor of the environment in the less arid regions with seasonal drought due to the prevalence of abundant ignition sources (lightning and human) (Goldammer and Crutzen 1993), together with an ideal fire climate with distinct wet and dry periods during which plant fuels can grow and accumulate and subsequently burn (West 1965, Komarek 1971). On a global scale, the most extensive areas of tropical savanna occur in Africa and are characterized by a grassy under story that becomes extremely flammable during the dry season. The use of fire in the management of vegetation for domestic livestock and indigenous large mammalian herbivores is widely recognized and deemed necessary by both commercial and communal land users. Research on the effects and use of fire has been conducted throughout the grassland and savanna areas in southern Africa since the early twentieth century, resulting in the development of effective and practical guidelines for prescribed burning for domestic livestock and wildlife management systems (Trollope 2007). However, these guidelines represent the commercial African fire paradigm in terms of burning practices emanating from intensive research programs. It is the objective of this paper to compare and contrast this commercial African paradigm practised by commercial operators with the communal African fire paradigm that has developed and been practiced by communal land users on the continent over the millennia. Although Australia has extensively addressed indigenous fire use in savannas, to date scant attention has been given to indigenous knowledge on the fire ecology of African grasslands and savannas practiced by communal African communities. In addressing and comparing these two paradigms, an attempt will be made to determine whether:

- these paradigms are moving farther apart.
- the commercial fire paradigm is incorporating communal knowledge into wildland fire management.

In attempting to meet these objectives, and in the absence of a formal structured investigation, I will draw on 44 years of personal experience in conducting fire research and formulating fire management plans for domestic livestock production and wildlife management in southern and east African grasslands and savannas (see Figure 1). Obviously, this will introduce an element of unintended bias into the interpretations and conclusions, for which I make no apologies.

Attitudes about Fire in Africa

In assessing the attitudes about fire in Africa by commercial and communal land users, respectively, it is necessary to introduce a his-

Figure 1. Discussing communal and commercial African fire paradigms in east Africa.

torical perspective to the assessment. The initial commercial attitude to fire in Africa can be represented by the views of the Dutch, who settled the Cape of Good Hope at the southern tip of Africa in 1652 (Hunt *et al.* 2005) (see Figure 2); the initial communal attitude to fire can be represented by the Khoikhoi, who, at that time as the Dutch settlement, were local herders of vast herds of cattle and sheep in the Cape. The Dutch administrators of the Cape had a very negative attitude to burning and passed a law in 1687 stating that the penalty for burning rangeland was a severe "scourging" for the first offence, and death by hanging for the second. This law was still in force when the British occupied the Cape in 1806, but they modified the sentences by imposing penalties of 100 pounds or six months in prison, or both, for burning natural vegetation (Bands 1977). This law was apparently enacted in response to the use of fire by the Khoikhoi to improve the grazing for their livestock. Therefore, initially, the commercial attitude to fire was highly negative in contrast to the positive attitude of indigenous peoples who led a communal lifestyle.

Additional evidence that indigenous peoples subscribed to extensive use of fire is provided by the Portuguese explorers who rounded the Cape of Good Hope in the fifteenth century. In their ships' logs, they referred to the interior of South Africa as "Terra dos fumos"—the land of smoke and fire (Scott 1971). This positive indigenous attitude to using fire has persisted to the present time and is well illustrated in Figure 3 by the high incidence of fire recorded by MODIS satellite during 2008 in the Sioma Ngwezi National Park and adjacent Masese Corridor in southwestern Zambia (Trollope *et al.* 2010). This region of Zambia is populated by isolated communities of communal indigenous rural dwellers.

Figure 2. Indigenous Khoikhoi pastoralists had positive views on the use of fire in managing vegetation for their livestock compared to the opposing western views held by the Dutch settlers who settled at the Cape of Good Hope at the southern tip of Africa in 1652 (Hunt *et al.* 2005).

The negative attitude to fire in the commercial African fire paradigm persisted until approximately the early period of the twentieth century, when it was eventually recognised through scientific research that fire is a natural factor of the environment and an important ecological factor in the grassland and savanna ecosystems of the continent. This led to research focusing on the effects of the fire regime on the biotic and abiotic components of grassland and savanna ecosystems (West 1965). In turn, this led to a general 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 (Trollope 2007). This information has clarified the use of fire as a range management practice in Africa and viable burning programs have been developed for commercial enterprises comprising livestock production, game farming, and nature conservation in African grasslands and savannas (Tainton 1999). The use of fire in terms of negative and positive effects is best summed up by Phillips (1965), who described it as, "a bad master but a good servant."

Reasons for Burning

The use of fire in the management of vegetation for domestic livestock and indigenous wildlife is widely recognized in both commercial and communal African fire paradigms.

