FIRE REGIME AND TREE/SHRUB/GRASS BALANCE AT PRETORIUSKOP IN THE KRUGER NATIONAL PARK: EVIDENCE FROM GROUND PHOTOGRAPHS

Refiloe Ntsohi
Botany Honours
University of Capetown
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ABSTRACT

Periodic burning is required to control the establishment and growth of woody plants in the mesic savanna of South Africa. Burning in different seasons and at different frequencies result in a variety of responses from the vegetation. Variation is also observed between different growth form and between different size classes within a single growth form. Fire exclusion result in the greatest increase in woodiness and decrease in grass. October burn result in the greatest suppression of woodiness and no effect on the grasses. Differences in soil regime result in differential pattern and results of Fayi plots revealed that soils in this area are not representative of the soils of Pretoriuskop region. The combined effect of season and frequency of burn determine the intensity of the fire, and intensity of fire appears to be the most important factor determining the effects of fire on the vegetation and hence the effectiveness of a regime in controlling bush encroachment. The period between 1971-1988, with above-normal rainfall, resulted in the largest increase in trees. Highest increase in shrubs layer were observed between 1988-2002. Ground pictures of the experimental burn plots at Kruger National Park have proved to be an effective tool in studying the effects of burn regimes on the tree/shrub/grass balance in the mesic savanna.

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difficult to understand

fuel load wind T°C etc.

INTRODUCTION

Fire is recognized as a dominant and important determinant of the structure and function of savanna ecosystems throughout the world (Andersen et al. 1998, Shackleton and Scholes 2000, Perterson and Reich 2001). Savannas are characterized by a continuous grass layer under a sparse canopy of trees (Andersen et al. 1998). Recurrent and frequent fires have played major a role in development of savanna from other vegetation types and for their maintenance (Adams and Skull 1996, Andersen et al. 1998,). During burning, survival of plants varies greatly between different plant forms and for different size classes within the same plant form. Grasses and young trees have shown the least resistance to fire, while mature trees are often resistant to burning (Bond and Wilgen, 1996). After fire, space is opened up which can be colonized by individuals of the same or different species (Bond and Wilgen, 1996). Trees and grasses' co-dominance in most savanna ecosystems is persistent and understanding the influence of fire on each growth form would give insight into the maintenance of this structure. Co-dominance is often explained by disequilibrium theories that state that disturbance enables co-existance by preventing competitive exclusion (Wilgen et al. 2000)

The effect of fire on vegetation will depend upon the combined effects of the different components of a fire regime: how often fire occurs (frequency), in which month of the year it occurs (season) and how fiercely the fire burns (intensity)(Bond and Wilgen 1996, Enslin et al. 2000, Shackleton and Scholes 2000). The frequency and season of burn directly influence the intensity of fire. Long intervals between fire result in a high accumulation of fuel load and hence increases fire intensities (Bond and Wilgen, 1996). In addition, fire intervals determine the degree to which trees grow or recover between fires (Trollope, 1984). Long fire intervals favour bush dominance as they allow trees to grow to escape height. The resultant shading suppresses grass and insufficient fuel load is produced, resulting in low intensity fires (Trollope, 1984). On the other hand, season of burn affects the moisture content of the fuel, so that fuel burns with a higher intensity when moisture content is high than when it is low (Trollope, 1984). In addition, actively growing plants appear to be more susceptible to damage by fire than dormant plants

(Trollope, 1984). But, dormant plants are dry and burn with great intensity and thus cause injury to plants. Differences in rainfall and soil regime between plots have been observed to cause variable responses of plants to fire (Skull and Adams 1996, Andersen et al. 1998), indicating that fire regimes determine the vegetation structure under the constraints set by rainfall and soil types. Nutrient-rich sites with high annual rainfall show higher rates of tree growth and greater bush dominance if fire intervals are long (Shackleton and Scholes 2000, Wilgen et al. 2000).

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Prescribed burning treatments applied on experimental plots have played an important role in shedding light on savanna responses to various fire regimes (Andersen et al. 1998). In 1954 such experimental burn plots (EBPs) were initiated in the Kruger National Park with the objective of studying the effects of fire on different natural plant communities of the park under the grazing pressure of wild animals and hence determining the suitable fire regime for the area. The four major veld types identified in the park are: the broad leaf deciduous woodlands with long grass of Pretoriuskop, the Combretum veld of Naphe, the Knobthorn-Marula veld near Satara and the Mopane woodlands between Shingwedzi and Letaba. Before applying the treatments a survey of woody and grass vegetation was conducted and tree species, basal diameter (single stem individuals) and coppice diameter (multistem individuals) were recorded and photographic survey of the plots was also conducted. These surveys were to be repeated every ten years using the methods outlined by Van der Schijff (1953) in reports available at the scientific services of Kruger National Park. Subsequent surveys were not done according to schedule and prescribed methods. In 1962, after an attempt to assess the available data, Broembsen and Muller concluded that there was no way to examine the effect of fire on the vegetation pattern. In addition, they said available data was incompatible and statistically useless. However various studies have been done on the plots and significant patterns have been observed (Van Wilgen et al. 1998, Biggs et al. 2000). These more recent studies include investigation of treatment induced soil changes in 1971, half-hectare vegetation surveys conducted in the early 1970s and late 1990s (Biggs et al. 2003) Details of more recent studies can be obtained from the Scientific Services Division of the park.

