Long term effects of fire frequency and season on the woody vegetation dynamics of the *Sclerocarya birrea/Acacia nigrescens* savanna of the Kruger National Park

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A lack of knowledge together with vacillating fire management approaches in the Kruger National Park until the mid 1950s, gave rise to a long term fire research experiment aimed at shedding light on savanna responses to various combinations of fire frequencies and seasons. This trial was laid out in 1954 in four of the six major vegetation zones of the park. With the future of the experiment now being reconsidered, full scale vegetation surveys have been conducted on all the plots and compared to the surveys done in 1954. This paper examines the woody vegetation responses to fourteen fire treatments in the Knobthorn/Marula savanna. Parameters of interest were woody species composition responses, together with tree & shrub density and structural changes. The results indicate that no significant changes in woody species had occurred for the period 1954 vs 1998, while density decreased on biennial and increased on triennial treatments. The proportion of single stemmed plants increased over the period. Season of burn has a marked effect on structure, with April and August burns giving rise to the largest basal areas but the lowest heights. Environmental parameters such as climate, varying herbivory and differing soils, and their respective interactions on vegetation morphology, together with fire behaviour, further influenced results.

Key words: fire, frequency, season, vegetation dynamics, savanna, *Sclerocarya birrea*, *Acacia nigrescens*.

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Introduction

According to Gertenbach (1979), burning was used between 1926 and 1954 to provide green grazing for wildlife in the Kruger National Park. This was followed by a period of fire suppression. In the mid 1950s systematic burning programs were introduced, and a fixed triennial burning program was applied for which the park was divided into more than 400 burning blocks. As part of the investigation reviewing the Kruger National Park's policy on fire management, it was decided in the mid 1950s that a comprehensive fire research experiment be conducted in the major veld types of the Kruger National Park. The stated objective of the program was to determine the effect of season of burning on the veld condition in the major veld types and although not specifically stated, but by implication, also the effect of frequency of burning (Van der Schijff 1958). The effect of fire on vegetation depends upon the combined effects of the different components of the fire regime, for example intensity of fire and season and frequency of burning. The effect of fire intensity on tree and shrub vegetation has been studied in the Kruger National Park, the results indicating that bush is very resistant to fire alone (Trollope *et al.* 1999). The effect of fire intensity on the top kill of bush was investigated in the Kruger National Park (Trollope *et al.* 1995), the results showing that there was a significantly greater topkill of bush with increasing fire intensities. According to West (1965), trees and shrubs are probably more susceptible to fire at the end of the dry season when the plant reserves are depleted due to new spring growth. However, the results of Trollope *et al*. (1995), showed that the mortality of bush in the Park was only 1,3 percent after fires that had been applied to bush ranging from dormant to actively growing plants. Conflicting results have been obtained on the effect of frequency of burning on the density of tree and shrub vegetation (Trollope *et al*. 1999). According to Van Wyk (1971), frequency of burning appears not to have any significant effect on the density of woody plants. The Kruger National Park has utilised a lightning-driven fire system since 1992 and with the possibility of closure of this experiment (Biggs & Potgieter 1999), it is all the more important that results of nearly half a century of experimentation be made available for guiding further decision making. The purpose of this paper is therefore, to yield more concrete evidence regarding the effect of fire, at least when applied on a fixed scale over time, in the hope that these insights will assist understanding under a wider range of circumstances.

Materials and Methods

Study Area

The vegetation of the *Sclerocarya birrea/Acacia nigrescens* savanna is characterised by open grassland with tall trees (Van der Schijff 1958). Gertenbach (1983), described 35 landscape vegetation types in the Kruger National Park, based on climate, geology, soils, vegetation and fauna, of which the *Sclerocarya birrea/Acacia nigrescens* savanna (landscape 17) is classified as a unique landscape. An average rainfall of 548 mm has been recorded for the Satara area (Gertenbach 1983). The Sabi River Basalt weathers to form a black, brown or red clayey soil and the soil depth normally does not exceed one metre. The terrain consists of flat plains with individual well defined drainage channels. Coetzee (1983), distinguished 14 different plant communities that represent different variations of the *Sclerocarya birrea/Acacia nigrescens* savanna. One of the more important communities of this landscape is the *Sclerocarya birrea/Acacia nigrescens/Themeda triandra/Bothriochloa radicans* – tree veld north of Tshokwane, which occurs throughout the study area, characterised by an open tree savanna with moderate to sparse shrub and a dense field layer. Other dominant tree species are *Lannea schweinfurthii* and *Combretum imberbe*.

