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FIRE AS A RANGELAND MANAGEMENT TOOL IN THE SAVANNAS OF SOUTHERN AFRICA: A REVIEW

[EL FUEGO COMO HERRAMIENTA PARA EL MANEJO DE PRADERAS EN LAS SABANAS DEL SURESTE DE AFRICA: UNA REVISIÓN]

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SUMMARY

Fire is critical to the maintenance of biodiversity and ecological processes and contributes to the distinctive nature of rangelands. However, the role of fire in maintaining rangelands has been misunderstood by the public in general; thus, over time the use of fire has been reduced. This is unfortunate because prescribed burning is an effective means for controlling selected unwanted and undesirable plant species on rangelands and enhances livestock productivity. On the other hand, inappropriate application of fire can eliminate useful forage and pose serious threats to human life, property, community assets, air quality and rangeland values including water, wood and biodiversity. These undesirable effects may be due to missing or lack of adequate information necessary to conduct specific prescribed burns on rangelands. This paper outlines the importance and limitations of prescribed burning, significance of fire regimes, effects of fire and possible ways of preventing breakaway fires in Southern African savanna rangelands and suggests future research areas.

Key words: Burning, fire regime, fireguard, livestock, vegetation.

RESUMEN

El fuego es crítico para el mantenimiento de la biodiversidad y los procesos ecológicos y contribuye a la naturaleza distintiva de las praderas. Sin embargo, el papel del fuego ha sido malentendido por el público en general; así, con el tiempo el uso del fuego ha sido reducido. Este hecho es desafortunado debido a que la quema prescrita es un medio efectivo para controlar de manera selectiva especies de plantas no deseables en la pradera y mejora también la productividad ganadera. Por otro lado, un uso inapropiado del fuego puede eliminar plantas forrajeras útiles y es un riesgo serio para la vida humana, propiedades, bienes de la comunidad, calidad del aire y valor de la pradera incluyendo agua, madera y biodiversidad. Estos efectos indeseables pueden ser debidos a la falta de información necesaria para realizar una quema prescrita en las praderas. Esta revisión delinea la importancia y las limitaciones de la quema prescrita, tipos de quema, efectos del fuego y medios posibles de prevenir los incendios descontrolados en las regiones de pradera de sabana del sureste de África, asimismo se sugieren posibles áreas de investigación futura.

Palabras clave: Quema, tipos de quema, guardaraya, ganadería, vegetación.

INTRODUCTION

Past experience in rangeland development efforts, has created growing awareness regarding the fragility of the Southern African savanna rangelands and the extent of irreversible deterioration that is taking place (Ringrose and Matheson, 1987). Rangeland deterioration is evidenced by soil erosion, unavailability of soil water and decreased soil water quality, declining forage yields, decreasing vegetation cover, changes in plant species composition and reduced livestock performance; which may lag behind deterioration in soil or vegetation attributes (Crowder, 1985; Patton and Nyren, 2004). Rangeland deterioration results in loss of biodiversity, poverty, unemployment and other economic stresses (Trollope, 1989). Rangeland deterioration is mainly ascribed to environmental factors especially low and erratic rainfall in combination with anthropological factors such as cultivation of the marginal agro-ecological zones and inappropriate grazing management, in particular, overgrazing and inappropriate fire regimes (Ringrose and Matheson, 1987).

Rangeland deterioration will continue to occur unless remedial measures are taken. The challenge is to integrate the conservation, preventative and remedial action and ongoing management of rangelands to protect biological diversity and maintain the ecological processes which provide the productive capacity of its natural resources. Intensive rangeland improvement methods such as fertilization, replacement and reinforcement, rapidly increase production by 100 to 1000 % within 1 to 3 years, but these are expensive and difficult to implement (Trollope, 1999). Although prescribed burning and grazing intensity rangeland management tools have comparatively low potential increases in forage production and plant species diversity potential benefits, they are not labor intensive and are widely applied cost-effective approaches that can be used to reverse or decelerate rangeland deterioration (Fuhlendorf and Eagle 2004; Mapiye *et al.,* 2006). Prescribed burning (or controlled burning) is the use of fire under specific conditions to achieve desired goals (Trollope, 1999). It has the potential to manipulate rangeland vegetation to favour optimum forage and animal productivity (Trollope and Trollope, 1996).