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Studies have shown that periodic use of a fire regime will have an effect on the tree/shrub/grass ratio (Van Wilgen et al. 1998). Studies conducted on woodland burning experiments in the savannas of Northern Rhodesia (Trapnell 1959) showed that plots burned in October lacked canopy and showed increased grass. These characterize dry season burns that have high intensities and result in top-kill of young trees and this effect was more pronounced on trees less than 4.5m in height. However, Trapnell (1959) observed that in their early stages, seedlings of many species show a remarkable resistence to being burnt than the in subsequent stages. Trollope (1959) further observed that the completely protected plots had remained as closed woodland with high intensity of small trees and shrub and a greatly suppressed grass layer. The results suggest that intensity of burning (due to varying moisture content in different seasons) is the important determinant of vegetation change (Trapnell, 1959). Trollope (1984) reported that his studies in South African savannas had revealed that generally trees and shrubs are resistant to fire due to possession of dormant buds at the base of stem, from which coppicing occurs. In high rainfall areas (annual rainfall 600mm), however, high grass fuel accumulation result in high intensity fires even under use of frequent burning treatments and bush encroachment is controlled (Trollope 1984). These results led Trollope (1984) to conclude that it is difficult to ascertain the effect of season or frequency of burning on trees and shrubs in savanna as this is generally confounded by fire intensity. Studies in North American semiarid grassland (Van Auken, 2000) have concluded that high level of herbivory lead to reduced above-ground grass biomass and reduction of fuel, resulting in low intensity fires. This author suggests that climate warming is a possible background driver of bush encroachment as it result in accelerated growth rate especially for plants with C_3 photosynthetic pathway.

For a big experiment such as EBPs in Kruger National Park it is difficult to find a homogeneous land big enough for all the treatments. Soil variations have been observed between plots within a single replicate string (Biggs et al. 2003). As mentioned earlier, studies have shown that variation in soils and the rainfall regime (Skull and Adams 1996, Andersen et al. 1998, Shackleton and Schodls 2000). A range of rainfall and soil type

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regimes exist within the Kruger National Park and experimental burning plots have been replicated in each of the four veld types representing major soil and moisture regimes. This project looks at the photographs of some of these experimental plots located at Pretoriuskop within the Kruger National Park, with the aim of exploring the following:

We assess whether application of the different fire regimes has resulted in a significant shift in a balance between trees/shrubs/grasses composition over the years, and we use the photograghs to detect when the major changes occurred. We explore whether the shift has been driven primarily by the season or the frequency in which the plots have been burned, or whether the major determinant of the vegetation response is the fire regime, which is a combination of the season and frequency of burn.

METHODS

Study area

Since 1954, periodic burning treatments have been applied to EBPs in the Kruger National Park and they have been diligently maintained by dedicated work of Andre Potgieter and co-workers and their predecessors, with more than 80% of the scheduled burns being applied on schedule (Biggs et al. 2003). The treatments are replicated in four different areas that characterize major veld types within the park. Veld types differ in terms of their vegetation, edaphic and climatic regimes. My study focused on the plots located at the lowveld sour bushveld of Pretoriuskop, representing the mesic savanna with annual rainfall ranging between 600 and 1000mm, the highest in the park (Gertenbach, 1983). The deeply leached uplands soils of Pretoriuskop vary from sand to sandy loam and bottomlands are clayer and have a well developed structure. Pretoriuskop consists of four replicate strings named Numbi, Fayi, Kambeni and Shabeni. Each string consists of 12 plots, each representing a different burn treatment. The treatments vary in terms of the month in which the fires are ignited and the interval in which this is repeated. Andre Potgieter (pers comms) pointed that the October treatments are normally applied after the first spring rains, but rains sometimes come late and to maintain the prescribed month of burn, the plots are burned before rains. A summary of fire regimes is given in Table 1.

Table 1. Summary of the treatments applied to the EBPs in Kruger National Park since 1954. Fire regimes represent combination of prescribed month and frequency of burn.

Fire regime	Frequency of burn	Month of burn
Aug1	Annual	August
Feb2	Biennial	February
Apr2	Biennial	April
Aug2	Biennial	August
Oct2	Biennial	October
Dec2	Biennial	December
Feb3	Triennial	February
Apr3	Triennial	April
Aug 3	Triennial	August
Oct 3	Triennial	October
Dec3	Triennial	December
No burn	0	-

The tree layer in the plots is dominated by *Terminalia sericea*. Other trees include *Sclerocarya caffra* and *Pterocarpus angolensis*. The shrub layer is dominated by *Dichrostachys cinerea*. The grass layer is dominated by *Hyperthelia dissoluta*. Similar vegetation occurs in all 4 strings. The plots are not enclosed and herbivory is not excluded. Within each strip, plots are separated from each other by graded firebreaks.

Ground photographs of the plots were taken in the years 1958/59, 1971, 1988 and 2002 (Appendix Figure 7). For this study, the pictures were labeled as picture 1, picture 2, picture 3 and picture 4 respectively. Pictures were kept in albums in the park's Scientific Services Section. Pictures are labeled string name, treatment type and year picture was taken (except pictures 2) and additional records for the pictures 3 and 4 dates were available.

Picture 2's date was confirmed by Potgieter (pers. comms.) Pictures were taken in the year the treatments were applied Potgieter (pers. comms.). Pictures 1 and 2 were black and white and pictures 3 and 4 were colour.

Pictures were taken at the corner of each replicate adjacent to the graded firebreak. The replicates varied from 3 to 7ha in extend and the area included in a photograph was only a small fraction of the plot. Repeat photographs were taken from more or less similar position but the photo points were not marked permanently. Due to edge effects, which resulted in less intense fires on the edges of the plots, woodiness was increased on the foreground so that visibility was obscured and in such cases assessment of the pictures proved difficult.