Experimental layout

Four replicates, comprising fourteen treatments each, were placed between the Tshokwane and Satara area. The replicates, named Lindanda, Marheya, Nwanedzi and Satara were spread out within this veld type, in an attempt to achieve representivity. In every case the replicates were placed either next to an existing fire break or close to a tourist road (Gertenbach & Potgieter 1979). The replicates are protected from other fires by a double firebreak. The veld between the fire breaks is burnt annually during winter. According to Van der Schijff (1958), a randomised replicate design was used. However, treatments with identical frequencies have been grouped together within each replicate, perhaps because of a staggered start to the trial: in 1954, an initial seven treatments were laid out on each replicate, with a further five treatments being added during 1956. The final two treatments were laid out during 1979. The physical layout of replicates with treatments are listed in Table 1. Apart from the groupings mentioned above, treatments were randomly assigned, such that the spatial layout of treatments within each replicate was different. The plots are rectangular and measure approximately 360 m x 180 m, an area of approximately 7 ha (Trollope *et al*. 1999).

Field data collection

The botanical composition and structure of the woody layer was surveyed during 1998 using a belt transect method (Mueller-Dombois & Ellenberg 1974). Each of the transects were 2 m x 300 m, stretching across the two diagonals of the plots. A similar technique was used to record the baseline vegetation data prior to the start of the burning trial in 1954 (Van der Schijff 1954). All rooted woody plants within the transects were recorded on a species basis and classed as multi- or single stemmed. Height as well as basal diameter of stems at ground level were measured for each individual. In the case of multi-stemmed plants the basal diameter was recorded as the distance between the two outermost stems. Basal diameters were converted to circular basal areas to give an indication of woody biomass. Heights were grouped into three classes in order to assess structural differences between treat-

Table 1

Physical layout of burning treatments applied in the Knob thorn / Marula savanna

Year started	Satara	Nwanedzi	Marheya	Lindanda
1954	Aug. biennial	Aug. annual	Aug. biennial	**Fire exclosure**
	Fire exclosure	Apr. biennial	Apr. biennial	Aug. annual
	Dec. biennial	Aug. biennial	Aug. annual	Apr. biennial
	Oct. biennial	[a]Oct. quad./Feb.bien.	Feb. bien./[a]Oct. quad.	Aug. biennial
	Apr. biennial	Oct. biennial	Oct. biennial	Feb. bien./[a]Oct. quad.
	Feb.bien./ [a]Oct. quad.	Dec. biennial	Dec. biennial	Dec. biennial
	Aug. annual	**Fire exclosure**	**Fire exclosure**	Oct. biennial
1956	Dec. triennial	[a]Oct. sexen./Feb. trien.	Dec. triennial	Dec. triennial
	Aug. trien.	Oct. triennial	Apr. triennial	Oct. triennial
	Oct. trien.	Dec. triennial	Aug. triennial	Feb. trien./[a]Oct. sexen.
	[a]Oct. sexen./Feb. trien.	Aug. triennial	Oct. triennial	Apr. triennial
	Apr. triennial	Apr. triennial	Feb. trien./[a]Oct. sexen.	Aug. triennial

[a] October quadrennial and October sexennial treatments were initiated in 1979

ments as affecting the amount of available browse material. Thus the classes have been chosen to coincide with the mean browse heights of the more common antelope species: heights < 1.75 meter (Aepyceros melampus), between 1.75 and 2.75 meter (*Tragelaphus strepciseros*) and > 2.75 meter (*Giraffa camelopardalis*) (Smit 1996). Comparisons between 1954 and 1998 were limited by the fact that no tree or shrub heights and only classed basal diameters were recorded in 1954. Other data recorded in 1998 include height of lowest browse and elephant impact, although these have not been examined in this analysis. The distance from the centre of each plot to the nearest permanent water was determined from aerial photographs, in an attempt to include the effect of herbivory on the observed vegetation responses.