Despite the significance of prescribed burning in the development of savanna rangelands, negative attitudes towards burning have frequently limited its application as a rangeland improvement tool in Southern Africa (Trollope, 1999). Factors such as temporary elimination of potentially usable forage, threat of fire escaping the boundaries of a prescribed burn and destructive effects of breakaway fires have all contributed towards reduced use of fire on rangelands (Wright, 1974; Bond and van Wilgen, 1996). The other aspect, which inhibits prescribed burning, is fear of the liability consequences if a fire breakaway. This fear affects individual landowners and also influences government agencies (Trollope, 1989). On the other hand, a lot of information is known about the effects of fire on savanna rangelands and its value as a management tool, but the information necessary to conduct specific prescribed burns is generally disjointed (Goldhammer and de Ronde, 2004; Mapiye *et al.,* 2006).

Since it has been widely accepted that most savannas are fire-adapted formations and that fire is a strong selective force in the evolution of the flora, the influence of different fire regimes and behavioural patterns should provide information that improves understanding of both rangelands ecosystems and its possible management strategies (Tainton and Mentis, 1984; Trollope, 1989). Therefore, this paper outlines the importance and limitations of prescribed burning, significance of fire regimes, effects of fire and possible ways of preventing breakaway fires in Southern African savanna rangelands and suggests future research areas. The review can assist rangeland users in Southern African savannas to formulate economically viable and ecologically acceptable strategies of utilising prescribed burning as a rangeland improvement tool.

IMPORTANCE OF PRESCRIBED BURNING

Fire is an extensively used management technique to simultaneously achieve several objectives in Southern African savanna rangelands (Tainton and Mentis, 1984; Goldhammer and de Ronde, 2004). The current view among scientists, progressive livestock farmers and wildlife managers on the permissible reasons for burning rangelands in Southern Africa is that it can be used to remove unacceptable plant material (top-hamper and/or moribund material) and eradicate and/or prevent the encroachment of undesirable plant species (Sweet, 1982; Trollope, 1989). These are the fundamental reasons for burning the rangeland (Trollope, 1999). Removal of surplus or unacceptable vegetation improves access to new growth and facilitates introduction of exotic species (Bailey, 1986). If top-hamper builds up over several years it can seriously reduce grass tufts. Animals do not graze, or only graze very little old grass, so it has a low forage value and reduce animal performance (Gammon, 1969).

Fire can be used to stimulate out of season growth as shown by burning of vleis in late winter to give an early winter flush (Bond and van Wilgen, 1996). This is also often practised in summer and late autumn to provide green grazing for livestock. However, this malpractice is completely unacceptable because it leads to rangeland deterioration (Pandey, 1988). While green flush may produce a green bite for livestock in the dry season, growth does not last long. The valuable root reserves are depleted affecting growth vigor in the following dry season, and there is general damage to grass plants. Early winter burns leave the soil exposed to insolation and erosion throughout the winter period, leading to compaction and erosion with the coming of the rains (Trollope, 1989).

Plant productivity can be influenced by use of fire to favour desirable plants or to reduce the abundance of unpalatable species (West, 1965; Tainton and Mentis, 1984). Improvement of palatability and nutritive value of the existing grazing and browse can be achieved by the appropriate use of fire (Dube *et al.,* 2006). Fire can also be used to attract animals to ungrazed areas and improve grazing distribution (Crowder, 1985). Livestock have a tendency to select and graze fresh plant material from burned treatments compared to the unburned ones (Trollope, 1989; Mapiye *et al.,* 2006). Fresh green shoots of new growth on burned rangelands are palatable and high in crude protein content (Munthali and Banda, 1992; Bebawi and Campbell, 2002).