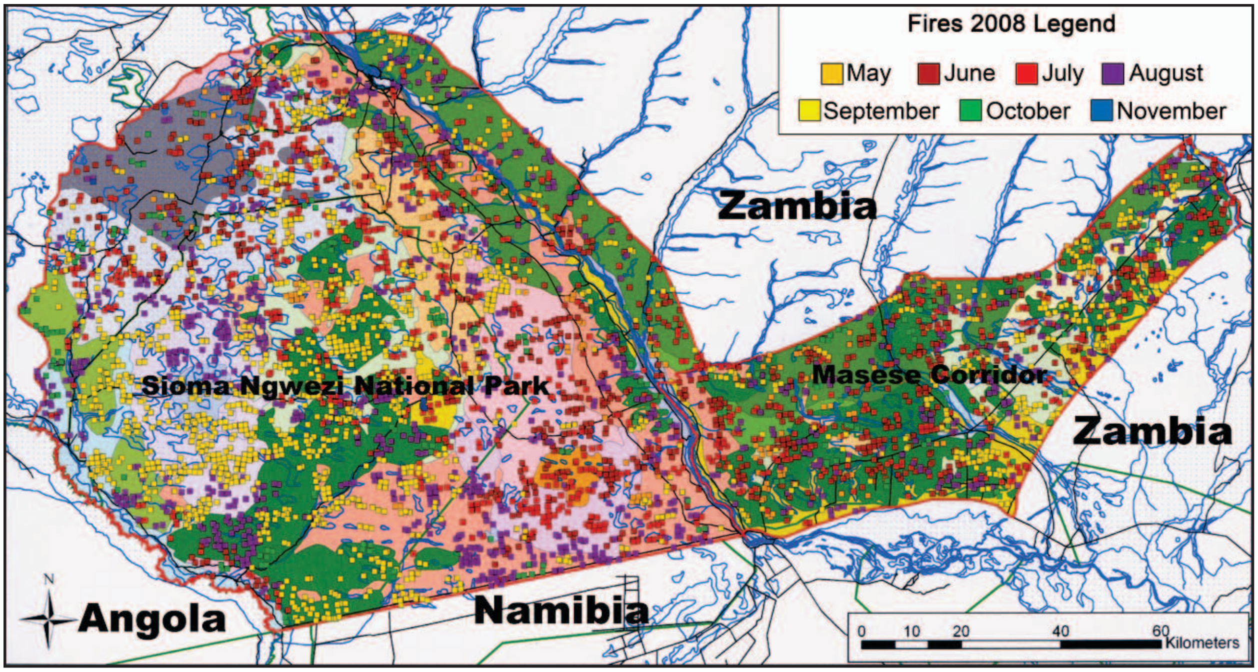

Figure 3. The high incidence of fire recorded by MODIS satellite during 2008 in the Sioma Ngwezi National Park and the adjacent Masese Corridor in southwestern Zambia (Trollope *et al.* 2010)

One of the most important reasons for burning grassland and savanna vegetation in Africa involves the removal of moribund and or unacceptable grass material to improve the quality of grazing for domestic livestock and wildlife. This is a widely recognized and accepted reason for prescribed burning in African grasslands and savannas (Tainton 1999), and applies to both commercial and communal fire paradigms. In the case of the commercial fire paradigm, another widely recognized reason for burning in African savannas is to control or prevent the encroachment of undesirable plants (Trollope *et al*. 1989), such as the encroachment of bush in savanna areas in Botswana (Field 1978). Besides burning to facilitate grazing livestock and wildlife, personal experience gained in the development of integrated fire management plans in the Okavango Delta Ramsar site in Botswana, and in the Kavango-Zambezi region in southwestern Zambia, rural African communities also use fire to:

- improve the quality of thatch grass and reeds used in rural dwellings by removing plant debris after harvesting;
- increase fish populations in swampy areas by stimulating new shoots palatable to fish;
- open up waterways to facilitate the placement of nets by fisherman;
- improve access for harvesting bulbs of water lilies in swamp areas;
- clear land in preparation for the establishment of crops;
- facilitate slash and burn agriculture, i.e., “Chitemene;”
- facilitate the harvesting of forest products like nuts from particular tree species, e.g., manketti tree (*Schinziophyton rautanenii* [Schinz] Radcl.-Sm);
- reduce the incidence of tsetse flies;
- reduce tick populations.

Another widely used reason for burning in the communal fire paradigm in east Africa is the control of ticks that cause tick-borne diseases like babesiois in livestock (Trollope *et al.* 2003). However, this reason is generally discounted in the commercial fire paradigm because it is argued that ticks persist in areas that are frequently burnt. However, Stampa (1959), in a study of the Karroo Paralysis tick in the Karroid Merxmuellera Mountain Veld in South Africa, showed that this parasite can be successfully controlled by altering the micro-climate at soil level and thereby creating an unfavourable habitat for this organism, resulting in its disappearance. Similar evidence has been obtained by Trollope *et al.* (2003) in the Ngorongoro Crater and Serengeti grasslands in Tanzania where controlled burning by nomadic and communal Masai pastoralists has resulted in a significantly lower incidence of ticks where this practice is applied. The incidence of ticks is high when the grass sward is in a moribund and unacceptable condition for grazing by livestock and the grass fuel load exceeds 4000 kg ha^{-1} (Figure 4). The relationship between the incidence of ticks and the grass fuel load in the Ngorongoro Crater in Tanzania is clearly illustrated in Figure 5.

Therefore, using fire to prevent the excessive accumulation of moribund grass material can minimize the incidence of ticks in areas

Figure 4. High incidence of ticks when the grass sward is in a moribund and unacceptable condition for grazing in the Ngorongoro Crater in Tanzania.