The pictures were used to analyze qualitative change in tree/shrub/grass abundance from 1958/59-2002 in EBPs initiated in the Kruger National Park in 1954. This change was attributed to fire and assessment of the effect of fire on the vegetation was made. Variations in the degree of change and in the dominant form of vegetation were observed between pictures of different plots, and these were attributed to the different fire regimes applied to the plots. Understanding of plants interaction with fire required understanding of plants' interaction with fire regimes.

To assess the effect of the fire regimes on the tree/shrub/grass balance on the plots we looked at the pictures and compared the series of 4 pictures for each plot. We estimated the amount of gain or loss in abundance of trees, shrubs and grass along an index of -2 to 2, where

-2 - significant decline
-1 - small decline
0 - no change
1 - small increase
2 - significant increase

The degree of cover estimations were done by three people and where we had differing views, a consensus was reached on a mean value. The scores reported were largely very similar. This was a subjective part of the study and the derived data do not, therefore, reflect exact figures. The comparisons were made between pairs of pictures in the following way: picture 1 and picture 2, picture 2 and picture 3, picture 3 and picture 4, and picture 1 and picture 4. The results of these scores were recorded in an excel spreadsheet. We made an estimate of our level of confidence in how well the pictures were matched by identifying trees that appeared on all of the four photographs of the same plot. Measures of confidence were assigned along a scale of 1 to 3 with 1 being a perfect match and 3 being a low match. Pictures 4 were missing for Kambeni and Pictures 3 were missing for Shabeni, Numbi and Kambeni.

The results of each picture-pair comparison were used to calculate the cumulative means for each growth form in each string. To determine the influence of fire on tree/shrub/grass in the 4 strings, cumulative means were analyzed against years the pictures were taken using xy scatter plots. The relationships between growth forms over the years were tested with linear regressions. Few outliers were observed in the result and original data revealed them to be Fayi plots. The analysis was repeated with Fayi excluded. To assess the impact of season of burn on the growth forms, treatments from Numbi, Shabeni and Kambeni were grouped according to month of burn and cumulative means of the scores for all growth forms were plotted against years pictures were taken. The months were February, April, August, October, December and "no burn". To assess the impact of frequency of burn on tree/shrub/grass, Numbi, Shabeni and Kambeni treatments were grouped according to frequency of burn and cumulative means of the scores were plotted against years pictures were taken. The frequencies were annual, biennial, triennial and "no burn". To explore the combined effect of the season and frequency of burn, the data were arranged in a table and the spread of the fire regimes across the scores of change in abundance from 1958/59-2002 (Picture 1 and Picture 2) was assessed for Fayi, Numbi and Shabeni. Pictures 4 were missing for Kambeni and it was excluded from this analysis.

To further explore the use of photography in studying long term trends of change in vegetation structure and plant growth especially under periodic fire disturbance, trees data were recorded from the photographs. We recorded species name and stem circumference at estimated breast height. Trees from the photographs were located in the field and species name, tree height, canopy diameter, stem circumference at breast height, canopy height were recorded.

RESULTS

Generally the four pictures of a plot were satisfactorily matched, except for a few cases where a bush had grown on the foreground and the background was not visible on the picture and where picture angle had slightly shifted and trees could not be well matched.

Change in growth form through time

An analysis of the photographic time series indicates that, for all four sites, trees and shrubs increased in abundance while grasses decreased as shown in Appendix Fig.1. a. For trees, the most notable increase occurred between 1970 and 1988. Kambeni showed the greatest increase in trees and Shabeni the lowest. b. Shrubs generally increased steadily between 1958 and 2002, with the greatest increase occurring between 1988 and 2002 and the least increase including decline at Numbi occurring between 1970 and 1988. Kambeni showed the greatest increase in shrub cover over the 44 year time series. c. Grass abundance declined in all four sites with Kambeni showing the greatest decline. The greatest decline in grass happened between 1988 and 2002 and between 1970 and 1988 grass cover increased.

Interaction of growth forms

The results of correlations tests between tree/shrub/grass indicated that there was a negative relationship between trees and grass, and shrubs and grass, while trees and shrubs had no relationship. An indication of how change in abundance of one growth form if explained by the other as shown in Appendix Fig. 2. a. Trees and grass show a negative relationship. n=34, r^2= 0.16 b. Shrubs and grass show a negative relationship. N=34, r^2= 0.58. c. No relationship exists between trees and shrubs n=34, r^2=0.03. The presence of outliers in the data might be affecting the relationships between growth forms. Original data sets were checked and the outliers were all data from Fayi plots (Feb2, Apr2 and Aug1).

When analysis was repeated with Fayi excluded, the r^2 and the p values were improved considerably and a significant relationship emerged between trees and shrubs as shown in Appendix Fig. 3. The new values were: For trees and grass relationship, n = 22, r^2=0.34. b. For shrubs and grass relationship, n = 22, r^2 =0.76. c. For trees and shrub relationship, n = 22, r^2 = 0.39.

Influence of burn season on the growth form

The result of the photographic time series data indicated that all five months of burn and the "no burn" treatments resulted in an increase in trees and shrubs, and a decrease in grass as shown in Appendix Fig. 4. a. For trees, "no burn" treatments showed the greatest increase in trees. February burns also showed a high increase in tree abundance. Moderate increase in tree abundance was observed from August, April and December treatments. October burns showed the least increase in tree abundance. b. For shrub abundance, "no burn" and February treatments showed the highest increase, with "no burn" showing a steep increase in 1958-1971. Shrub increase was least for December and October burns and moderate for August and April burns. c. For grass, February burn showed the higher decline in grass than "no burn" treatments. The October burn showed no change in grasses. Moderate decline in grass was observed for April, August and December burns.