It has been suggested that rangeland burning can control pests and parasite infestation (by burning and killing of nymphs and adult stages of insects) and disease vectors in the dry season (Trollope and Trollope, 1996). Prescribed burning reduces fire hazards or accidental fires, which could destroy buildings, wildlife and protected pastures (Trollope, 1999). However, some studies have shown evidence that prescribed burning has little effect on the occurrence of destructive wildfires (Brown *et al.,* 1991; van Wilgen *et al.,* 2004). Use of fire to improve rangeland habitats for livestock and wildlife may provide economical and ecologically sound alternative to present rangeland management methods (Munthali and Banda, 1992). There is need to validate and provide more evidence of the benefits of prescribed burning to rangeland and animal productivity.

LIMITATIONS OF PRESCRIBED BURNING

The undesirable effects of fire on the environment when burning is incorrectly used in rangeland management have brought greater clarity to the conclusion drawn by Phillips (1965) that fire is a “bad master but a good servant”. Thus, under certain circumstances fire can be a useful tool of management, but due to inappropriate fire regimes and inability to control fires it often ends up doing more harm than good. Fire can burn off all standing grass cover both the moribund material and the recent growth (Bond and van Wilgen, 1996). As grass provides feed base for the livestock industry, removal through burning can represent a major loss if the fire breakaway. In addition to the value of lost grazing, there is the value of associated losses of hay, fence posts, buildings, wildlife and human life (Bailey, 1986). Inappropriate use of fire on rangelands lead to accelerated erosion and loss of soil nutrients, loss of forage and adverse changes in species composition, increased wood weeds and undesirable herbs, and consequently decreased animal performance (Tsvuura, 1998; Trollope, 1999).

In general, air borne particulates are the primary pollutants of fire (van Wilgen *et al.,* 1997). Short-term exposure to smoke can cause debilitating health effects to humans with respiratory conditions such as asthma, emphysema, or cardiovascular diseases. Hydrocarbons are other combustion products, but few if any appear in the combustion of wood products that are important in photochemical reactions. Carbon monoxide is a pollutant from fires, but it seems to oxidise readily and does not pose an immediate threat to people, plants or animals (van Wilgen *et al.,* 1997). Fire, at a wider scale, can significantly increase emission of green house gasses such as carbon dioxide, methane and nitrous oxide, which entrap incoming solar energy and thus enhance the process of atmospheric warming (Abrams *et al.,* 1983). Environmental consequences of rangeland fires depend on the environmental context and conditions of application (Phillips, 1965). In order to minimize these harmful effects of fire on the savanna rangelands the knowledge of fire regimes is important.

FIRE REGIMES

The occurrence and biological effects of fire are determined by fire regimes. Fire regime is the combination of intensity, frequency, season and type of fire that prevail in a given area (Trollope, 1999). It has been proposed by Gill (1975) that plant species are adapted to a particular fire regime, so that altering the regime will change the relative abundance of species and is linked to changes in rangeland health and vitality, regeneration patterns, weed invasion and occurrence of pests and diseases. This proposal forms the basis for most prescribed burning.

Fire Intensity

Fire intensity refers to the rate of heat release during a fire and determines the severity of fire in terms of vegetation recovery (Bond and van Wilgen, 1996). It depends on topography, season, fuel properties and wind among other weather conditions at the time of fire. Fire intensities range from 100-4000 KJ/s/m in wet savannas (Trollope 1999) but Govender *et al.* (2006) reported higher ranges of 11000- 17 500 kW m^{-1}. Trollope and Potgieter (1985) categorised fire intensity into six groups: very cool, <500; cool, 501-1000; moderately hot, 1001-2000; hot, 2001-3000 and extremely hot, >3000 KJ/s/m. When burning to remove moribund and or unacceptable grass material a cool or low intensity fire < 1000 kJ/s/m is recommended. This can be achieved when air temperature is < 20^{o}C, wind speed is 5-15 km/h and relative humidity is > 50 % (Trollope and Trollope, 1996). Cool fire temperatures usually reach 300^{o}C and its effects rarely go beyond 2 cm below ground level. In Zimbabwe cool fires are practiced in the Hyparrhenia type of grassland and in other grasslands types, where the dominant grass species become coarse, unpalatable and extremely low in nutritive value (Bond and van Wilgen, 1996).