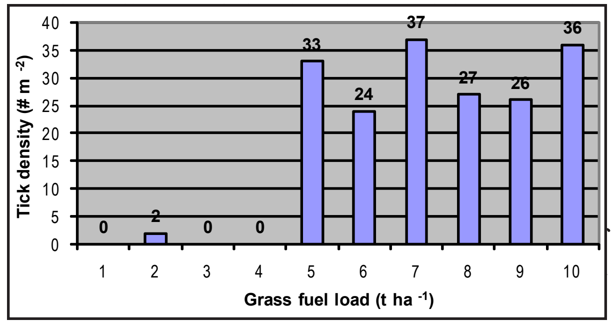

Figure 5. The relationship between the standing crop of grass and the density of ticks recorded in the Ngorongoro Crater and environs in Tanzania (Trollope *et al.* 2003).

using fire to control ticks. The aforementioned results would therefore suggest that it would be very beneficial for the commercial African fire paradigm to further investigate the use of fire to control ticks and to include this management practice in domestic livestock enterprises and wildlife management programs. Such investigations would be an example of how the communal fire paradigm could benefit the commercial fire paradigm.

Ecological Criteria for Burning

In the commercial fire paradigm, ecological criteria based on the condition of the grass sward have been developed in southern and east Africa by which to decide objectively whether rangeland should be considered for prescribed burning or not. These criteria are based on the general response of grassland and savanna vegetation to season and frequency of burning. The necessity for rangeland to be burnt or not depends upon its ecological status and physical condition. Generally, the condition of the grass sward determines whether rangeland should be considered for burning as this component of the vegetation reflects the ecological status of the ecosystem and the presence of, or its ability to produce, adequate grass fuel to carry and support a fire. Quantitative techniques have been developed to assess the condition of the grass sward in relation to prescribed burning. The first technique involves determining the condition of the grass sward in terms of its ecological status and basal cover, and involves classifying the different grass species into different ecological categories according to their reaction to a grazing gradient, i.e., from high to low grazing intensities (Table 1; Tainton 1999).

Table 1. Classification of the grass sward in terms of ecological categories according to a grazing gradient.

Decreaser species	Grass and herbaceous species that decrease when rangeland is under or over grazed
Increaser I species	Grass and herbaceous species that increase when rangeland is under or selectively grazed;
Increaser II species	Grass and herbaceous species that increase when rangeland is over grazed

The second technique involves estimating the grass fuel load using the Disc Pasture Meter developed by Bransby and Tainton (1977). This technique involves relating the settling height of an aluminum disc dropped onto the grass sward to the standing crop of grass holding it up, expressed in kilograms per hectare. This instrument has been successfully calibrated for the grasslands and savannas in southern and east Africa; the calibration developed in the Kruger National Park in South Africa by Trollope and Potgieter (1986) can be used as a general calibration for estimating grass fuel loads for management purposes in these regions of Africa.

One criterion that can be used to objectively decide whether rangeland grazed by domestic livestock or wild ungulates needs to be burnt or not is that prescribed burning should not be applied if the grass sward is in a pioneer condition dominated by increaser II grass species caused by overgrazing (Figure 6). Burning is generally not recommended when rangeland is in this condition in order to enable it to

Figure 6. Grass sward should not be considered for burning when it is in a pioneer condition (a) in contrast to well developed sub-climax and climax grass communities (b).

develop to a more productive and resilient stage dominated by decreaser grass species. Conversely, when the grass sward is either in an under- or selectively grazed condition dominated by increaser I species, it needs to be burnt to increase the better fire adapted and more productive decreaser grass species.

Finally, controlled burning is necessary when the grass sward has become overgrown and moribund as a result of excessive self-shading. These conditions develop when the standing crop of grass is generally >4000 kg ha^{-1}.

Evidence used for deciding whether to burn to control or prevent the encroachment of undesirable plants involves the same ecological criteria describing the condition of the grass sward. However, the grass fuel loads required for prescribed burning will vary depending on the encroaching plant species. This procedure has proved to be very successful in terms of quantitatively indicating whether burning is necessary and whether fire will have a desirable or deleterious effect on the grass sward's productivity and species diversity when utilized by domestic livestock and wildlife. Evidence for the efficacy of the these criteria for improving the condition of the grass sward are provided by results from the Phinda Game Reserve located in the Western Maputaland Clay Bushveld vegetation type (Mucina and Rutherford 2006) in Zululand, South Africa. The reserve has been using these criteria for managing a prescribed burning program since 1998. Range condition data are available on the percentage frequency of decreaser grass species and forage scores representing the forage production potential of the grass sward on a scale of 0 to 1000 for the period 2004 to 2010 (Figure 7; Simon Naylor, unpublished data, Phinda Game Reserve, Zululand, South Africa).

The results shown in Figure 7 clearly demonstrate the significant improvement in the condition of the rangeland following the implementation of an integrated fire management program using the aforementioned ecological criteria for controlling the prescribed burning program on Phinda Game Reserve. The overall improvement occurring in the condition of the rangelands on the reserve has also contributed significantly to the successful use of high intensity fires for controlling bush encroachment.