Data Analysis

Parameters examined were density responses, single versus multi-stemmed ratios, basal area, height and species composition responses. All data were tested for significant effects using analysis of variance. Each parameter was initially examined across all treatments and subsequently across a subset of the data for specific season and frequency effects. Data were log-transformed (where necessary), to correct for non-normal distributions. Tests on percentages were carried out on arcsine square-root transformed data. Counts in contingency tables were examined using the chi-squared test. Basal area was calculated as: Area = (½ diameter)^2. Density, basal area and tree height in relation to distance from permanent water were examined using linear regression analysis. Species community data were ordinated, using a principle component analysis model together with a redundancy analysis model.

Results

Trends in the density of woody vegetation

No simply discernible change in density between 1954 and 1998 was apparent. A *t*-test comparing the average densities in the two years yielded a downward trend, but only at $P = 0.2268$. However, the change in density between 1954 and 1998, (with density in 1954 as a covariate ($P < 0.00005$)), proved significant over the replicates ($P = 0.0004$), the treatments ($P = 0.0006$) and the interaction of these parameters ($P < 0.00005$). The Satara and Marheya replicates showed a decrease in density, differing significantly from the Nwanedzi and Lindanda replicates which showed no significant change in density over the period. Examined for separate effects of season and frequency of burn, the data (change in density between 1954 and 1998 being the response), show a non significant seasonal effect ($P = 0.3959$), as well as non significant interactions between season and both frequency and replicate. It was thus possible to examine the main effect of frequency across all treatment frequencies (annual, biennial, triennial and fire exclosure). With the density in 1954 as a

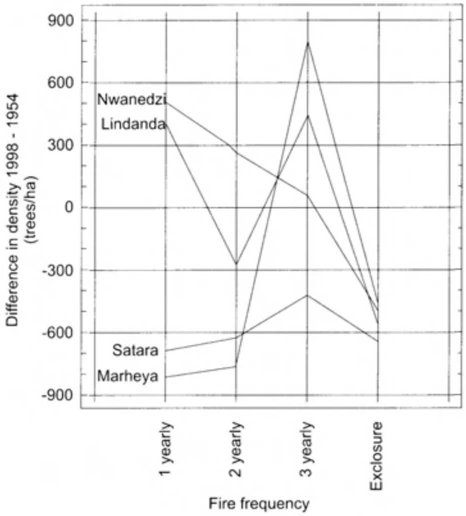

Fig. 1. Change in density of woody vegetation between 1998 and 1954, as a function of the interaction between fire frequency and replicate.

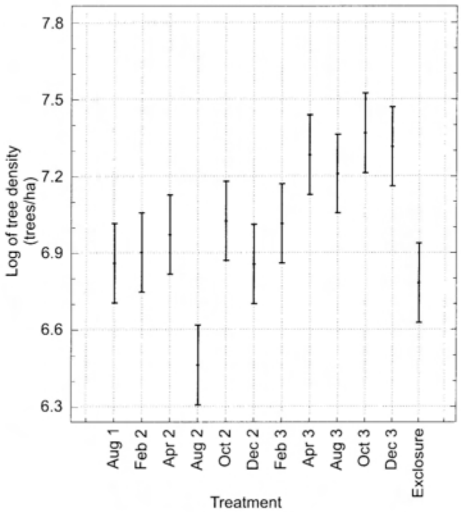

Fig. 2. 1998 tree density as a function of fire treatment (expressed as month of burn and frequency in years).

covariate (P = <0.00005), both frequency (P = <0.00005) and replicate (P = 0.0148) as well as their interaction (P = 0.0003) proved to have significant effects on the change in density over the period 1954 to 1998. Biennial fires resulted in decreased densities whereas triennial fires resulted in increased densities. The fire exclosure treatment yielded decreased densities, although not more so than the biennial burns. Figure 1 shows *inter alia* that density responses to fire (annual, biennial and triennial burns) differ across the replicates. However, all replicates have responded similarly to the fire exclosure treatment in that all have experienced a similar and significant decrease in density.