When burning to control undesirable plants like encroaching bush, a high (hot and/or very hot) fire intensity of > 2000 kJ/s/m is necessary. This can be achieved when the grass fuel load is > 4000 kg/ha, the air temperature is 25-30^{o}C and the relative humidity is < 30 %. Wind speed should not exceed 20 km/h. This will cause a significant topkill of stems and branches of bushes up to a height of 3 m. A hot fire moves rapidly and flame heights range from 1-3 m above the ground and 5 cm below the ground and temperatures can reach 600^{o}C (Tainton and Mentis, 1984). In order to ensure adequate fuel load to obtain a hot killing burn, it is recommended that the area scheduled for burning be rested from grazing through the late summer and winter preceding the burn (Trollope, 1989; Goldhammer and de Ronde, 2004). Despite the importance of fire intensity as a key element of the fire regime, it is seldom measured or included in fire records (Govender *et al.,* 2006).

Frequency of Burning

The frequency (interval between burns) of fires is determined by the availability of fuel, suitable climate and an ignition event (Bigalke and Willan, 1984). The best time to burn the rangelands to achieve the desired effect varies with objectives and can be based on the physiological stages of the plants (West, 1965; Tainton and Mentis, 1984). When burning to remove moribund and/or unacceptable grass material the frequency of burning will depend upon the accumulation rate of excess grass litter. Field experience indicates that excess grass litter should not exceed 4000 kg/ha and therefore, the frequency of burning should be based on the rate at which the phytomass of this grass material accumulates (Trollope, 1989). 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 (Trollope and Trollope, 1996).

Govender *et al.* (2006) reported an increase in mean fuel loads with post-fire age, from annually burnt plots to biennial, triennial and quadrennial burnt plots and a decrease on sexennial burnt plots. Generally, in moist savanna rangelands the recommended frequency of burning is every 3 years (van Wilgen *et al.,* 1997; Dube *et al.,* 2006). In semiarid savanna rangelands, it will be much lower (5-8years) and in fact, this rule of thump will exclude fire where the condition of the rangeland is so poor that excessive grass fuel loads slowly or never accumulates (Snyman, 2006). The frequency of burning cannot be prescribed when using fire to control undesirable plants because it depends upon species under consideration (Sweet, 1982). Some species require only a single hot burn whereas others require numerous fires for their control (Boultwood and Rodel, 1981).

Season of Burning

Based on the response of African savanna rangeland vegetation to the season (time of year) of burning it is recommended that when burning to remove moribund and/or unacceptable grass material, fires should be preferably applied after the first spring rainfall (15-20 mm) when the grass is still dormant and the fire hazard is low (Trollope and Trollope, 1996). Fire intensity is lowest in summer fires, increases in autumn fires and is highest in winter fires (Govender *et al.,* 2006). This is attributed to differences between the mean moisture content of grass fuels in winter and summer. If soil moisture is not adequate at the time of the fire or replaced soon after, areas that are subjected to prescribed fire may actually produce less forage than unburned areas (Bailey, 1986).

Soil moisture is a critical aspect of the fire prescription and should be carefully considered in conjunction with other elements of the fire plan. Conversely, when burning to control encroaching plants, fire should be applied before the first spring rains when the grass is dry and dormant (Sweet, 1982; Trollope, 1989). Early rain season burns in the savannas are often cool, whereas late dry season burns are more thorough, hotter and damaging. In this context a cool fire can be loosely defined as an early rain season fire, set before the fuel has completely dried out whilst a hot fire refers to fire set at the end of the dry season, when the grass cover is completely dry (Trollope, 1989). Burning in semiarid savanna rangelands or during summer in humid savannas is usually not recommended because of the risk of drying the soil and fuel conditions, excessive consumption of litter and surface soil organic matter, and damage to physiologically active plants (Sweet, 1982; Snyman, 2006).

