The potential of burning and grazing intensity management for rangeland improvement.

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Abstract

A study was carried out to assess the effect of eight burning and grazing intensity treatment combinations on rangeland vegetation attributes. The number of grass species was significantly higher in the unburned than in the burned treatments and declined as grazing intensity increased from zero to heavy levels. Basal cover in all treatments increased throughout the season and declined with increase in grazing intensity ($P < 0.05$). Litter weight significantly increased with grazing intensity in unburned treatments. The increase in biomass was highest in the burned treatment followed by moderate grazing intensity treatment in the mid and late growing seasons ($P < 0.05$). The number of seedlings and flower heads significantly increased with grazing intensity in burned treatments throughout the season. Burning followed by moderately intense grazing treatment had the highest seedling, flower heads and biomass values and it was concluded that this treatment might have the potential to enhance rangeland condition. The range of grazing intensities that result in these positive effects needs to be further investigated over longer periods to allow more flexible grazing management options to be developed.

Keywords: Burning, increaser, rangeland, seed, species composition, vegetation

Introduction

The rangeland ecosystems of southern Africa are diverse and extremely vulnerable (Trollope, 1993). Past experience in rangeland development efforts has created growing awareness about the fragility of the rangelands and the extent of irreversible deterioration that is taking place (Tainton, 1999). Rangeland deterioration is evidenced by declining forage yields, decreasing vegetation cover and changes in plant species composition (Elliot and Folkertsen, 1961). Other indicators of poor rangeland status are soil erosion, decreased soil water availability, and declining livestock productivity levels, which may lag behind deterioration in vegetation or soil attributes (Patton and Nyren, 2004). Rangeland deterioration results in loss of biodiversity, unemployment, poverty and other economic stresses (Trollope, 1989). It 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 (Ringrose and Matheson, 1987).

In southern Africa, the relationships between livestock management practices and rangeland attributes have rarely been quantified and have often been misinterpreted or misunderstood and technological interventions have often been inappropriate (Bebawi and Campbell, 2002). Rangeland deterioration will continue and animal production will decline further unless holistic remedial measures are taken. 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 put into practice (Tainton, 1999). Although burning and grazing intensity management have a low ability to dramatically improve rangeland they are not labour-intensive and are widely applied cost-effective approaches that can be used to reverse or decelerate rangeland vegetation deterioration (Trollope, 1993; Fuhlendorf and Eagle, 2004).

There is a marked interaction between grazing intensity and the effectiveness of fire in maintaining savanna rangelands (Bailey, 1986). Heavy grazing intensities reduce the amount of fuel available for burning as well as the competition between grasses and the bush. This leads to ineffective fires and rapid bush encroachment (Patton and Nyren, 2004). Light grazing intensities are necessary for maintaining the vigour of the grasses and serves to prepare the fuel for the fire, which is required to control the advance of the plant succession (Malechek, 1984). A combination of fire and grazing intensity leads to marked improvement in rangeland condition, forage and animal productivity when compared to the use of fire and grazing intensity separately (Fuhlendorf and Eagle, 2004). Burning and grazing intensity treatments have the potential to manipulate rangeland vegetation to favour optimum forage and animal productivity (Holechek and Galt, 2000; Fuhlendorf and Eagle, 2004). The objective of this study was to assess the effect of burning and grazing intensity on rangeland vegetation attributes at the University of Zimbabwe (UZ) farm.

