SHORT-TERM INFLUENCE OF FIRE IN A SEMI-ARID GRASSLAND ON (1): PRODUCTIVITY

H.A. Snyman
Department of Animal, Wildlife and Grassland Sciences, University of the Free State
E-mail: SnymanHA.Sci@Mail.uovs.ac.za

Introduction

Although fire is a natural phenomenon in the grassland areas of southern Africa (Everson 1999), large parts of the semi-arid grasslands are characterised by large-scale accidental, runaway fires (Snyman 2003a). In these semi-arid areas the density of lightning flashes could be approximately four strikes/km^2/yr (Everson 1999). Even if the frequency of ignition is low (say one fire from 500 ground flashes), a large number of fires would have been ignited each year in semi-arid areas. Either lightning or man caused these unplanned events which normally took place during the dormant winter period (June to August), they not only have a short-term influence on productivity of the grassland ecosystem (Snyman 2003b), but may also have a major residual effect on the next growing season, depending on successive climatic conditions and post-fire management (Zacharias and Danckwerts 1999). This information can serve as guideline in court cases where production losses are claimed, in which thousands of Rands can be involved and often being based on unscientific evidence. The low and unreliable rainfall characterising the semi-arid areas accompanying with unplanned fires also cause enormous fodder flow problems (Snyman 1998). Therefore, it was the objective of this study to estimate the short-term (two years) impact of fire, which is a normal phenomenon in the semi-arid areas, on the productivity (aboveground phytomass and litter) of the grassland ecosystem.

Procedure

The research was conducted in Bloemfontein (28°50'; 26°15'E, altitude 1350m), in the semi-arid (summer annual average 560mm) region of South Africa. At the start of this study the grassland was in good condition (grassland condition score was 92% of that of the benchmark site) and dominated by the climax species *Themeda triandra*, with *Eragrostis chloromelas* and *Elionurus muticus* also occurring relatively abundantly. The soil is a fine sandy loam soil of the Bloemdal Form (Roodepoort family 3200). Clay percentage increases down the profile from 10% in the A-horizon (0 to 300mm depth), to 24% in the B1-horizon (300 to 600mm) and 42% in the B2-horizon (600 to 1200mm depth).

The research was conducted on 6 plots of 3m x 10m each, re-applied every year on a new area, over a seven year period (1995/96 to 2001/02 season). Each plot was monitored only over a two year period. The treatments randomly applied, included burning (head fire) and a control with no burning taking place. The experimental layout was a fully randomized design with three replications for each treatment.

The burning (head fire) treatments were applied each year at the end of August by which time the grass fuel was dry. To limit the fire to every burnt plot, the plants surrounding each plot (edge effect of 2m) were cut short and soaked before burning. The plots were protected from grazing over the trial. Before the burnt and unburnt treatments were applied the grassland was harvested to a height of 30mm at the end of each growing season. At the end of each growing season, every treatment was harvested to a height of 30mm. This was to enable comparison of growth between burnt treatments and the unburnt plots.

Temperatures reached and duration 10mm under the soil, at ground level, grass canopy height and 1m aboveground level during burning were measured only for the 2001/02 season's burn. These results are fully discussed by Snyman (2003b). Each year's burning took place in the morning with the wind blowing along the plots from a westerly direction. Air temperature (ground level, 220mm and 1m aboveground) and relative humidity were measured immediately prior to burning with a whirling psychrometer. The wind velocity was recorded during the fire with a hand anemometer held at a height of approximately 1.7m. Wind velocities recorded during the fire were assessed to be the most representative for that time of the year.

The mean height of the flames (m) was estimated visually once the fire was burning uniformly. The rates at which the fire moved over the plot were also measured. Basal cover and botanical composition were determined with a bridge-point apparatus, where 500 points (nearest plant and strikes) were recorded per plot before the fire and at the end of the two growing seasons following burning.

Fuel load included the aboveground phytomass as well as the litter just before burning (August). Firstly the litter (dead plant parts separate from grass tufts) was hand-raked in 10 quadrats ($1m^2$ each) randomly placed in control plots, adjacent to the burning plots. After that, in the same plots, the aboveground phytomass production component, comprising the previous seasons production, was measured by cutting the grass to soil level. In the laboratory, the litter was washed under running water over a 2mm sieve to get rid of attached soil particles. Harvested materials were oven-dried at 90°C for 72 hours before being weighed. Care was taken that the annual litter collection and production measurements took place in a new area each time by marking it with steel pens.