Type of Fire

Gill (1975) used the term fire type to distinguish between fires that burn in organic layers of the soil (ground fires), those burning in fuels contiguous with the ground (surface fires) and those burning in the canopies of trees (crown fires). Surface fires are more common on savanna grasslands compared to crown fires and ground fires (Bond and van Wilgen, 1996). Surface fires are usually more desired in savanna burning than crown fires. Surface fires spread slowly and do not produce high intensity burning sufficient to ignite the wood exteriors of structures beyond about 3-5 m. Crown fires tend to burn with much greater intensity, spread faster and may get out of control. Crown fires usually results in 100 % tree mortality, a lot of smoke production, and it's not as easily suppressed by normal firefighting techniques (Trollope, 1999). The majority of crown fires generally burn in conjunction with surface fires. Fuel types with certain physical or chemical characteristics have been known to support crown fires independent of surface fires under extreme environmental conditions, usually including strong winds (Trollope, 1999).

The term fire type has sometimes been used in the literature on African savanna fires to distinguish between head fires (those burning with the wind or upslope) and back fires (those burning against the wind or downslope) (Trollope, 1999). Based on the effect of type of fire on savanna grassland and savanna vegetation, head fires are recommended for rangelands used for domestic animals than back fires. This is because African savanna head fires have shorter residence times and are less severe than back fires. Head fires cause least damage to the grass sward but can cause maximum damage to woody vegetation (Trollope and Trollope, 1996). Although back fires are safer to conduct than head fires they do more damage to the grass sward and are more difficult to keep burning in many fuel types unless wind and relative humidity are unsafe (Trollope, 1989). Back fires are often used to create a fire break (fireguard) around the area to be burned with a head fire.

EFFECTS OF BURNING

Fire has direct and indirect effects on soils, vegetation and animals (Phillips, 1965; Trollope, 1999; Bradstock *et al.,* 2002; van Wilgen *et al.,* 2004; Govender *et al.,* 2006). Limited research has been conducted on the long-term effects of burning on soil, forage and animal attributes of the savanna rangelands, especially during the early rain season when prescribed burning would be recommended (Mapiye *et al.,* 2006). Most data that is available on Southern African savanna rangelands following a fire is short-term because generally long-term trials are expensive and difficult to manage over long periods. However, long-term fire studies help to buffer effects of periodic or short-term impacts. They provide valuable information on the functional processes affecting vegetation and ecological trends over time. Long-term trials generate useful data on the fundamental equilibrium or change in vegetation and on the impact of prolonged disturbance factors such as fires (Tsvuura, 1998). Therefore, international and inter-institutional collaborative and participatory long-term fire trials should be set to continuously investigate the effects of fire on soil, plant and animal attributes on savanna rangelands in Southern Africa.

Effects of Burning on Soil Properties

Fire affects soil moisture, temperature, fertility, infiltration rates and water holding capacity (Bond and van Wilgen, 1996). With respect to soil fertility, several reports document an initial increase in nutrients and desirable soil properties after burning including pH, exchangeable cations and NO_3-N, followed by decline to the original or lower values with the passage of time (Trollope, 1989; Tsvuura, 1998). Availability of soil nutrients promotes recruitment of new species in the savanna rangelands. Some reports have argued that fire results in loss of nutrients from rangelands in the form of particulates in ash and smoke, and volatilization (Gill, 1975; Bradstock *et al.,* 2002). Regular burning can also result in substantial nutrient losses in some ecosystems, especially if followed by heavy rainfall. On sandy, readily drained soils, alluvial nutrient losses are likely to be greater than in more fine textured soils (Bond and van Wilgen, 1996). Despite the frequent use of fire in rangeland management, detailed knowledge about the responses of soil properties and soil, plant and animal relationships are lacking for many Southern African savanna rangeland ecosystems. Generally, there is a notable scarcity of conclusive information on the status of the soil nutrients after several years of applying a fire regime in a naturally grazed savanna ecosystem (Tsvuura, 1998).