Materials and methods

Study site

The study was run at the University of Zimbabwe (UZ) farm, 13 km North-west of Harare. It lies between longitudes 31° 5' and 32° 0' E and latitudes 17° 5' and 18° 0' S at an altitude of 1420 m. It is in agro-ecological zone IIa that is characterized by mean annual rainfall of 825 mm (range between 600 to 1200 mm); the rain season stretches from November to March. Ambient temperatures fluctuate between 7 °C and 29 °C, with minimum and maximum temperatures recorded in June and October, respectively (UZ farm guide, 1988). The farm has deep well-drained granular clay soils and occupies a total area of 1 805 ha of which 800 ha are rangelands dominated by perennial increaser grass species namely: *Loudetia simplex, Heteropogon contortus, Cynodon dactylon* and *Sporobolus pyramidalis* (tussock-forming), and *Hyparrhenia filipendula* a decreaser. The most common tree species on the farm include *Brachystegia* species, *Julbernardia globiflora* (Munondo) and *Combretum molle* (Mupembere). Cattle are grazed in summer and given maize stover and supplementary feeds in winter in addition to grazing. Rotational grazing is practised on 13 paddocks at an average stocking rate of 1 Livestock Unit (LU) ha^{-1} throughout the grazing season and there have been reports of deteriorating rangeland condition (Personal communication UZ farm livestock manager).

Experimental procedure

Two burning levels and four grazing intensity levels were tested in a completely randomized block design with eight treatments (Table 1). All treatments were allocated 0.2 ha and replicated twice. Burning was done between 0800 and 0900 hours on the 25th and 26th of November 2003 when the maximum temperatures at the time of burning were 27 °C and 28 °C, respectively. Average relative humidity and wind velocity for the two days were between 50 to 60 % and 4 to 6 mph, respectively. Average fuel in the study plots was 2000 kg DM ha^{-1} and flame heights during burning ranged from 0.5 to 1 m above the ground. Grazing intensity was defined by stocking density and grazing period (Table 1). The minimum forage biomass allocated to the grazing animals was 600 kg DM ha^{-1} and available forage was estimated by clipping using a sward height of 25 cm. The periods of grazing were adjusted depending on the quantity of available biomass. Dairy heifers and steers with a weight of 450 kg were used. Grazing occurred between December 2003 and March 2004.

Data collection

Three 30 m long transects were randomly positioned in each treatment and ten 0.25 m^2 quadrats were placed 3 m apart along each transect for sampling of all rangeland vegetation attributes in December 2003, February 2004 and March 2004. Sampled quadrats were marked to avoid sampling the same quadrat more than once. Rangeland condition was assessed using grass species composition, basal cover, litter weight and herbaceous above-ground standing biomass. Grass persistence assessment included seed viability, seed and seedling production.

Grass species composition

The Ecological Index method (Vorster, 1982) in which the grasses are classified into ecological categories namely; increasers, decreasers and invaders and weighted was used for grass species composition assessment. The total score for the species composition was calculated as the sum of products of species relative abundances multiplied by their weights (Camp and Hardy, 1999).

Herbaceous basal cover and litter weight

The longest and shortest diagonal distances across each plant base in a quadrat were measured and averaged to estimate plant diameter. Basal cover was computer calculated using the formula πr^2; where π = 3.14 and r = radius. The sum basal cover for each quadrat was expressed as a percentage of the quadrat area.

Table1: Burning and grazing intensity treatment combinations

Burning	Stocking density	Grazing periods			Grazing intensity
		Early (Dec)	Mid (Jan-Feb)	Late (Mar-April)	
No	Zero $haLU^{-1}$	-	-	-	Zero
Yes	Zero $haLU^{-1}$	-	-	-	Zero
Yes	0.2ha LU^{-1}	2 days (2hrs day^{-1})	4 days (2hrs day^{-1})	2 days (2hrs day^{-1})	Light
Yes	0.2ha LU^{-1}	2 days (4hrs day^{-1})	4 days (4hrs day^{-1})	2 days (4hrs day^{-1})	Moderate
Yes	0.2ha LU^{-1}	2 days (6hrs day^{-1})	4 days (6hrs day^{-1})	2 days (6hrs day^{-1})	Heavy
No	0.2ha LU^{-1}	2 days (2hrs day^{-1})	4 days (2hrs day^{-1})	2 days (2hrs day^{-1})	Light
No.	0.2ha LU^{-1}	2 days (4hrs day^{-1})	4 days (4hrs day^{-1})	2 days (4hrs day^{-1})	Moderate
No	0.2ha LU^{-1}	2 days (6hrs day^{-1})	4 days (6hrs day^{-1})	2 days (6hrs day^{-1})	Heavy

*All 2 and 4 days grazing periods were followed by a 7-day rest period.
*LU = an animal with a mass of 450 kg.