When the (log transformed) densities in 1998 are examined as the response variable, similar trends emerge, although the covariate (density in 1954) is not significant. Figure 2 shows the 1998 density of all woody species combined, as per fire treatment. Except for the August biennial treatment, which has a significantly lower density than any other treatment, there appears to be a trend of increasing density from annual to triennial burns, irrespective of season. Examined for separate season and frequency effects, 1998 densities differed significantly across replicates (P = <0.00005), frequency (P= <0.00005) and, in this case, also season (P = 0.0155). Biennial burns yield lower densities in comparison to triennial burns. August burns resulted in lower densities than April, October and December treatments. The season by frequency interaction is not significant (P = 0.0776), with all seasons experiencing increased densities between biennial and triennial burns. The replicate by season and replicate by frequency interactions proved to have significant effects on the 1998 woody densities. Linear regression analysis indicates a negative correlation between 1998 density and average species height (P = 0.00002, r^2 = 0.1528), indicating that when large numbers of individuals are present, heights tend to be lower. Further linear regression analysis indicates that there is no significant relationship between density per plot and distance to nearest permanent water (P = 0.10082, r^2 = 0.0491).

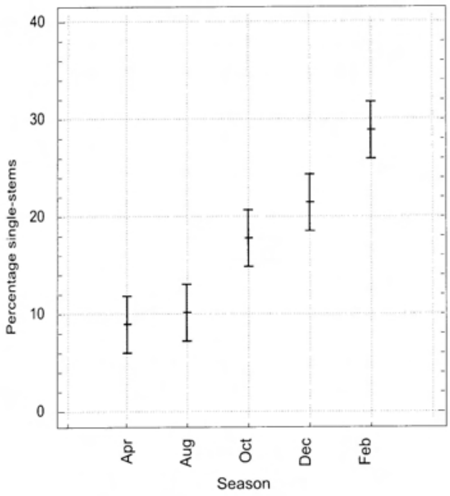

Fig. 3. Percentage of single-stems in the woody vegetation stand, as a function of season of burn.

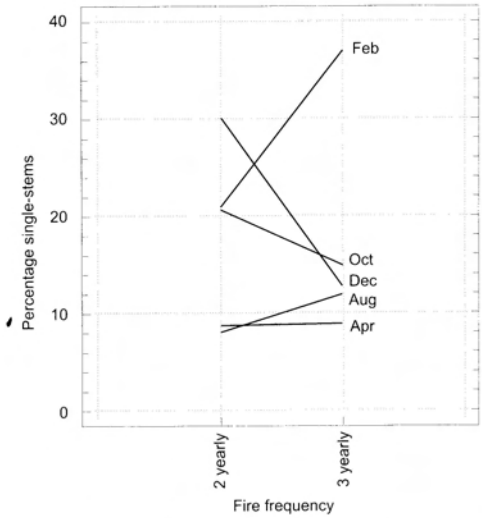

Fig. 4. Percentage of single-stems in the woody vegetation stand, as a function of the interaction between frequency and season of burn.

Percentage single versus *multi-stemmed individuals*

A chi-square test indicates that the ratio of the number of single to multi-stemmed individuals in 1998 is significantly different from the ratio in 1954 (P =<0.00005). Overall there has been a 6 % increase in single-stemmed individuals, from 10 % in 1954 to 16 % in 1998. The effect of different treatments on the percentage of multi-stemmed individuals is significant (P = <0.00005). Multi-stemmed plants constitute more than 75 % of the total on all treatments except the February triennial, December biennial and the fire exclosure. Figure 3 indicates the main seasonal effect on single-stemmed individuals (P = <0.00005), with a progressive increase from April (at the end of the rainy season) to February. The main effect of frequency on percentage single-stemmed plants is not significant. However, a strong season by frequency interaction exists (P = <0.00005), as indicated by Fig. 4. Linear regression analysis revealed that no relationship exists between percentage single-stemmed individuals and distance to nearest permanent water ($P = 0.47899$, $r^2 = 0.0093$).