Seasonal herbage production or regrowth from burnt grassland and control plots were determined by clipping the plants in 10 quadrats ($1m^2$ each) randomly placed to a height of 30mm in each plot at the end of the growing season (April). The relation between aboveground phytomass production loss due to fire, and two independent variables namely, seasonal rainfall and fuel load were examined. Multiple regression analysis was used to analyse the seven years' data. The fuel load before burning and the season's rainfall following the burning were regressed on the seasonal production loss due to burning (seasonal unburnt production minus regrowth of burnt grassland).

Results and discussion

Fire behaviour

The long-term average aboveground phytomass production of the study area is 1692 (range: 2678 to 613)kg/ha/a (1977/78 to 1996/97 growing season: Snyman 1998, and 1995/96 to 1998/99 growing season: Snyman 1999) compared to the 1740kg/ha/a on average for the seven years preceding burning in this study. Therefore, the fuel load approached the long-term loads for the study area.

The average air temperatures over the study period measured at ground level, 220mm and 1m aboveground during the fire were 12.2^{0}C ($\pm 1.5^0$), 15.4^{0}C ($\pm 1.8^0$) and 17.3^{0}C ($\pm 1.9^0$) respectively. The relative humidity varied over the study period between 42 and 49%. The average wind speed over the study period was 3.2 (±0.6)m/s. The flames of the fire reached an average flame height of 1.1m. The head fires move on average 4.7m/min over the plots. Building the above-mentioned parameters as obtained in this study into the fire behaviour model of Trollope (1999), the predicted fire intensity should have been 1145k/J/s/m^2. Therefore, the fire intensity was a moderately hot fire.

Basal cover and botanical composition

The head fire caused a decrease ($p \leq 0.01$) in basal cover of 39% over the first season after burning (Figure 1). Two growing seasons following the fire, the basal cover was still 22% less ($p \leq 0.01$) than that of unburnt grassland (Figure 1).

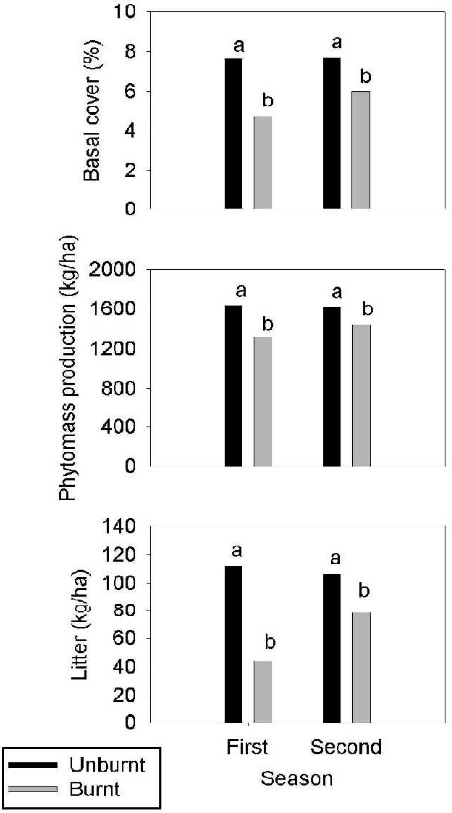

Figure 1: *Average basal cover (%), aboveground phytomass production (kg/ha) and litter production (kg/ha) for the unburnt and burnt (first season and second seasons after burning) grassland over the 1996/97 to 2001/2002 growing seasons. Bars with letters in common within seasons are not significantly different at the 1% level.*

The fire did not influence the botanical composition drastically. The climax grasses like *Cymbopogon plurinodis*, *Elionurus muticus* and *Themeda triandra* were influenced most by fire, with a decrease in species composition of 8, 9 and 13 percentage points respectively. The subclimax *Eragrostis chloromelas* grass increased in species composition after the fire by 4%.

Aboveground phytomass production

The rainfall varied between 319 and 689mm, with three years above the long-term average of 560mm for the study area. The average seasonal production or regrowth of the burnt and unburnt grassland differed significantly ($p \leq 0.01$) from each other for both seasons following the fire (Figure 1). This was also the case for all growing seasons within the study period. Over the first and second seasons following the fire, the burnt grassland produced on average 23% and 12% respectively less over the study period than unburnt grassland (Figure 1). According to most researchers burning clearly reduces yield in the summer immediately following the burn treatment (Everson 1999; Morris and Fynn 2001). In the Tall Grassveld of KwaZulu-Natal, for example, December yields following spring burning averaged only about 40% of those recorded after mowing. By February, however, differences between burnt and mown rangeland had declined to between 10% and 35%, and the next season differences were even less pronounced (Everson 1999). The decrease in production due to fire in this study was still evident ($p \leq 0.01$) after two growing seasons, for all seven studied seasons. Production losses due to fire, which is also a function of seasonal rainfall (between 319mm and 687mm) varied between 225kg/ha and 430kg/ha.