Litter was defined as the uppermost layer of organic debris on the soil surface or essentially as the freshly fallen or slightly decomposed vegetal material (Sutherland, 2000). Plant litter was manually collected from thirty quadrats in each treatment. Fresh litter weight was measured in the field using a spring balance. It was then packed in plastic bags and stored in refridgerator overnight at 5 °C. The litter was then dried to a constant weight in an oven at 60 °C for 48 hrs to determine dry weight using a mettler scale.

Above-ground herbaceous biomass production

Above-ground herbaceous biomass in a quadrat was cut to ground level using shears and fresh weight was measured using a spring balance. The biomass was then packed in plastic bags and stored in refrigerators at 5 °C overnight. Dry weight was determined by drying the biomass to a constant weight in an oven at 60°C for 48 hrs.

Seedling production

A seedling refers to a young herbaceous plant that is generally less than 5 cm high or a newly sprouted plant (Sutherland, 2000). The number of seedlings was estimated by physically counting the seedlings in each of the thirty quadrats.

Seed production

Intact seeds and flower heads were harvested from all plants in each quadrat and manually counted. A soil core with a diameter of 10 cm and a depth of 3 cm was used to sample fallen seeds for counting. Viable seeds are strongly concentrated in the top 3 cm of the soil and these are the seeds most likely to be recruited into the community (Sutherland, 2000). Soil core samples were randomly collected within quadrats and packed in plastic bags to avoid seed loss or contamination.

Germination tests were carried out on soil samples to determine seed viability. Soil core samples for each quadrat were thoroughly mixed, and two kilograms of soil were taken and spread over a seed tray and put in a glasshouse protected from herbivores and contamination by air-borne seeds. The trays were watered twice weekly and monitored daily whereby any seedlings that emerged were counted, identified where possible and then uprooted. The number of flower heads was estimated by physically counting the flower heads in each quadrat.

Statistical analysis

The data were subjected to analysis of variance using the Generalised Linear Model (GLM) of the SAS (1998). The model fitted the effects of burning (no burning and burning), grazing intensity (zero, light, moderate and heavy), time of sampling (December, February and April) and their interactions. The analyses were carried out on the records of dependant variables, which were measured for each treatment throughout the study period. These included number and frequency of grass species, basal cover percentage, litter weight, above-ground biomass, number of seeds, seedlings and flower heads, and seed viability percentage. Where F-tests were significant, Least Square Means were used for mean separation.

Results

Grass species composition

There was significant (P < 0.05) interaction between grazing intensity and burning treatments. The number of grass species was significantly higher in the unburned than in the burned treatments and declined as grazing intensity increased from zero to heavy levels (Table 2). Generally, the number of grass species increased from December to February and then declined towards April. Burning followed by moderate grazing intensity and burning followed by heavy grazing intensity treatments had the lowest (41.47 %) and highest (73.58 %) frequency of *S. pyramidalis,* respectively. The frequency of decreaser species was highest in burned, lightly grazed treatments and it declined throughout the season (P < 0.05). On average, for all treatments decreasers had a very low relative abundance of (11.68 %) compared to increasers (88.32 %)(P < 0.05) (Table 3). The dominant increaser species were *S. pyramidalis* (56.04 %*), H. contortus* (16.02 %) *and C. dactylon* (12.26 %). Overall species composition score was 29 % of that expected for the original climax vegetation (Camp and Hardy, 1999).