Regarding the use of ecological criteria in the communal fire paradigm, it is my personal experience and conclusion resulting from research and investigating the fire ecology of African grasslands and savannas throughout southern and east Africa that African communities in communal areas do not specifically consider the ecological status of the plant communities in the rangelands that they frequently burn, particularly in the more mesic regions of

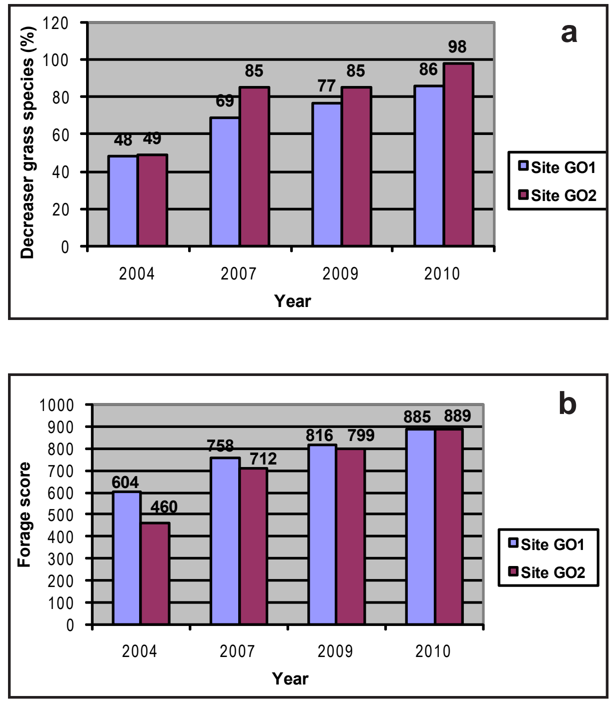

Figure 7. The relative frequency of palatable and productive decreaser grass species (a) and the forage scores reflecting the forage production potential (b) of the grass sward at two sample sites (GO1 and GO2) on the Phinda Game Reserve located in the Western Maputaland Clay Bushveld vegetation type (Mucina and Rutherford 2006) in Zululand, South Africa, for the period 2004 to 2010.

the continent. Based on the beneficial effects on range condition that have been achieved with using ecological criteria in integrated fire management in the commercial fire paradigm, it is clear that including the use of ecological criteria for prescribed burning in the communal fire paradigm would be highly beneficial.

Fire Regime

Fire ecology is concerned with the interactions of fire with the biotic and abiotic components of the ecosystem. In South Africa, the fire regime has been defined as the type and intensity of fire, and the season and frequency of burning (Trollope *et al.* 1990). As noted earlier, research on the effects of fire has been conducted throughout the grassland and savanna areas of Africa since the early period of the twentieth century. An interesting feature about these early investigations and subsequent research, up until 1971, was that they focused only on addressing the two key questions: 1) what are the effects of season and frequency of burning on the forage production potential of the grass sward; and 2) what is the ratio of bush to grass in savanna areas (West 1965, Rose-Innes 1971, Scott 1971, Gill 1981).

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 behaviour and its effects on the ecosystem, as described by type and intensity of fire, had been largely ignored in all of the fire research that had been conducted up until that time. After the conference, fire research in the savanna and grassland areas in South Africa was begun, and a research program was initiated to determine the effect of all the components of the fire regime on the vegetation, i.e., effects of type and intensity of fire and season and frequency of burn. Unfortunately, a similar research program was not initiated elsewhere in Africa as far as is known, but the South African research has contributed significantly to describing the effects of the entire fire regime on the vegetation in the grassland and savanna areas of the continent. These developments in the fire ecology of African grasslands and savannas have resulted in the commercial fire paradigm specifically focusing on the different components of the fire regime, and in using fire regimes effects in formulating fire management practices in grassland and savanna communities.

Types of fire. In the commercial fire paradigm, it is recommended that prescribed fires burning with the wind, either as surface head fires in grassland or a combination of surface head fires and crown fires in tree and shrub vegetation (savannas), be used because they burn quickly through the grass sward but can cause maximum damage to woody vegetation, if necessary (Figure 8; Trollope 1999). This is achieved by applying prescribed burns as pe-

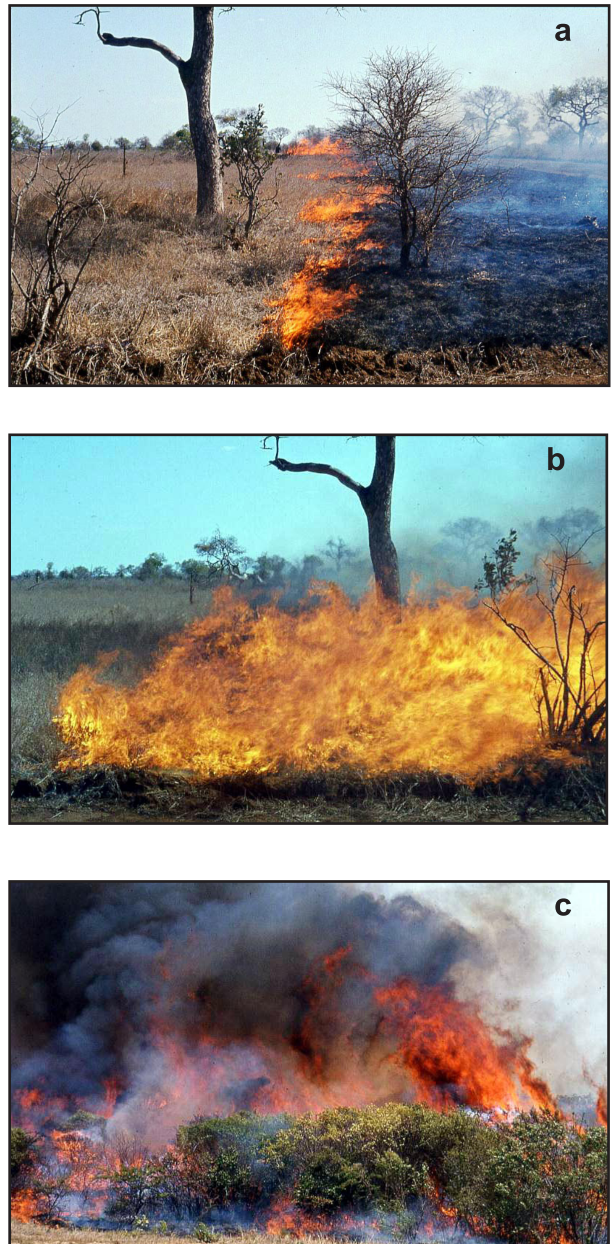

Figure 8. Examples of back (a), head (b), and crown (c) fires burning in African savannas —head and crown fires are recommended because they cause least damage to the grass sward but can cause maximum damage to woody vegetation, if necessary.

rimeter ignitions (block burns) where the majority of the area is burnt as a head fire burning with the wind.