Fire effects on basal area. The mean basal area (log transformed) as measured in 1998, differs significantly across the replicates (P = <0.00005), treatments (P = <0.00005) and these parameter's interaction (P= <0.00005). Average basal areas are smallest on the Nwanedzi replicate. Figure 5 shows the treatment effects on basal stem area. The main effect of season is significant (P= <0.00005), whereas the main frequency effect does not result in significant differences in basal area. April and August treatments yield the largest basal areas, whereas February burns result in the smallest basal areas. Examining the replicate/season (P = <0.00005) and replicate/frequency interaction ($P < 0.00005$), Marheya shows a significant decrease (as opposed to the other replicates, which showed an increase) in basal area between biennial and triennial burns. The season by frequency interaction (P = 0.0186) reveals an increase in basal area between biennial and triennial burns in April and December, as opposed to a decrease during other seasons. A linear regression analysis of average basal area per plot on distance to nearest permanent water reveals a significant positive correlation between these para-

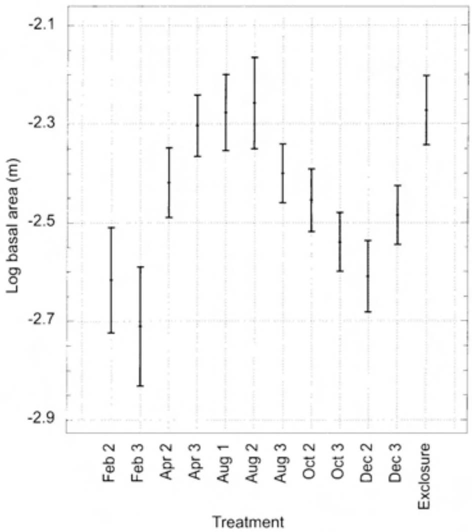

Fig. 5. Basal area as a function of fire treatment (expressed as month of burn and frequency in years).

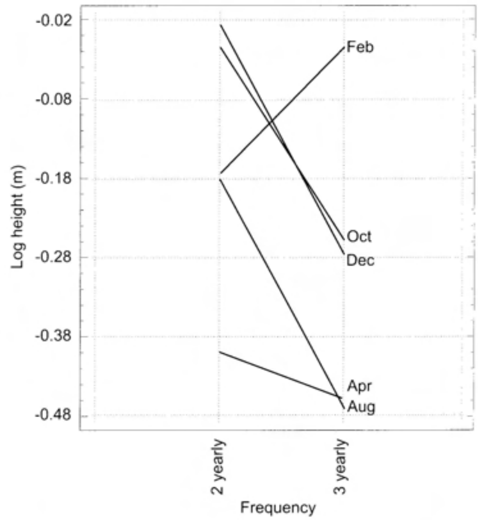

Fig. 6. Mean height of woody individuals, as a function of the interaction between frequency and season of burn.

meters ($P = 0.00087$, $r^2 = 0.1870$), but yielded no significant relationship between average basal area and percentage multi-stemmed plants per plot ($P = 0.23922$, $r^2 = 0.0126$). Linear regression analysis further showed that height is not well correlated with basal area ($P < 0.00005$, $r^2 = 0.0035$).

Height responses. Woody plant heights (log transformed), differ significantly across replicates ($P = <0.00005$) (every replicate differing from every other), treatments ($P = <0.00005$) and their interaction ($P = <0.00005$). February triennial, October and December biennial, and the fire exclosure treatments give rise to the tallest individuals, whereas the April and August biennial and triennial treatments result in the shortest individuals. Examined for separate season and frequency effects, replicate, season, frequency and all interactions are significant ($P = <0.00005$). February, October and December treatments yield the tallest plants. Individuals on biennial treatments are significantly taller than those on triennial treatments by an average of 0.07 m. Regarding the interactions, February treatments show the greatest variation in height across replicates, whereas April treatments show almost no variation in height across replicates. Figure 6 shows the frequency/season interaction with regard to height, where February treatments are the only to show an increase in woody height between biennial and triennial treatments. Linear regression analysis reveals that distance to nearest permanent water does not influence average woody height ($P = 0.06913$, $r^2 = 0.0599$), the only replicate having a significant (negative) correlation, being Satara ($P = 0.0300$).