Influence of burn frequency on each growth form

The treatments show variable responses between the year intervals and no uniform pattern is observed. Between 1958 and 1971 there was a gentle increase in trees and a generally steeper increase in shrubs for all burn frequencies and a general trend of decline in grass. Between 1970 and 2002 the responses are very variable as shown in Appendix Figure 5.

Interaction of season and frequency of burn

The results have shown that vegetation at different sites responded variably to similar treatments as shown in Appendix Tables 2, 3 and 4. No decline in trees was observed in any treatments, the trees either showed no change or an increase. Shrubs generally showed no change or an increase, except for two treatments at Fayi and one at Numbi. Grass abundance has generally remained the same or decreased from 1958-2002. Dec3 treatment consistently showed a small increase in grass. The treatments do not necessarily show association of treatments according to either frequency or season of burn. Table 2. No burn and Feb3 treatments showed the greatest tree abundance at Fayi and Numbi. Dec3 showed the most consistent response of very small to no decline in trees. Table 3. Feb3 has resulted in the greatest increase in shrub abundance at Fayi and Numbi. Dec3 showed consistent result of no change across the sites. Table 4. For grass, Aug3, Oct2 and Dec3 show a consistent response over the sites with the former two treatments showing a very small decline and the latter showing a very small increase. Dec2 resulted in a decrease in grass and Dec3 resulted in an increase in grass.

DISCUSSION

The Pretoriuskop region of the Kruger National Park generally had a greater abundance of woody plants and lesser abundance of grass in 2002 than it did in 1958. None of the plots showed a decrease in trees and only three treatments (Oct3, Feb2 and Apr2) showed a decrease in shrub cover. Results of the correlation tests between tree/shrub/grass indicated that an increase in the woody component on the plots resulted in decline in grass abundance. These results suggest that with bush becoming more dominant on the plots, the resultant overstorey shading suppresses the understorey grass and reduces its density. When anomalous Fayi plots are excluded from the analysis, 34% of decline in grass is explained by increase in trees and 76% is explained by increase in shrub abundance. The findings suggest that since trees canopies are higher and more sparse, they can be penetrated by light and understorey growth can still be maintained. Shrubs on the other hand have lower and denser canopies that cast heavier shading and result in a greater suppression of grass underneath and hence reduced grass abundance. In addition, the increased tree and shrub abundance means that there is reduced space for grass growth.

The period between 1971 and 1988 showed a steep increase in trees while shrubs declined. This high increase in trees during this period has been attributed to the fact that South Africa experienced above-normal rainfall during the 1970s (Tyson and Dyer, 1978) and high soil moisture content during this period resulted in low intensity fires, allowing trees to grow to escape height as this wet spell lasted for almost a decade. Van Wilgen et al. (2000) have mentioned that in the Kruger National Park, the effects of this wet period were evident for areas receiving high annual rainfall, including the Pretoriuskop region. A steep increase in shrubs and a decrease in grass was observed between 1988 and 2002, a period that included another major wet spell in South Africa (Dyer and Tyson, 1978). It is interesting to note that during the first wet spell trees abundance increased and during the second wet spell shrub cover increased. Though this was not visible from the pictures, inspection of plots in the field revealed that the shrub layer is actually composed of shrubs and small trees so the result might be an artifact of estimating low resolution of the photographs. Another confounding effect was that 1988 pictures for Shabeni, Kambeni and Numbi plots were missing indicating that trends between 1970 and 1988 could be a result of poor sampling as it reflects the results of Fayi alone, which has proved to be an anomaly. Complete sampling might yield insightful trends. However, the available data clearly indicate that there was little increase in tree cover from the1958 to 1970.

Burning in August, October, December, February, April and not burning at all favour increase in woodiness. February burns most resembled "no burn" in increased tree cover and would therefore be expected to be of low severity to trees. February fires are considered low intensity fires as they burn during the wet season while the vegetation is green. This causes less injury to trees as tree mortality is less in low intensity fires. October and August burns showed the least change in tree cover and they therefore cause greater tree mortality. December and April treatments show intermediate increase in tree cover. April fires are of moderate intensity as they burn at the end of the wet season. December, however represent the wet season and burns are expected to show a greater increase in trees. Schutz's (Honours project, 2003) studies of the effects of season of burn on the species of *Dichrostachys cinerea* and *Acacia nigrescence* have shown that burning in December result in lower rate of increase in *D. cinerea* abundance than all other months of burn. The different seasons had no effect on the species of *A. nigrescence*.

All the burn months favour increase in shrubs. Burning in February result in a greater shrub density than applying "no burn" treatment. The result implies that low intensity fire has actually accelerated the process of bush encroachment. For shrubs, August and April burns show the effect more similar to the "no burn" treatment implying this treatment has the least effect on shrubs. Burning in December and October has the greatest suppression effect on shrubs. These results were unexpected as December represent a low intensity and April represent moderate fire while October and August burns represent high intensity fire. Other factors may be confounding the pattern here. As it has been mentioned herbivory is not excluded from the plots and browsing may be confounding the effects of fire treatments Van Wyk (1971 in Trollope 1984).

Grasses have declined for all burn seasons except the October burns which produced no change in grass. This burn treatment was noted as producing the least increase in tree and shrub density. The February burn resulted in the greatest decline in grass. In addition, burning grass in August and April shows a less effect on the grass, consistent with the previous observations (Trapnell, 1959).