Following burning, litter and organic properties decline, thus exposing soil to insulation, wind erosion and rain drop action (Ringrose and Matheson, 1987). This results in reduced infiltration, and increased runoff erosion, soil capping and desiccation. Moreover, reduction of litter and plant biomass alters energy, nutrient and water fluxes between the soil, plants and atmosphere (Trollope, 1989). Burning decreases the surface reflection coefficient, which in turn increases net radiation, energy entering the soil and energy terms associated with sensible and latent heat and photosynthesis. It is probably these factors, in presence of water, which cause rapid vegetation growth following burning and not soil temperature increases (Trollope, 1999).

Conversely, build up of litter lowers soil temperatures and this reduces bacterial activity, ties up nutrients, and slows the general nitrogen cycling (White and Currie, 1983). Excessive litter weights negatively affect seed germination, tiller growth and biomass production (Abrams *et al.,* 1983; Bebawi and Campbell, 2002). Most microorganisms appear to be affected by fire but fungi seem to thrive under burnt conditions at the expense of bacteria and actinomycetes (Bigalke and Willan, 1984). Fires have been shown to affect basal cover, but this depends on the type of fire and rainfall associated with plant growth (White and Currie, 1983). Kennan (1971) in Zimbabwe observed that on red and gneiss sand soils, the most frequent annual burns had the lowest basal cover, followed by less frequent biennial and then triennial burns.

Effects of Burning on Vegetation

Burning benefits plant growth primarily because of changes in the physical rather than the chemical environment (Bond and van Wilgen, 1996). Direct effects stimulate seeds to germinate and indirect effects provide a more favourable environment for germination to occur (Senthilkumar *et al.,* 1998). Direct effects following burning are generally to do with the exposure of seeds to high temperatures or plant derived smoke that have scarifying effects on seeds (Bebawi and Campbell, 2002). The removal of shade and the exponential growth of younger tillers are two important factors that stimulate shoot production in burned treatments (Bond and van Wilgen, 1996). Fire creates opportunities for enhanced plant reproduction through increased flowering, seed dispersal and by removing plant covers thereby reducing competition from established plants (Pandey, 1988).

Fire affects herbage yield, in the early growing season burning reduces herbage biomass production by 50-70 % to 5-35 % in the mid growing season but in the late growing season burnt plots have more biomass, which is more palatable, nutritious and readily available than forage in unburned areas (West, 1965; Tainton and Mentis, 1984; Senthilkumar *et al.,* 1998). In the long-term, annual burns result in stunting of plants and encourage annual species domination and 3-5 years burns support perennial grass species (Kennan, 1971). In the long-term, if a fire climax is maintained; better quality herbage is on offer than in post-fire climax grassland in humid areas. In drier areas if pioneer species replace perennial species, lower quality herbage is produced (Pandey, 1988; Fuhlendorf and Engle, 2004). Research on the response of key or individual forage species to fire could further validate prescribed burning for these effects in future.

There are conflicting results on the impact of burning on browse species composition and density. Kennan (1971) in Zimbabwe found out that there were no significant differences in bush density in response to different burning frequencies. Conversely, Sweet (1982) in Botswana, and Boultwood and Rodel (1981) in Zimbabwe found that annual burning resulted in a significantly greater reduction in the density of bush than less frequent burning. Generally, three-year burns were found most cost-effective in controlling bush-encroachment in Zimbabwe (Dube *et al.,* 2006). There is little and inconclusive information available on the effect of burning on the production and nutritive quality of browse in the savanna rangelands. From earlier research it may be postulated that the result of prolonged burning would be a progressive shift towards the more grassland end of the savanna spectrums, while conversely fire protection would lead to an increased woody component and eventually with sufficient rainfall and nutrients to a savanna woodland and possibly deciduous forest (Sweet, 1982; Tsvuura, 1998; Trollope, 1999). This has considerable implications for management, depending on whether it is intended to develop herbaceous cover for grazing or to retain the savanna woodland. In general, these studies have demonstrated that fire has management potential although additional research is needed to determine how key browse species may respond.