The percentages of individuals (arcsine transformed) in the lowest height class (<1.75 m), show significant differences between replicates ($P = 0.0006$), treatments ($P = < 0.00005$), and their interaction ($P = 0.0008$). Similar results were obtained for the other two height classes (1.75–2.75 m, and > 2.75 m), except that replicates did not differ significantly for the tallest height class. Satara and Marheya have a smaller percentage of individuals < 1.75 m compared to Nwanedzi and Lindanda replicates, and consequently a higher percentage of trees between 1.75 m and 2.75 m. The highest percentage of plants under 1.75 m were found in the August annual (94 %) and triennial (93 %) treatments. The lowest percentages of plants under 1.75 m were recorded on the October biennial (76 %) and the fire exclosure (74 %) treatments; the October biennial treatment yielding the highest percentage of individuals in the middle height class (21 %) and the control the highest percentage in the tallest height class (12 %). Similar trends emerge when the data are examined for season and frequency effects, with the main seasonal effect ($P = <0.00005$) being significant for the lowest and middle height classes. April and August treatments yield the greatest percentage of individuals below 1.75 meters (both 91 %), while the greatest number of individuals in the middle height class are found in the October (17 %) and December (15 %) treatments. The main effect of frequency is not significant, although the replicate by frequency, replicate by season as well as the season by frequency interactions have significant effects on the percentage of individuals in the three height classes.

Species composition

Examined across the entire spectrum of species recorded, there appear to be no significant compositional changes due to treatments. *Acacia nigrescens* indicated an overall decrease over the 44 years ($P < 0.00005$), from around 230 plants/ha to 150 plants/ha, this decrease occurring mainly on Nwanedzi and Marheya. There was no significant difference for *Acacia nigrescens* between treatments. There were no density changes recorded for *Sclerocarya birrea*, the main treatment effect just not significant ($P = 0.0582$)—the highest density for this species is on the October triennial burn. Density for *Combretum imberbe* has not dropped significantly from 1954 to 1998. This species did however, show a density difference between certain treatments, with the highest density in the April biennial treatment. *Dichrostachys cinerea* showed an increase on all treatments (not significant), less so on the February biennial and triennial and on the fire exclosure plot.

The community data were ordinated, using a principle community analysis model. This explained 72.9 % of the variation in species data and this value dropped to 14.7 % when a redundancy analysis model was run, which showed that the species variation was constrained by the available environmental variables, like frequency and season. The Monte Carlo tests for significance, did not prove to be significant.

Discussion

Trends in the density of woody vegetation

The Satara and Marheya replicates (decreasing), differed significantly from the Nwanedzi and Lindanda replicates (unchanged). Comparing the different treatments individually, the most significant decrease in woody density occurred on the August biennial burns (mean decrease of 41%, with the Marheya August biennial treatment on its own showing a decrease of 81 %). Other treatments showing a density decrease were the October biennial and December biennial burns (both 34 %) and the fire exclosure plots (16.5 %). The biennial decreases are probably due to the shorter fire return periods, resulting in a lower incidence of seedling recruitment. On the other hand the only significant increase when treatments were examined individually, was the October triennial burn (mean increase of 61 %), with no apparent density changes on the remaining fire regimes.

Examining the density responses on the annual burns, it appears that all of these plots are subjected to severe overutilisation—it is felt that the annual fire regimes most probably stimulate continous regrowth, with subsequent herbivore pressures also having important effects on the density. These opposing trends in density could possibly also be ascribed to regional soil differences. Nwanedzi is located on red basalts (Sabie River basalt formation), with possible lower water retention, resulting in *Dichrostachys cinerea* thickening, as a result of a loss of cover, as opposed to Marheya, of which a large proportion is located on black basalts (Letaba basalt formation), with higher water retention, resulting in minimal woody recruitment. The interpretation of these differences is further complicated due to different herbivory regimes, both in terms of seasonal herbivory patterns and the number of herbivores, together with the fortuitous proximity of three of the four annual burn plots to water.