Different burn frequencies resulted in increased trees and shrub cover and decreased grass between the period 1958 and 1971. 1971-2002 showed great variation in the response of vegetation to different burn frequencies. Such variable results have been observed at Matopos Research Station in Zimbabwe where at the initiation of the treatments annual burning had the most deletetious effect on trees and shrub, but grass sward deteriorated with the continued application of the treatment and burning became less damaging to the bush. This observation is consistent with our results that show that annual burn has resulted in the greatest increase in trees especially during the period from 1970-1988 compared to the other treatments. High increases in trees and shrubs have been observed for "no burn" and biennial treatments. Triennial treatments have resulted in the least increase in trees. This result is contrary to the general view that the longer the intervals between burns the greater the increase in woodiness. The result indicate that three year fire interval is not long enough for small trees to grow to escape height and high accumulation of fuel during this interval result in high intensity fires that consequently top-kill the smaller trees. Shrubs show a greater increase when frequencies of burn are longer and grasses show a greater decline when the plots are burned triennially than when burning is excluded.

Over time, response of vegetation to fire varies greatly between different plant forms, different sites and different fire treatments. The vegetation does not show a consistent response to a similar treatment across sites. The only notably consistent treatments are the Dec3 for shrubs and grass and Oct2 for grass. Past studies have regarded fire as a secondary determinant of the vegetation structure (Skull and Adams 1996, Andersen et al. 1998, Schackleton and Scholes 2000). The studies point out that the patterns of plant distribution are primarily determined by moisture and nutrient availability. The observation that similar fire regimes show a range of responses when applied at sites with varying rainfall and soil type regimes may indicate that soils are the main drivers of the patterns at Pretoriuskop. Fayi has shown an unexpected pattern of responses. The Aug1 highly resembled the "no burn" plot. A field inspection of the soils in the Aug1 plot at ? Fayi revealed that the soils comprised of a granite horizon over molten subsoil, a condition that is not representative of the general Pretoriuskop landscape.

Hoffman and O'connor's (1998), Dunham (1989), Turner (1990) studies proved that photographs are an effective tool for monitoring vegetation change as compositional and structural changes are evident on the pictures. They point out that each photograph samples a large area of ground at an adequate resolution. To make series of pictures informative and useful in ecological research, the same camera position and height should be maintained when photographs are taken so that the pictures can be useful in comparative studies. The season and time of day the pictures were taken should also be matched to facilitate interpretation of the images. It is also important to maintain similar camera specifications. They further suggest that studies based on panoramic photographs should be coupled with ground inspection. Photographs of EBPs at Kruger National Park do not meet the above recommendations. In some cases pictures were taken from the ground and in others from the back of a bakkie (Potgieter, pers. comms. 2003). However our ability to detect changes in tree/shrub/grass cover using these pictures implies that they were adequate in revealing qualitative changes in vegetation over time, proving photographs to be an important tool for this study.

Biggs et al. (2003) have suggested that analysis of variance (ANOVA) be used to investigate the rate of vegetation change in the EBPs. However, ANOVA was not done here because the data we could derive from the pictures were not quantitative observations but qualitative measures of increase in abundance of tree/shrub/grass. Our aim was to observe changes on a specific treatment over a period of time and to identify period of major changes while Biggs et al. (2003) suggested approach would be useful to detect differences in vegetation at a specific point in time. Quantitative tree data which included measurements of stem diameter at the roughly estimated breast height were recorded from the photographs using digital calipers. The data however proved difficult to analyze as the pictures were not taken from a fixed point and observations were not to a similar scale.

CONCLUSION

Time series of photographs have proved to be an adequate tool in comparative studies of vegetation change as patterns of change were evident from the pictures. The analysis could however be improved by improving the match of the pictures so that comparable quantitative data obtained from the pictures could be statistically analyzed. To fully comprehend the effect of season and frequency of burning on the vegetation and the other factors that influence the vegetation, further studies of the impact of different soil substrate and the effects of herbivory on burned plots should be undertaken. Currently it is difficult to separate the effects of the fire regimes from the confounding effects of herbivory and soils differentiation. The soils at Pretoriuskop, especially at the location of Fayi plots need further studying as they are not representative of the general landscape. Van Auren (2000) alluded to the possibility of elevated CO_2 being responsible for increased bush encroachment. Similar predictions have been made by the use of simulation methods and experiments are in progress to test the predictions (Bond et al. 2003). If CO_2 does have an influence on the tree/grass balance, then its influence would have to be considered in assessing the interaction of vegetation with fire regimes. Stochastic climatic conditions lead to deviations in the treatments from year to year due to late summers rains or drought. Andersen et al. (1998) have suggested a 'Progressive' approach to burning where fires are lit progressively throughout the dry season, so that parts of the landscape are burned as they progressively get drier. Biggs et al. (2003) have also suggested that timing of burning should be related to specific conditions, such as after first spring rains, rather than to specific calender months. EBPs in the Kruger

National Park have been maintained for a long time and their modification would result in loss of valuable long-term data. Careful consideration is needed to determine the future of the EBPs.