In contrast, surface head and back fires and crown fires are used in the communal fire paradigm by lighting fires as point ignitions, but there is no clear reason why point ignitions are used to ignite the fires other than convenience. Currently, point ignitions are assumed to have a greater pyrodiversity than perimeter-ignited fires. Pyrodiversity refers to the degree of variation in fire effects in terrestrial ecosystems and is assumed to promote biodiversity (Parr and Andersen 2006) because it is hypothesized that point ignitions generate more variable fires in terms of type and intensity resulting in highly diverse fire patterns, i.e., greater pyrodiversity. The effects of point ignitions versus perimeter ignitions on pyrodiversity are currently being investigated in a research project in the Kruger National Park in South Africa, referred to as the Savanna Fire Ignition Research Experiment (SavFIRE). The current fire policy in the park, involving Patch Mosaic Burning, uses point and short line ignitions as a means of promoting and maintaining biodiversity that has replaced the previous block burning program that used perimeter ignitions. This change in the fire policy in the Kruger National Park was influenced by the development of the patch mosaic burning system in the Pilansberg National Park in South Africa, where point ignitions have been used for several decades (Brockett *et al.* 2001). The experiment in the Kruger National Park is still in progress, but preliminary results suggest that, contrary to expectations, the major factors affecting pyrodiversity are weather conditions rather than type of ignition and size of burn. These preliminary results indicate that when burning fully cured grass fuel, the goal of greater pyrodiversity is achieved if fires are ignited when the air temperature is <25 °C and the relative humidity >50 %.

It would therefore appear that the types of fires used and recommended in the commercial fire paradigm are becoming similar to those used in the communal fire paradigm, particularly in the management of wildlife areas like the Kruger and Pilansberg national parks in South Africa.

Fire intensity. In the commercial fire paradigm, there are clear guidelines available for using low and high intensity fires for different range management objectives. This is a direct result of the research stimulated by attending the 11th Annual Fire Ecology Conference on "Fire in Africa," organized by the Tall Timbers Research Station in Tallahassee, Florida, USA. Research on fire behaviour in the Eastern Cape Province and Kruger National Park in South Africa has shown that fire can be classified into the following categories according to fire intensity (Table 2; Trollope and Potgieter 1985, Trollope 2007).

Table 2. Fireline intensities and descriptions for sward burning in Kruger National Park, South Africa.

Fireline intensity (kJ s^{-1} m^{-1})	Description
<500	Very cool
501 to 1000	Cool
1001 to 2000	Moderately hot
2001 to 3000	Hot
>3000	Extremely hot

When burning to remove moribund and unacceptable grass material, a cool fire of <1000 kJ m^{-1} s^{-1} is recommended. This can be achieved by burning when the air temperature is <20 °C and the relative humidity >50 %. When burning to control undesirable plants like encroaching bush, a hot fire of >2000 kJ s^{-1} m^{-1} is necessary. This can be achieved when the grass fuel load is >4000 kg ha^{-1}, the air temperature >25 °C and the relative humidity <30 %. This will cause a significant top kill of stems and branches of bush species up to a height of 3 m. In all cases, the wind speed should not exceed 20 km h^{-1}, the grass sward should be dormant, and the grass fuel fully cured (Figure 9).

In the communal fire paradigm, it is again my personal experience in investigating the fire ecology of African grasslands and savannas in southern and east Africa that African communities in communal areas do not have clear guidelines related to fire intensities to use for achieving different management objectives.

Season of burn. Initially, in the commercial fire paradigm, it was recommended by Scott (1971) that, in the summer rainfall areas of South Africa, prescribed burning for removing moribund grass material and controlling bush encroachment should be conducted after the first spring rains. Research by Trollope (1987) showed that the physiological condition of the grass sward at the time of the burn, rather than the moisture content of the soil, was the important criterion governing the correct season of burn. Research elsewhere in southern Africa also clearly indicated that the least damage is caused to the grass sward if prescribed burning is applied when the grass is dormant (Figure 10; West 1965).

Therefore, it is recommended that, when burning to remove moribund and or unacceptable grass material, burning should preferably

Figure 9. Grass sward is not sensitive to fire intensity and high intensity fires are necessary for controlling bush encroachment in African savannas.