Litter

Fire decreased ($p \leq 0.01$) litter for both growing seasons following the fire (Figure 1). As expected, an increase in litter occurred in burnt grassland due to the increase in plant cover and production with the onset of the growing seasons following the fire. The litter was still 27% less ($p \leq 0.01$) on average due to the burning treatments, after two growing seasons. Similarly other researchers also found a significant decrease in litter after burning (Blank *et al.* 1994; Snyman 2003a).

The average litterfall from the unburnt grassland of 109kg/ha in this study, is far less than the 750kg/ha from semi-arid *Astrebla pectinata* grassland in Australia (Ingram 2002). As a proportion of annual phytomass production of the unburnt grassland, average litterfall of 6.7% in this study, is less than from other semi-arid rangelands of 16% (*Astrebla pectinata* grassland: Ingram 2002), 11% (*Themeda triandra* grassland: Ingram 2002), 9% (*Eragrostis xerophila* grassland: Ingram 2002). In most arid and semi-arid grasslands, litter turnover is very slow (Whitford *et al.* 1988).

Relation between production loss due to fire, fuel load of unburnt grassland and seasonal rainfall

The significant ($p \leq 0.01$) multiple linear regressions obtained for one and two seasons after the fire, are presented separately in Figure 2. For one and two years after an accidental fire, the production losses can be respectively estimated by 81% and 79% accurately (Figure 2) if the fuel load before burning is determined or known. Figure 2 clearly indicated that the higher the fuel load before burning, the greater the production loss due to fire. Grassland that has been burnt appeared to be inefficient in using higher quantities of water to benefit aboveground phytomass production, whereas unburnt grassland appeared to be more effective in this regard.

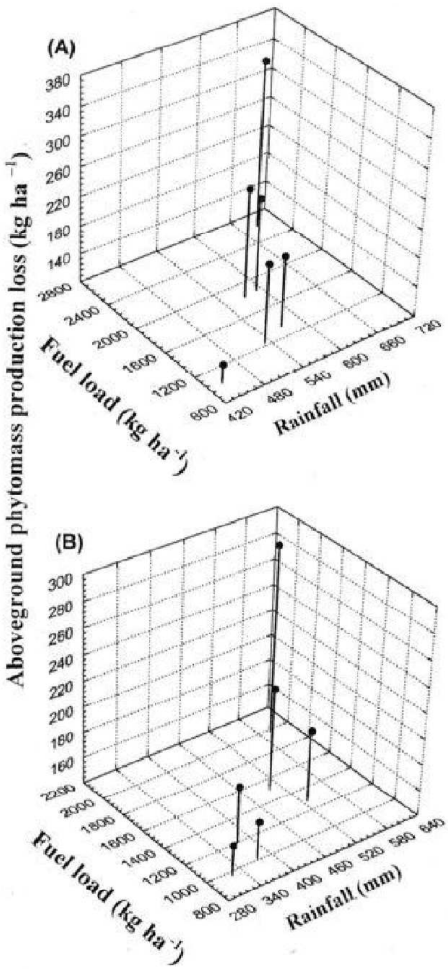

Figure 2: *Relationship between seasonal aboveground phytomass production loss due to burning (kg/ha), seasonal rainfall (mm) and fuel load (kg/ha) without burning (n=6). (A) relation for one year after burning and (B) relation for two years after burning, illustrated as a scatterplot.*
Equations where x_1=seasonal rainfall and x_2 = fuel load without burning, are:

$$A: y = -118.00 + 0.46x_1 + 0.05x_2 \quad (r = 0.90; p \leq 0.01)$$
$$B: y = 49.55 \;\; 0.07x_1 + 0.14x_2 \quad (r = 0.89; p \leq 0.01)$$

The simple linear regressions obtained between aboveground phytomass production loss due to fire, with seasonal rainfall, and aboveground phytomass production without fire (fuel load), is presented in Table 1 for the first and second season after burning.

Table 1: *Relationships between aboveground phytomass production loss due to fire (y), with seasonal rainfall or fuel load before burning, for two growing seasons after burning (n=6). **1% level of significance and *5% level of significance.*

	Equations			
Seasons after burning	**Seasonal rainfall (mm)**	**r**	**Fuel load (kg/ha)**	**r**
First	y=0.80x - 226.89	0.95**	y=0.11x+46.39	0.98**
Second	y=0.36x +40.65	0.87*	y=0.12x +42.53	0.99**

The high correlation (r = 0.95 average for the two seasons) between seasonal rainfall and fuel load indicated that production increases with higher rainfall, in turn leading to an increase in production loss due to fire.