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APPENDIX

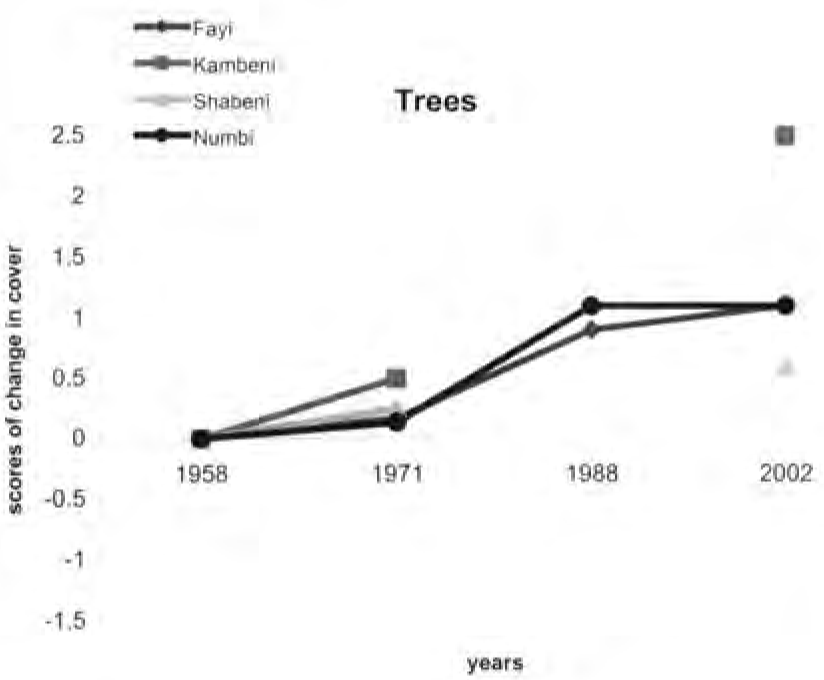

figure 1. a. Changes in trees in the 4 replicate strings scored over the period 1958 - 2002

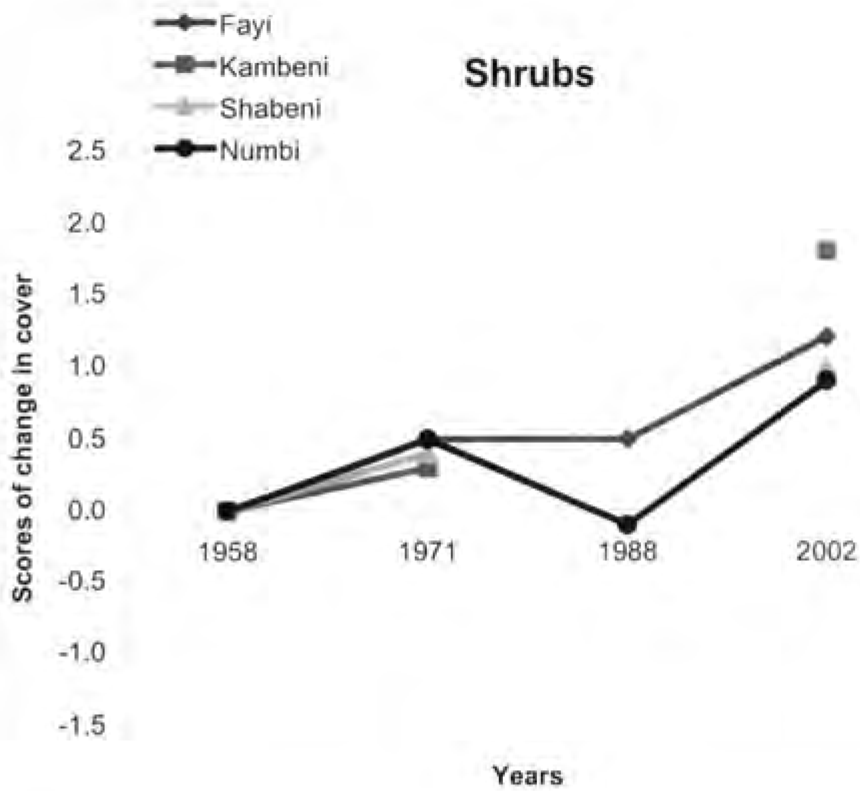

figure 1. b. Changes in shrubs in the 4 replicate strings scored over the period 1958 - 2002