Herbaceous basal cover and litter weight

The interaction between burning and grazing intensity was significant for both basal cover and litter weight. Basal cover was higher (P < 0.05*)* in the unburned, lightly grazed treatments than in the burned, heavily grazed ones in early growing season but was the same in all treatment in mid and late growing season (Table 4). Litter weight was higher and increased with grazing intensity from zero to heavy levels in unburned treatments than in burned ones (P < 0.05). Fresh and dry litter weight values ranged from 0.5 to 10.5 kg ha^{-1} and 0.42 to 9.3 kg ha^{-1}.

Table 2: Grass species, ecological status and their relative abundances.

Grass species	Ecological status	Weighting	Relative abundances %
Acroceras macrum	Decreaser	10	0.9
Brachiaria brizantha	Decreaser	10	0.9
Chloris gayana	Decreaser	10	0.2
	Decreaser	10	2.17
Cynodon nlemfluensis			
Digitaria milanjiana	Decreaser	10	0.1
Hyparrhenia filipendula	Decreaser	10	3.31
Hyperthelia dissoluta	Decreaser	10	1.1
Rhynchelytrum repens	Decreaser	10	0.5
	Decreaser	10	1.2
Setaria anceps			
Panicum maximum	Decreaser	10	1.3
	Decreasers total frequency		*11.68*
Aristida congesta	Increaser III	1	1.6
Cynodon dactylon	Increaser II	4	12.26
Eragrostis curvula	Increaser I	6	1.2
Heteropogon contortus	Increaser II	4	16.02
Loudetia simplex	Increaser III	1	1.2
Sporobolus pyramidalis	Increaser III	1	56.04
	Increasers total frequency		**88.32**
Total score		**295.96**	
Maximum possible score		***(10 x 100) = 1 000**	
Overall grass species composition score		**(295.96/1 000) = 29% (poor)**	

**10 = Maximum weighting*
**100 = Total frequency*

Table 3: The effect of burning and grazing intensity treatments on the number of grass species in the early, mid and late growing season

Treatment	Number of grass species (Mean ± se)		
	Month of sampling		
	December	*February*	*April*
No burning followed by zero grazing intensity	330 ± 44^{b1}	390 ± 52^{b2}	360 ± 41^{b1}
Burning followed by zero grazing intensity	210 ± 22^{a1}	240 ± 12^{a2}	210 ± 21^{a1}
Burning followed by light grazing intensity	180 ± 1^{a1}	240 ± 11^{a2}	240 ± 12^{a2}
Burning followed by moderate grazing intensity	150 ± 9^{a1}	210 ± 21^{a2}	180 ± 11^{a1}
Burning followed by heavy grazing intensity	150 ± 8^{a1}	210 ± 21^{a2}	150 ± 9^{a1}
No burning followed by light grazing intensity	330 ± 43^{b1}	390 ± 53^{b2}	360 ± 43^{b3}
No burning followed by moderate grazing intensity	300 ± 33^{b1}	360 ± 42^{b2}	330 ± 32^{b3}
No burning followed by heavy grazing intensity	300 ± 32^{b1}	360 ± 42^{b2}	300 ± 31^{b1}

[ab] Least Square means with different superscripts within a column are significantly different.
[123] Least square means with different superscripts within a row are significantly different

Table 4: The effect of burning and grazing intensity treatments on basal cover percentage

Treatment	Basal cover percentage (Mean ± se)		
	Month of sampling		
	December	*February*	*April*
No burning followed by zero grazing intensity	15.6 ± 1.7^{a1}	36.9 ± 3.8^{a2}	46.4 ± 5.8^{a3}
Burning followed by zero grazing intensity	7.5 ± 2.4^{b1}	34.3 ± 3.3^{a2}	44.5 ± 5.3^{a3}
Burning followed by light grazing intensity	7.2 ± 1.9^{b1}	33.9 ± 3.1^{a2}	43.5 ± 5.1^{a3}
Burning followed by moderate grazing intensity	7.0 ± 1.4^{b1}	32.2 ± 2.9^{a2}	42.9 ± 4.9^{a3}
Burning followed by heavy grazing intensity	6.9 ± 1.3^{b1}	31.6 ± 2.3^{a2}	45.7 ± 5.3^{a3}
No burning followed by light grazing intensity	14.9 ± 2.8^{a1}	36.4 ± 3.8^{a2}	43.9 ± 5.8^{a3}
No burning followed by moderate grazing intensity	14.5 ± 2.4^{a1}	33.3 ± 2.3^{a2}	44.5 ± 5.3^{a3}
No burning followed by heavy grazing intensity	14.3 ± 2.1^{a1}	32.9 ± 2.6^{a2}	43.8 ± 5.6^{a3}