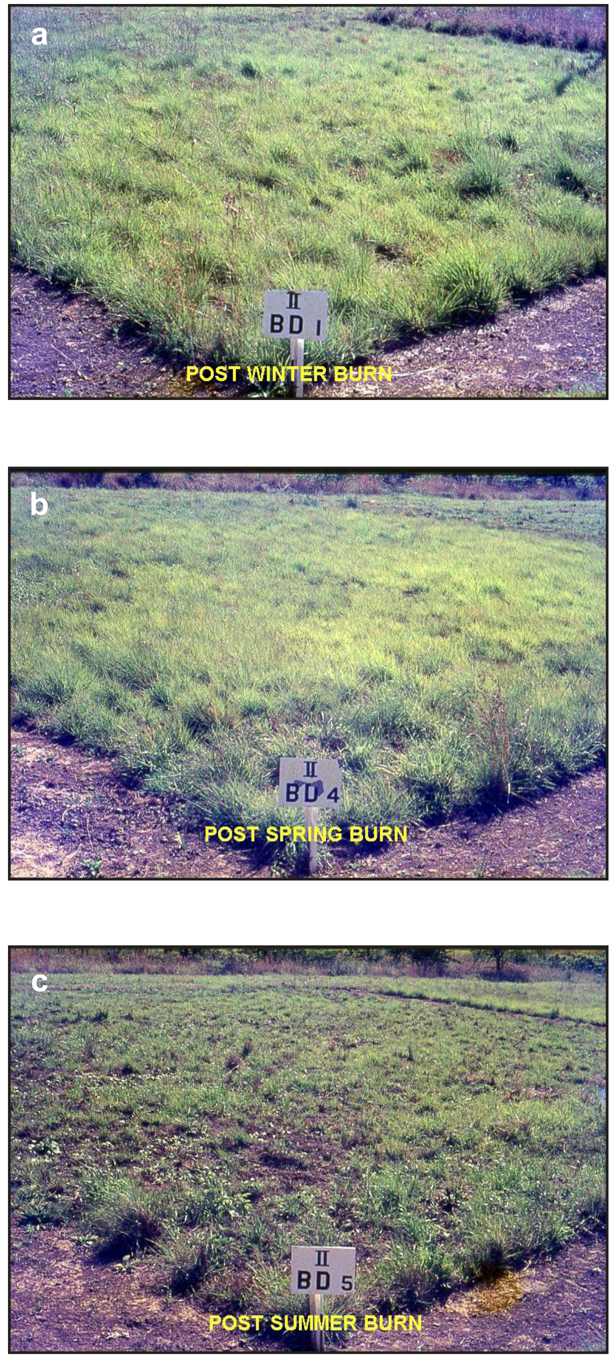

Figure 10. Post burn recovery in the grass sward when burnt in winter (a), spring (b), and summer (c), illustrating the importance of burning when the grass is dormant.

be applied after the first rains of >13 mm, at the commencement of the growing season, i. e., when the grass is still dormant and the fire hazard is low. Conversely, when burning to control encroaching plants, burning should be applied before the first rains that initiate the commencement of the growing season, i.e., when the grass is very dry and dormant to ensure a high intensity fire. The actual time of the year when prescribed burning will be applied in Africa will depend upon the latitude and rainfall pattern of the region. For example, in the central highlands of Kenya, which receives a bi-modal rainfall, the main burning windows are the dry period between May and September and a shorter period during January and February (Trollope and Trollope 1999). Conversely, in the summer rainfall areas of southern Africa, the recommended season of burning is approximately before and immediately after the first spring rains in September or October (Trollope 1999).

In the communal fire paradigm, burning of communal rangelands throughout southern and east Africa occurs primarily with the onset of the dry season in winter, spanning the period approximately May to October. This is clearly illustrated in the number of fires recorded by MODIS satellite in the Sioma Ngwezi National Park and the adjacent Masese Corridor in southwestern Zambia during the period 2003 to 2008 (Trollope *et al.* 2010). In this region, the majority of fires are ignited by local communities living in the national park and adjacent areas, with most occurring in the latter part of the dry season from July onwards (Figure 11).

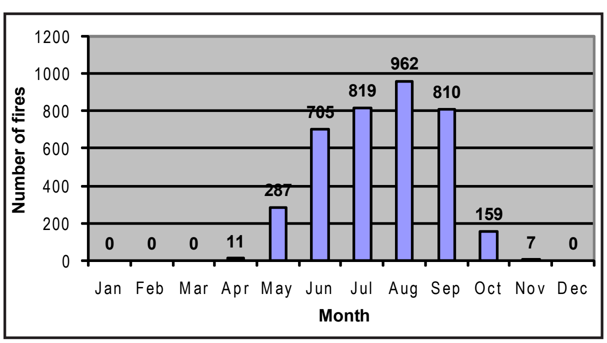

Figure 11. Mean number of fires recorded by satellite for different months of the year for the period 2003 to 2008 in the in the Sioma Ngwezi National Park and the adjacent Masese Corridor in southwestern Zambia (Trollope *et al.* 2010).

Similar results from satellite data were obtained in the Okavango Delta Ramsar Site in Botswana for the period 2000 to 2005, where anthropogenic fires ignited by local communities living in a communal lifestyle occurred mainly during the dry winter period commencing in April, with the main fire season occurring in the late winter between August and October (Trollope *et al.* 2006).

A significant feature of the season of burning in the communal fire paradigm is that the majority of the fires occurs when the grass sward is dormant, and the burning season spans the entire dry winter period. This is in contrast to the commercial fire paradigm in which, initially, the season of burn was after the first spring rains when the grass sward was often not totally dormant. This was, however, later modified to include burning before the spring rains in late winter when the grass sward was completely dormant as a means of generating high intensity fires for controlling bush encroachment. The major difference between the two paradigms is, therefore, the timing of the fires.