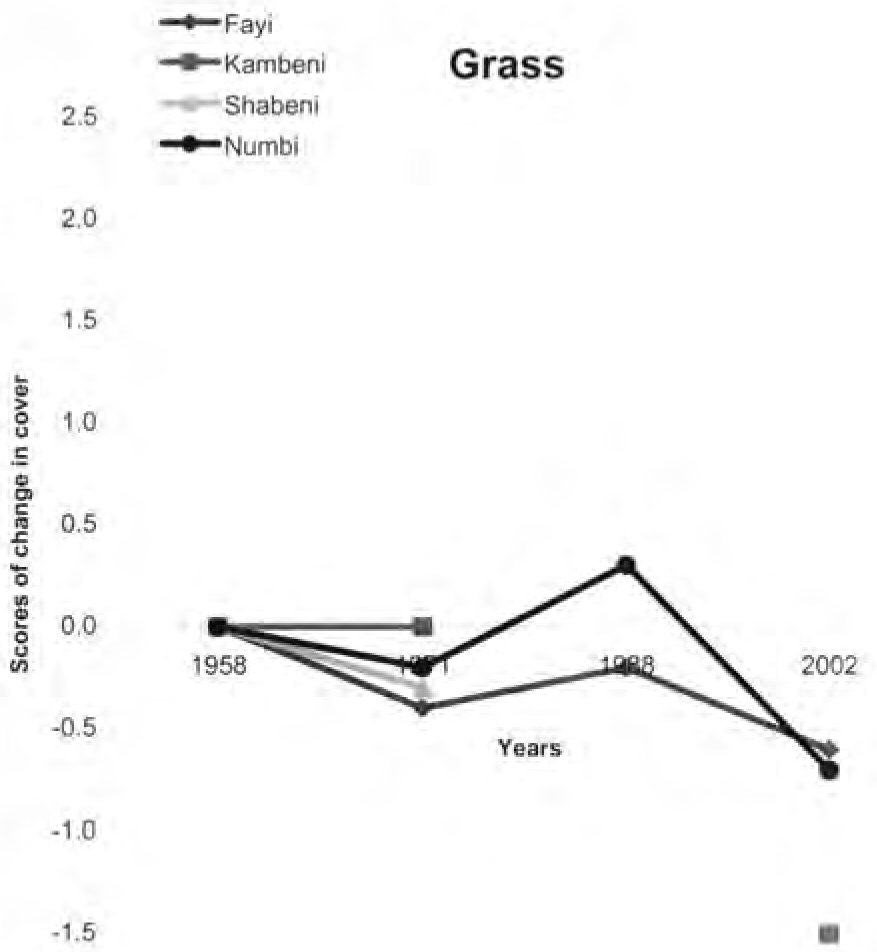

figure 1. c. Changes in grasses in the 4 replicate strings scored over the period 1958 - 2002

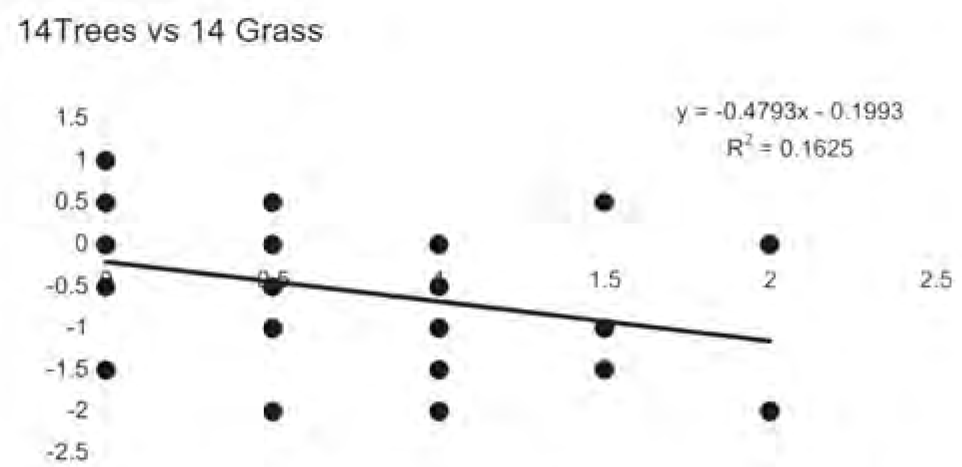

Figure 2. a. Relationship between trees and grass cover at Fayi, Numbi, Shabeni at Kambeni over the period 1958-2002

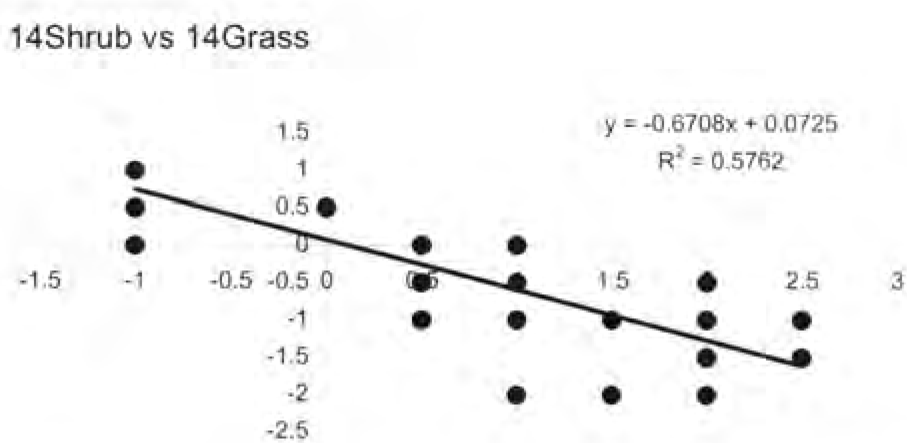

Figure 2. b. Relationship between shrub and grass cover at Fayi, Numbi, Shabeni at Kambeni over the period 1958-2002

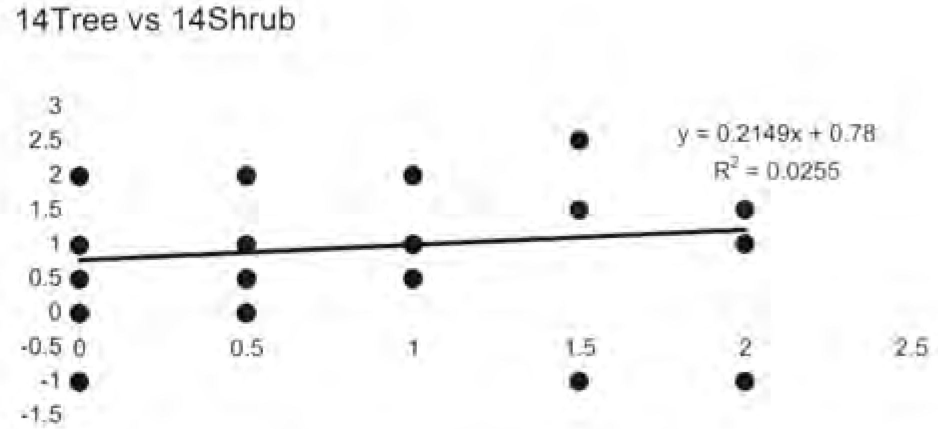

Figure 2. c. Relationship between trees and shrub cover at Fayi, Numbi, Shabeni at Kambeni over the period 1958-2002