Conclusions

The study clearly pointed out the negative impact of fire on the basal cover, which was still lower than that of unburnt grassland after two growing seasons. The decrease in plant cover and litter exposed the soil surface to assault by the natural elements and must be considered in management programmes.

It was clear from the results that the decrease in production due to fire in semi-arid grasslands could still be evident after two growing seasons following the fire. Production losses due to fire, which is also a function of the amount and distribution of the rainfall, can vary between 225kg/ha and 430kg/ha. The necessary knowledge of the influence of fires on productivity is important for adjusting stocking rates and ensuring sustainable utilisation of the grassland ecosystem. Although the findings in this study are based on only seven years of observations, these significant relations between production loss due to fire, rainfall and fuel load can therefore serve as a simple empirical model for managers in obtaining short-term production loss due to fire. This information can also serve as scientific guidelines in estimating production claims for damages in case of negligent grassland fires.

If the burnt grassland in this study has also been grazed, the decrease in production may be much higher with a longer recovery period. Fire can seldom be isolated from its association with grazing and therefore further in depth research on grazing management following burning is important for the stability and sustainable utilization of semi-arid grasslands.

References

Blank RR, Leah A and Young JA 1994. Soil heating, nitrogen, cheatgrass and seedbed microsites. Journal of Range Management 47**:** 33-37.

Everson CS 1999. Veld burning in different vegetation types. In: Tainton NM (ed.). Veld management in South Africa. University of Natal Press, Pietermaritzburg, South Africa, 472 pp.

Ingram LJ 2002. Growth, nutrient cycling and grazing of three perennial tussock grasses in the Pilbara region of NW Australia. PhD thesis, University of Western Australia, 280 pp.

Morris C and Fynn R 2001. The Ukulinga long-term grassland trials: reaping the fruits of meticulous, patient research. Bulletin Grassland Society of Southern Africa 11(1): 7-22.

Snyman HA 1998. Dynamics and sustainable utilization of the rangeland ecosystem in arid and semi-arid climates of southern Africa. Journal of Arid Environments 39: 645-666.

Snyman HA 1999. Quantification of the soil-water balance under different veld condition classes in a semi-arid climate. African Journal of Range & Forage Science 6 (2 & 3): 108-117.

Snyman HA 2003a. Short-term response in productivity following an unplanned fire in a semi-arid rangeland of South Africa. Journal of Arid Environments 56:465-485.

Snyman, HA 2003b. Fire and the dynamics of semi-arid grassland: influence on plant survival, productivity and water-use efficiency. African Journal of Range and Forage Science 20(1): 29-39.

Trollope WSW 1999. Fire behaviour. In: Tainton NM (ed.). Veld management in South Africa. University of Natal Press, Pietermaritzburg, South Africa, 472 pp.

Whitford WG, Stinnett J and Anderson J 1988. De-composition of roots in a Chihuahuan desert ecosystem. Oecologia 75: 8-11.

Zacharias PJK and Danckwerts JE 1999. Management of humid grasslands after burning in southern Africa. In: Proceedings VI International Rangeland Congress, Townsville, Australia 1: 527-528.

OPINIONS

G'day Alan

Am not sure if this is what you want but it is worth a try to see if I can start some sort of discussion forum? So here goes...

Cheers

Eugene Moll

I have been in the plant ecological field for several decades and my interests have been many and varied. As I come to the end of my active research life I am focussing down and am most interested in two topics/problems:

1. Management of small nature reserves, particularly those that are fragments of once much larger ecosystems. There are particular difficulties with managing such areas, and I would like to correspond to others who have a similar interest - and with those who have some experience managing such areas. My observations are that such reserves, once set aside, are then NOT MANAGED adequately.

Let me give one example of some Strandveld vegetation (now called Sub-Tropical Thicket) near Melkbosch Strand just north of Cape Town (in the modern era almost contiguous with the greater UniCity). From 1982 to 1992 I took my third year population and community plant ecology students to this area annually in February for them to collect structural/functional data of the higher plants. In those times the structure of the vegetation consisted of some 50-60% canopy cover of short thicket (average height about 1m) of evergreen (with some deciduous) shrubs, some spinecscence, mainly of a sub-tropical origin but with many Cape endemic species (examples are *Olea exasperata* and *Euclea racemosa*, others being *Rhus* spp., *Maytenus heterophylla*, *Putterlickia pyracantha*, *Cussonia thrysiflora*, etc.). In the gaps between the thicket clumps there were with sandy "pathways" that had some perennial dwarf succulents and in spring were filled with annuals and geophytes.