Frequency of burning. In the commercial fire paradigm, the frequency of burning is dictated by the reason for burning. When burning to remove moribund or unacceptable grass material, the frequency of burning will depend upon the accumulation rate of excess grass litter (Trollope 1999). Field experience indicates that grass litter should not exceed 4000 kg ha^{-1}; therefore, the frequency of burning should be based on the rate at which this phytomass of grass material accumulates in response to rainfall and grazing pressure of domestic livestock and wild ungulates. This approach has the advantage that the frequency of burning is related to the stocking rate of grazers and to the amount of rainfall the area receives. Generally, in high rainfall areas (>700 mm yr^{-1}), this will result in the frequency of burning being every 2 yr to 4 yr. In lower rainfall areas, the frequency will be much lower. In fact, the threshold of a grass fuel load >4000 kg ha^{-1} will generally exclude fire in these regions, particularly where the condition of the rangeland is degraded and excessive grass fuel loads never accumulate. In the case of burning to control the encroachment of undesirable plant species, the frequency of burning will depend upon the ecological characteristics of the encroaching species, and will and can vary from a single burn to frequent burning.

Generally, there appear to be no clear guidelines regarding the frequency of burning in the communal fire paradigm except to say that fires are applied as frequently as possible whenever the grass sward is in a flammable condition. However, this aspect of the communal fire paradigm deserves further research attention. While investigating the relationship between the incidence of ticks and range condition in the Ngorongoro Crater in Tanzania (Trollope *et al*. 2003), where Masaai pastoralists burn to control ticks, it was found that the grass fuel load in areas where they grazed their livestock never exceeded 3000 kg ha^{-1}, and field surveys yielded no evidence of ticks in these areas. This was in contrast to areas preferred by buffalo in the Ngorongoro Crater where the grass fuel loads always exceeded 4000 kg ha^{-1} and where there were severe infestations of ticks. During repeated visits to the crater during the period 1995 to 2003, there were ample and repeated examples in the areas inhabited by the Masaai surrounding the crater of their burning the rangelands where they grazed their livestock (Trollope *et al*. 2003). These data suggest that the Masaai actively burn the rangelands to prevent the grass fuel loads from exceeding 3000 kg ha^{-1}, thereby reducing the incidence of ticks and safeguarding the wellbeing of their livestock. The annual rainfall in these areas occupied by the Masaai and their livestock is up to 1980 mm yr^{-1} (Runyuro 1995), and based on my own professional experience as an African range scientist, it would require approximately biennial burning of the rangeland to prevent grass fuel loads from generally exceeding 3000 kg ha^{-1}. While this conclusion and interpretation is scientific conjecture, it does highlight the value of the communal fire paradigm for controlling ticks in this region of Africa, as well as the necessity to investigate further the control of ticks by the Masaai pastoralists through the use of fire at a particular burning frequency. The commercial paradigm therefore can benefit from the experience of the communal paradigm in using fire to minimise the impact of tick borne diseases in commercial livestock enterprises and wildlife management systems.

Finally, besides the control of ticks with fire in the communal fire paradigm, it is believed that the frequency of burning is generally too high and that adopting the practice in the commercial fire paradigm of burning only when the grass sward becomes moribund would benefit both the condition of the rangelands and livestock of the communities in communal areas in Africa.

Post Burn Management

With regard to livestock production, the commercial paradigm recommends that, when burning to remove moribund and or unacceptable grass material, grazing be applied as soon as possible after the burn to take advantage of the highly nutritious regrowth of the grass plants. There is a lack of clarity as to whether rotational or continuous grazing should be applied after the fire. However, there is complete consensus amongst rangeland scientists on the necessity of applying a rotational resting system when prescribed burning is used (Figure 12; Zacharias 1994, Kirkman 2001).

A rotational resting system involves withdrawing a portion of the rangeland from grazing for an extended period of at least a growing season or longer (6 months to 12 months) to maintain the vigour of the grass sward and enable seed production to occur for plant recruitment. The rest period is applied during the season prior to the prescribed burn. In

Figure 12. Grazing can be applied as soon as possible after a burn to benefit from the highly nutritious regrowth of the grass plants provided that a rotational resting is included in the management program.

terms of rotational grazing after a burn, great success has been obtained with the so-called "open camp system" developed in South Africa. This involves burning a camp and grazing it as soon as possible after the fire, after which the livestock are moved rotationally to other camps until such time as the burnt camp is ready to be grazed again. By following this procedure, the burnt rangeland is maintained in a palatable and nutritious condition for as long as possible after the burn to the benefit of the livestock. The same procedure is then followed in subsequent years. This system presupposes the availability of adequate camps to apply this form of grazing management. In situations where there are few grazing camps available, emphasis must be given to applying a rotational resting system. In the case of using fire to control the encroachment of undesirable plant species, specific guidelines involving resting and follow-up burning have been developed for the control of specific encroaching plant species, e.g., macchia and karroo vegetation in South Africa (Trollope *et al.* 1989).

Another aspect of the commercial fire paradigm is the guidelines for grazing after burning in wildlife areas. In order to prevent overgrazing, it is advised that the size of the burnt area exceeds the short term forage requirements of the grazing animals that are attracted to the highly palatable and nutritious regrowth that develops after a burn, i.e., burn relatively large areas at any one time (Trollope 1992). Another strategy that has been successfully used in southern Africa is to apply a series of patch burns at regular intervals throughout the duration of the burning window during the dormant season. This has the effect of attracting the grazing animals to the newly burnt areas after the different fires, thereby spreading the impact of grazing over the entire burnt area and avoiding the detrimental effects of heavy continuous grazing after the burns (Brockett *et al.* 2001).