[ab] Least Square means with different superscripts within a column are significantly different.
[123] Least Square means with different superscripts within a row are significantly different.

Above-ground herbaceous biomass production

A significant grazing intensity and burning management treatments interaction was recorded. The biomass was highest in the burned treatment followed by the moderate grazing intensity treatment in the mid and late growing seasons ($P < 0.05$) (Table 5). The above-ground dry herbaceous biomass for all treatments significantly increased from early to late growing season.

Seedling production

There was significant interaction between burning and grazing intensity ($P < 0.05$) treatments. Burning followed by moderately intense grazing treatment had the highest number of seedlings (990 m^2) in the early growing season. The overall number of seedlings recorded varied from 1.5 to 990 per m^2. The number of seedlings decreased as the season progressed in all treatments ($P < 0.05$).

Table 5: The effect of burning and grazing intensity treatments on the aboveground standing biomass

Treatment	Aboveground dry biomass (kg DMha^{-1}) (Mean ± se)		
	Month of sampling		
	December	*February*	*April*
No burning followed by zero grazing intensity	1940±280^{a1}	4940±540^{a2}	4931±520^{a2}
Burning followed by zero grazing intensity	999±180^{b1}	3925±490^{a2}	7367±640^{b3}
Burning followed by light grazing intensity	420±120^{b1}	4420±440^{a2}	7354±620^{b3}
Burning followed by moderate grazing intensity	770±150^{b1}	4950± 510^{a2}	7600± 690^{b3}
Burning followed by heavy grazing intensity	720 ± 148^{b1}	4720± 480^{a2}	7300± 680^{b3}
No burning followed by light grazing intensity	2090±340^{a1}	4060±420 ^{a2}	5808 ±580^{a2}
No burning followed by moderate grazing intensity	2800±360^{a1}	5210±560 ^{a2}	5863± 590^{a2}
No burning followed by heavy grazing intensity	3160±390^{a1}	4250±430 ^{a2}	4323±580^{a2}

[ab] Least Square means with different superscripts in a column are significantly different.
[123] Least Square means with different superscripts in a row are significantly different.

Flower heads

Burning followed by moderate grazing intensity treatment had the highest number of flower heads. The number of flower heads rose significantly from December to April in all treatments ($P < 0.05$). *S. pyramidalis* (60 %) and *C. dactylon* (20 %) contributed significantly to the total flower heads counted. In viability tests, there was no seed germination observed in any of the soil samples collected.

Discussion

Grass species composition

The increase in the frequency of increasers from early to late growing season can be partially attributed to the recruitment of increaser seedlings and selective grazing. The low grass frequencies in burned and heavily grazed treatments can be ascribed to fire consumption and partly to greater defoliation (Fuhlendorf and Eagle, 2004). This may also have been due to other factors that affect species diversity, such as biomass production that increases with species diversity and reaches a peak in the mid growing season and then declines during the late growing season (Voster, 1982). It can also be ascribed to selective grazing which might have led to overgrazing of fresh post-fire growth. Cattle have a tendency to select and graze fresh plant material from burned treatments compared to the unburned ones (Trollope, 1993). Fresh green shoots of new growth on burned rangelands are palatable and high in crude protein (Bebawi and Campbell, 2002).