Effects of Burning on Animal Production

Fire affects animals by changing plant palatability and availability as well as indirectly altering water availability (Bigalke and Willan, 1984). Livestock prefer burned to unburned areas and generally have greater weight gains on burned areas (Wright, 1974). This is attributed to increased forage protein content, palatability, digestibility, availability, and absence of litter in the plants following early rain season burning (Munthali and Banda 1992; Senthilkumar *et al.,* 1998). It has been noted that best weight gains of 15-20 kg/ha/yr/head accrued 60-90 days following the fire, with no difference in weight gain between burned and unburned plots after that time (Crowder, 1985). Research has shown that yearling or stocker animals can gain 10-12 % more on late spring burned than on either unburned or early burned pastures and these benefits are realized only during the year of burning (Trollope, 1999). There is a dearth of information relating livestock performance to the prescribed burning in the Southern African savanna rangelands. Prescribed burning is a potential tool to increase livestock production from savanna rangelands, but its utilisation by livestock must receive sufficient research consideration to ensure optimum benefits. It is essential to effectively and efficiently manage the rangeland after prescribed burning to prevent soil erosion, death of desirable forages and overgrazing.

RANGELAND MANAGEMENT AFTER BURNING

Management after burn is essential for obtaining desirable and sustainable livestock production levels. After burning, management depends on geographic locality and the nature of the resident vegetation among other factors. It is recommended that when burning to remove unacceptable grass material, grazing can commence soon as the rangeland is recovered to a grazeable condition (Crowder, 1985). Subsequent grazing distribution, stocking rate, graze periods and rest periods should be managed to obtain desired plant responses. When burned areas are managed improperly, livestock often concentrate on and overgraze them because the forage regrowth is more palatable, nutritious and readily available than forage in unburned areas (Munthali and Banda, 1992). The burned area should be rested after burning for at least the first 6-12 weeks of grass growth (Boultwood and Rodel, 1981). This permits adequate grass growth to build root reserves, establish good basal cover, and to lay down litter against compaction and erosion (Tainton and Mentis, 1984). When burning to control undesirable plants post-fire grazing management will depend upon the ecological characteristics of encroaching plant in question (Trollope, 1989). There is a continuing need to increase the understanding of the effects of post-fire rangeland management within the context of societal and ecological goals for communal rangelands in Africa.

CONTROL OF FIRE

Prescribed burns should be done safely so that they do not go beyond the planned fire lines. Although burning is site specific, there are various precautions which can be applied to reduce breakaway fires during prescribed burning in most savanna rangelands in Southern Africa. An accurate local weather forecast is required to determine the fire hazard index before, during and after burning. Ideally a prescribed burn to control top-hamper should be conducted at the beginning of the wet season soon after a good rain of 15-20 mm and when relative humidity is 40-60 %, at average wind velocities of 5-15 km/h and air temperature should be between 15-25^{o}C (Trollope 1999). The most desirable time to initiate burning is in the late afternoon between 1500 and 1700 hours, as moisture levels rise. Fires started at this time of the day are less subject to thermal convection abnormalities, more easily controlled and generally have much less chance of getting out of hand through windborne sparks thereby igniting areas not set to be burned (Trollope and Trollope, 1996). When burning to control undesirable plants, grass fuel load should be > 4000 kg/ha and air temperature of 25-30^{o}C, wind speed less than 20 km/h and relative humidity less than 30 % are recommended (Trollope and Potgieter, 1985; Trollope, 1989). However, due to species variability in savanna rangelands it is difficult to approve optimum climatic conditions required to burn undesirable plants.