The fact that triennial burns (other than in February) yield higher densities is probably due to longer fire return periods, which presumably benefit some tree recruitment. The particularly low density observed on the August biennial treatment, seems to be detrimental to woody recruitment, perhaps at a specific point (season) when woody plants, are more sensitive to higher fire intensities and heavier utilisation.

Percentage single- versus multi-stemmed individuals

The increase in single-stemmed individuals is perhaps due to current high counts of single-stemmed young plants, e.g. of *Dicrostachys cinerea*. It is speculated that treatments such as April to December triennial burns give rise to higher fire intensities, which might be the primary reason for topkill, and thus for stimulating coppicing into the multi-stemmed morphology. A progressive increase in the percentage of single-stemmed individuals from April (at the end of the rainy season) to February (Fig. 3), might be related directly to decreasing fire intensities over this seasonal span. The greatest change between any two seasonal treatments is the drop in the percentage of single-stemmed individuals between February and April. This could be related to a drastic increase in fire intensity by April, due to increased dormancy of the herbaceous layer, at a point when the woody layer is at a physiologically sensitive state (at a growth peak), thus resulting in increased vulnerability to coppicing. Observational experience with April burns, in terms of fire behaviour indicates unpredictability due to periodic seasonal changes (in some years, extended rainy seasons), resulting in differing but sometimes very high fire intensities. The highest percentage of single stemmed plants occurs as an apparent result of triennial February burns, which combine lower intensity fires with a one year longer fire return period (Fig. 4). This probably enables woody species to grow beyond a fire sensitive height. Conversely the one year longer fire return period for August, October and December, appears to be a reason for fuel accumulation, hence higher intensity fires and fewer single-stemmed plants.

Fire effects on basal stem area

Figure 5 shows the treatment results on basal stem area, which turns out to be directly related to the presence of multi-stemmed individuals in the same treatments (graphics not shown here). The presumed high fire intensities in April triennial and in the August annual and biennial burns, are thought to produce more extreme topkill, resulting in basal coppicing. On the other hand less intense fires, together with longer fire return periods (October and December), seem to generate narrower basal areas, probably due to a high count of single-stemmed, as oppose to multi-stemmed individuals, (a pattern, closely resembling that of multi-stemmed percentages). The opposite might be true for the fire exclosure treatment, where a wide basal area is mostly brought about by tall, single-stemmed trees, with a wide basal stem area on Nwanedzi replicate and as a result of a high incidence of multi-stemmed *Commiphora* trees on Marheya replicate. A very narrow mean basal area on Nwanedzi replicate, is probably the result of a high incidence of *Dichrostachys cinerea* and to a lesser extent, *Acacia nigrescens* seedlings over the treatment span. Marheya's significant decrease (as opposed to the other replicates, which showed an increase) in basal area from biennial to triennial burns, might be due to localised soil differences (triennial treatments are located on shallower soils, as opposed to the rest of the replicate (Venter 1999)) and this together with a one year longer fire return period, might stimulate *Commiphora* spp. regeneration, manifesting as a high incidence of seedlings (resulting in a narrow basal area), on triennial burns.

Height responses

Apart from the February triennial treatment, which has a one year longer fire return period (yet, probably still a low intensity fire), woody species on the biennial treatments probably have a greater chance to grow beyond a fire sensitive height, due to a frequent fire return period, with a relatively low build up of grass biomass and subsequent low intensity fires. The frequency/season interaction (Fig. 6), shows triennial burns resulting in lower tree heights, except for February. This indicates that a longer fire return period does not necessarily enhance tree height, but might lead to a build up of fuel, with subsequent high intensity fires, that result in top kill. The fact that February triennial, October and December biennial and the fire exclosure treatment have the lowest percentage of trees under 1.75 m, might be due to competition from the herbaceous layer (together with an increase in the moribund state of the woody layer in the fire exclosure plot), impeding on the generation of younger woody individuals.

Species composition

The fact that there is no evidence of species composition changes is in line with the ordination results which indicate that there may be other environmental gradients (than frequency and season) responsible for variation.