Herbaceous basal cover and litter weight

A basal cover of 11 % in the early growing season was slightly below the 12 to 14 % reported by Tainton (1999) and Voster (1982) in southern African savanna rangelands. The increase in basal cover observed in the mid and late growing season for all treatments was attributed to the combined effects of seed germination, growth of tillers, defoliation and domination by the tufted *S. pyramidalis*. Although there was significant interaction between burning and grazing intensity there were no clear differences observed between varying levels of grazing intensity. This may suggest that the grazing effect was not heavy enough or the study period was not long enough to manifest the effect of grazing intensity.

Litter weight values of 0.42 to 10.60 kg ha^{-1} obtained in this study are in the range of the results of van Wilgen, Andrea, Goldammer and Lindeysay (1997) in Southern African savannas that varied from 0.40 to 12.00 kg ha^{-1}. High litter weights observed in unburned and heavily grazed treatments may be ascribed to selective grazing or low biomass harvest efficiency. High litter weights negatively affect seed germination, tiller growth and biomass production (Bebawi and Campbell, 2002).

Above-ground herbaceous biomass production

The biomass figures obtained are higher than other findings of Elliot and Folkertsen (1961) at Henderson Research Station, (8 km north of UZ farm), where biomass production increased from 599 kg DM ha^{-1} in

December to 3 243 kg DM ha^{-1} in April. The elevated aboveground biomass production observed in the burned, moderately grazed treatment can be attributed to increases in soil temperature, compensatory growth in the burned treatments and good rainfall (985 mm) received during the study period. The effect of fire may be direct or may result indirectly from increased microbial activity and mineralisation of the soil and organic matter (Trollope, 1993). Low biomass production in unburned and lightly grazed treatments may be a function of the higher amount of litter and dead standing plant material that may signify that both non-use and overuse of rangelands in the long-term can be detrimental to its productivity.

Seedling production

Seedling production in this study concurs with the results of Trollope (1993) in southern Africa, which varied from 8 to 120 seedlings per m^2. There was a decrease in number of seedlings from December to April probably due to the increase in competition as plants grew or to a decline in the soil seed bank. Direct effects that stimulate seeds to germinate and indirect effects that provide a more favourable environment for germination to occur may have caused the observed burning and grazing intensity interactions in the early growing season. 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 (Malechek, 1984). High numbers of seedlings can also be attributed to the defoliation effect of altering the balance between replacement by seedling and replacement by vegetative buds. Grazing animals affect the accretion of seed to soil reserves directly by prehension of flowers or seeds in different stages of development (Holechek and Galt, 2000).

Flower heads

The number of flower heads, types of seeds and seedlings present in a rangeland indicate the type of plant species that will persist (Pandey, 1988; Voster, 1982). The greater contribution of increasers to total number of flower heads observed in this study signifies poor rangeland condition that may continue to deteriorate if current management practices continue. The increase in the number of flower heads with increase in grazing intensity in burned treatments can be ascribed to improved seed germination and tillering due to removal of dead plant material, treading and fouling which reduced flower head consumption by cattle. The decrease of flower or head numbers with increase in grazing intensity in unburned treatments could have been partly due to high values of litter volumes and partly to increasing defoliation. According to Bebawi and Campbell (2002) most seed germination occurs at the beginning of the rain season (November). No intact or fallen seed were harvested because most seeds were not mature enough to be identified and counted by the time of the last sampling. The absence of fallen seed can be attributed to seed consumption by fire or massive recruitment of the seed from the previous season's soil seed bank.

Conclusions

There was a significant interaction between burning and grazing intensity on rangeland condition and grass persistence attributes. Burning followed by moderately intense grazing was the most effective treatment in increasing the rangeland condition as indicated by the lowest frequency of *Sporobolus pyramidalis,* and the highest values of flower heads, seedlings and above-ground standing biomass. Burning followed by moderately intense grazing might have the potential to enhance rangeland condition. The range of grazing intensities that result in these positive effects needs to be further investigated over longer periods to allow for more flexible grazing management options to be developed.

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