Greater care should be maintained during prescribed burns. In all cases burning should always be done on a manageable unit basis. Before lighting a fire the neighbors, local authorities, police, department of natural resources and other stakeholders should be alerted and a permit should be acquired where necessary (Gammon, 1969; Bailey, 1986). Moreover, the user should be an experienced professional with thorough knowledge of ecosystems, weather and fire behavior. Adequate labour should be available at a burn to ensure control of the fire at all times, and an emergency plan of action should always be formulated prior to any burn that is about to take place (Wright, 1974). There is need for good communication, especially radio communication during the ignition phase when undertaking landscape-scale rangeland fires.

The most important preliminary step in preventing breakaway fires is to have an adequate system of fireguards and suitable equipment (Gammon, 1969; Tainton and Mentis, 1984). A fireguard (or firebreak) is defined as strip of land, whether under trees or not, which has been cleared of inflammable matter and serves as barrier to prevent or retard the spread of a fire (Trollope, 1999). An adequate, planned system of fireguards should be developed on each grazing area to be burned. Ideally a fireguard should be able to stop a fire on its own accord when there is only a moderate wind blowing. It should also provide a front along which virtually any fire can be extinguished when the guard is suitably manned (Phillips, 1965; Trollope, 1989).

There are various types of fireguards that fulfil the aforementioned requirements to varying degrees which differ in suitability according to the area involved; these include cleaned strips of tracers, fire tracks, burnt fireguards, buffer strips, mown fireguards and boundary paddocks (Gammon, 1969). It is up to the individual to decide which type of fireguard will be easiest to construct under his/her conditions and serve his/her purpose best. The manner of construction will depend on the availability of implements, and the type of terrain and vegetation (Wright, 1974). Fireguards can be set up by grading, ploughing, disking, slashing, mowing, hoeing or burning. Fire fighting equipment that should be available before burning includes vehicles, tractors, pump units with hoses, knapsack sprayers and hand tools. Training of labour in the use of fire fighting equipment is of great importance.

A fireguard should be at least 10-15 m on either side of the common boundary (Gammon, 1969). Obviously the wider the fireguard the more effective it is, but there is a width above which the extra security does not warrant the extra expense. On the other hand there is a width below which a guard has little value. Naturally, the desired width will depend upon the nature of the vegetation, topography, the type of the rangeland to be protected and the type of fireguard (Wright, 1974). Fireguards should be strategically located along natural features where possible (bare rocks, stream banks, roads, railway lines, telephone and power lines, etc.) to be of greatest effect in the event of breakaway fires as well as to reduce costs (Trollope, 1999). They should be sited slightly obliquely to the prevailing wind directions, the chance of fires hitting fireguards on a broad front are reduced, hence making control easier (Gammon, 1969). To effectively contain fires on any farm, fireguards should protect all farm boundaries. Fire breaks along fence lines around paddocks or group of paddocks aid prescribed burning of paddocks (Bailey, 1986).

Despite the importance of fireguards, it should be noted that they are not however, intended to be a complete protection on their own; they only serve as a control measure in prescribed burning programmes. The first objection usually raised against fireguards is the expense involved in labour, fencing, fuel and in equipment required (Wright, 1974). However, when the cost of a fireguard construction is considered in relation to the area protected it is astoundingly low (Gammon, 1969). Secondly, fireguards by their nature constitute an erosion hazard. However, by enabling prescribed burning, and rangelands to be protected from fire, fireguards can help bring about great improvements in the rangeland productivity and an increase in carrying capacity (Trollope, 1999).

CONCLUSIONS

Fire has important beneficial effects on savanna flora and fauna, which are modified by fire regimes. Thus, rangeland managers of can manipulate rangeland and animal productivity by using appropriate burning frequency and season and type of fire. The use of fire needs to be carefully planned in advance, and rest periods where appropriate need to be incorporated after its use. Prescribed burning must be integrated with other grazing management techniques to gain the full benefits. The current legislative frameworks and integrated policies on fire control should be adjusted and effectively enforced to promote the use of prescribed burning and minimise breakaway fires through the use of fireguards. Sharing information across tenures and nations is important; effective fire management practice and policy requires better awareness and understanding of techniques and issues among fire users and the broader community.

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