In the communal fire paradigm, there are apparently no specific post-burn management guidelines available to maintain the condition and sustainability of the rangeland ecosystem. The common practice is to graze livestock as soon as possible after the burn to promote livestock performance through the utilization of the highly palatable and nutritious forage that develops after a burn. However, this practice has been highly detrimental to range condition in communal grazing areas when applied together with excessively high stocking rates of grazing animals and the absence of rotational resting to maintain the productivity and cover of the grass sward. These deleterious effects are, however, overcome where transhumance livestock systems still occur such as practiced by the Masaai pastoralists in the Ngorongoro Conservation Area in Tanzania.

GENERAL DISCUSSION AND CONCLUSIONS

In comparing whether the commercial and communal paradigms are moving farther apart, the answer is definitely "no," and there is ample evidence to show that there is significant consensus in the burning practices used in the two paradigms. For example, initially, the Eurocentric attitude to fire in the commercial fire paradigm represented by the Dutch who settled the Cape of Good Hope at the southern tip of Africa in 1652 was completely against the use of fire as a range management practice, in contrast to the highly positive attitude of the Khoikhoi pastoralists who burnt the rangelands regularly to improve the grazing for their livestock. This all changed during the early period of the twentieth century when, in the commercial fire paradigm, fire was recognised as being a natural and often essential ecological factor in African grassland and savanna ecosystems. Subsequent research in Africa on the effects of fire in these ecosystems clarified the use of fire as a range management practice for domestic livestock production and wildlife management, and today there is complete consensus in the two fire paradigms on the use of fire. This consensus is illustrated by the similarities of both paradigms when managing rangeland for domestic livestock, except for in the communal fire paradigm of using fire to control ticks, which is in contrast to the belief in the commercial fire paradigm that fire does not control ticks because they persist in areas that are frequently burnt. However, this difference in attitude is, in my opinion, a result of the lack of research on the effects of fire on the ecology of ticks rather than an objection in principle to the use of fire to control ticks as illustrated by the preliminary research conducted by Stampa (1959) and Trollope *et al.* (2003).

As to whether the commercial fire paradigm is incorporating communal knowledge in wildland fire management, there is evidence to show that this is occurring in some cases. The use of the patch mosaic burning system in the Pilansberg National Park and its adoption in the Kruger National Park in South Africa follows the method of burning used in the communal fire paradigm practiced by local African communities throughout Africa. While the use of patch mosaic burning in the Pilansberg National Park originated from Aboriginal fire practices in Uluru and Kakadu national parks in northern Australia, it is not in conflict with the patch mosaic burning system used in the communal fire paradigm. In the case of the Kruger National Park, patch burning has been accepted because of its widespread use and perceived positive ecological effects in neighbouring Mozambique, where communal livestock farming is practiced. Therefore, the commercial fire paradigm is incorporating indigenous knowledge in wildland fire management.

Another example of where indigenous fire practice is being incorporated in the commercial fire paradigm is the extension of the fire season in wildlife areas, like the Kruger National Park, to the entire dry winter period. Previously, prescribed burning was limited to the end of the dry season either before or after the first spring rains. Pertinently, research on the effects of season of burn on the grass sward in southern Africa (West 1965, Trollope 1987) has shown the importance of plant dormancy in minimizing the harmful effects of fire on the regrowth of grass plants, thereby promoting support for the desirability of applying prescribed burns throughout the entire dry winter period. The practice in the communal fire paradigm of applying grazing as soon as possible after a burn to take advantage of the highly palatable and nutritious regrowth of the grass sward is also now incorporated into the commercial fire paradigm. Intensive research conducted by Zacharias (1994) and Kirkman (2001) showed the benefits of this practice on positive animal performance, provided it was accompanied by a regular rotational resting program in the overall range management system, and encouraged the adoption of this indigenous practice.

In conclusion, it must be stated that there are, however, certain aspects of the communal fire paradigm that need to be modified in the light of research results that form part of the commercial fire paradigm. For example, the use of patch mosaic burning in the communal fire paradigm minimises the occurrence of surface head fires necessary for the control of encroaching tree and shrub species. It would therefore be highly beneficial for local communal communities to use perimeter ignitions (block burns) rather than point ignitions (patch burns) in situations where it is necessary to use fire to control the encroachment of tree and shrub species. Also, the practice in the communal fire paradigm of applying immediate grazing with livestock after a burn without including a regular rotational resting program is highly detrimental to range condition and needs to be adapted as a means of ensuring the continued ecological health and ecosystem functioning of the communal rangelands in Africa.

Comparing the positive and negative aspects of burning practices involved in commercial and communal fire paradigms on a global scale is a most exciting and worthwhile exercise. I have attempted to compare the burning practices included in the commercial paradigm arising from fire research programs that I have personally been involved in on the African continent, with those of communal communities. It must be stressed though that the conclusions that I have drawn about the differences and similarities in the practices associated with the commercial and communal fire paradigms need to be investigated further and in greater depth. This requirement provides a wonderful opportunity for fire ecologists in Africa and elsewhere in the world to objectively assess the pros and cons of indigenous fire management practices that have been long denied or dismissed by traditional range scientists and Western society in general. The practical value of traditional knowledge that is and has been practiced successfully for millennia is well illustrated in recent discoveries involving ethnobotany.

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