Implications for management

The results of this study strengthen those of Trollope *et al.* (1995), where changes in woody vegetation do not involve a decrease in species diversity or composition, but primarily a change in structural diversity, on a horizontal and vertical scale. This suggests that over all treatments, woody vegetation is being transformed into a lower woodland community interspersed with a low density of large trees, together with significant basal diameter changes. The results of August triennial burns, resulting in a marked decrease of woody height, co-incide strongly with a similar trends shown on many basaltic landscapes in the Kruger National Park. This might help to explain part of the structural changes developing as a result of the historical fire regime, where management blocks was burned triennially around August. Frequent fires would also serve to prevent smaller trees from developing into larger ones, especially in combination with browsing, (Bond & Van Wilgen 1996). It thus seems as if a longer fire return period can often be beneficial to woody recruitment (thus increased density), but at the same time might suppress height increase, because of higher intensity fires resulting in topkill. Thus the October quadrennial and sexennial burns might give valuable information in the future, not only as a result of their infrequent fire application, but also because October burns might produce results more acceptable to managers than August burns. Vegetation is thus stimulated to coppice just prior to the growing season that generally begins in November as opposed to August which is sufficiently early in the season to result in flush growth, with resultant severe herbivory, at a time when the spring rains are still two months away. Results and discussion in terms of the four and six yearly treatments was excluded, the reason being that they were subjected to February biennial and triennial burns for over 25 years. They were therefore only subjected to their present fire regime for 20 years (October quadrennial 4 fire applications, with October sexennial 3 fire applications).

Even with the great spectrum of different fire treatments applied within this experiment, it becomes clear that woody vegetation shows resistance to changes in density over time. Eckhardt *et al.* (1999), state that it is difficult to identify the possible causes for trends

Table 2(a)
Main Seasonal trends for biennial and triennial burns

	Season				
	April	August	October	December	February
Change in density (1998 – 1954)	Not Significant				
1998 density	2	1	2	2	Not different from others (1and 2)
Percentage single-stems	1	1	2	2	3
Basal area	3	3	2	2	1
Height	1	2	3	3	3

Significant differences: 1 = smaller 2 = intermediate 3 = greater

Table 2(b)
Main frequency trends for biennial and triennial burns

	Frequency			
	Biennial	Triennial	Exclosure	August annual
Change in density (1998 – 1954)	decrease	increase	decrease	—
1998 density	lower	higher		
Percentage single-stems	Not significant			
Basal area	Not significant			
Height	taller	smaller		

It was possible to examine all frequencies as season was not significant

Table 2(c)
Season by frequency interaction trends for biennial and triennial burns

		Season				
	Frequency	Apr.	Aug.	Oct.	Dec.	Feb.
Change in density (1998 – 1954)	biennial	Not significant				
	triennial	Not significant				
1998 density	biennial	Not significant				
	triennial	Not significant				
Percentage single-stems	biennial				*	*
	triennial	/	/			
Basal area	biennial					
	triennial					
Height	biennial		*	*	*	
	triennial	/				

* Statistical significant internal differences ▭ Shows proportional differences

detected in this type of study in the absence of an interactive ecosystem modelling framework. Such a modeling framework should be developed in order to assess the contributions of factors such as fire frequency, season and intensity against variable environmental paramaters like herbivory, rainfall and soil properties, within the replicates. The summary presented in Table 2 might assist in setting up such a framework. Fire, herbivory and cycles in rainfall are the major disturbances responsible for the dynamics of savannas, (Van Wilgen *et al.* 1998). In the case of the Kruger National Park, the goal is to conserve biodiversity through *inter alia* the application of variable fire regimes. An ecologically sound combination of fire frequency and season on this trial might not be apparent from a floral species composition point of view, but structural diversity changes will play an integral part in securing optimal biodiversity conservation. This approach is also integrated with other management issues such as the closure of certain water points which commenced in the park in 1994. Although the continued existence of the experimental burning plots is uncertain because of newer schools of thought such as those supporting a lightning-driven policy, the experimental burn plots may yet play an important role in comparative fire behaviour studies in the future.

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