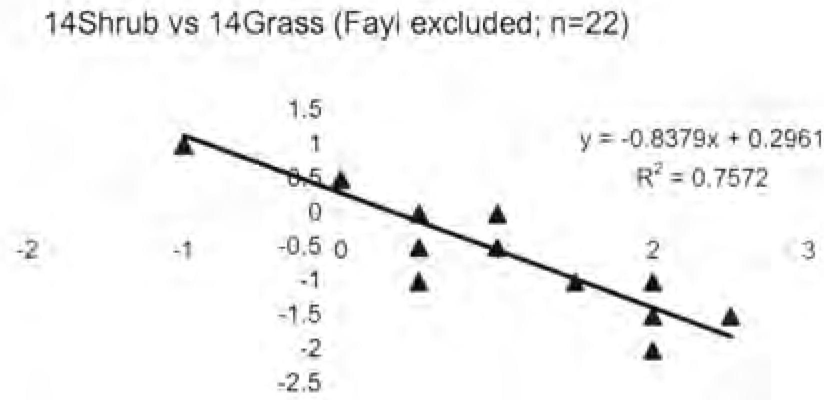

Figure 3. a. Relationship between grass and shrub cover at, Numbi, Shabeni at Kambeni over the period 1958-2002

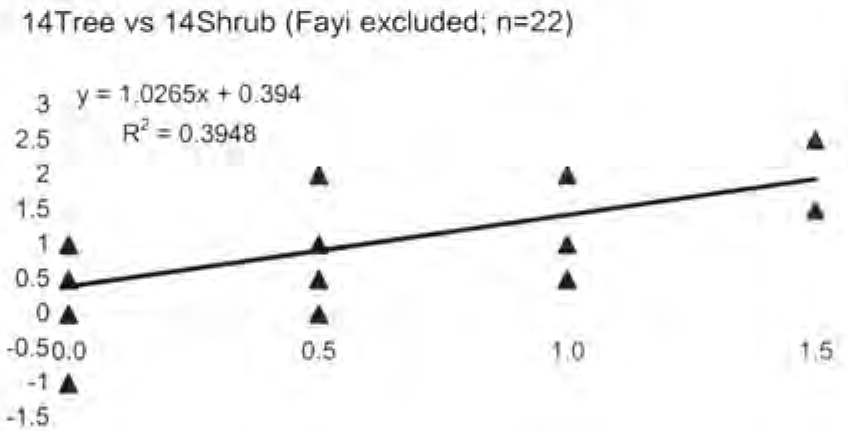

Figure 3. b Relationship between trees and shrub cover at, Numbi, Shabeni at Kambeni over the period 1958-2002

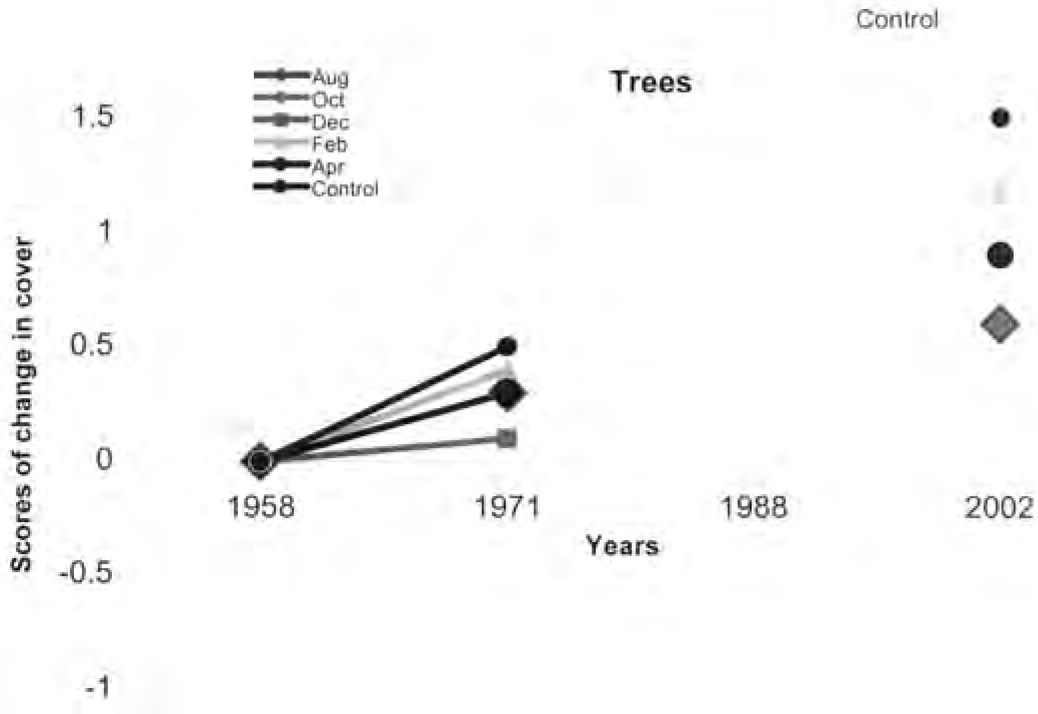

Figure 4. a The effect of month of burn on grass cover over from 1958-2002 for Numbi, Shabeni and Kambeni

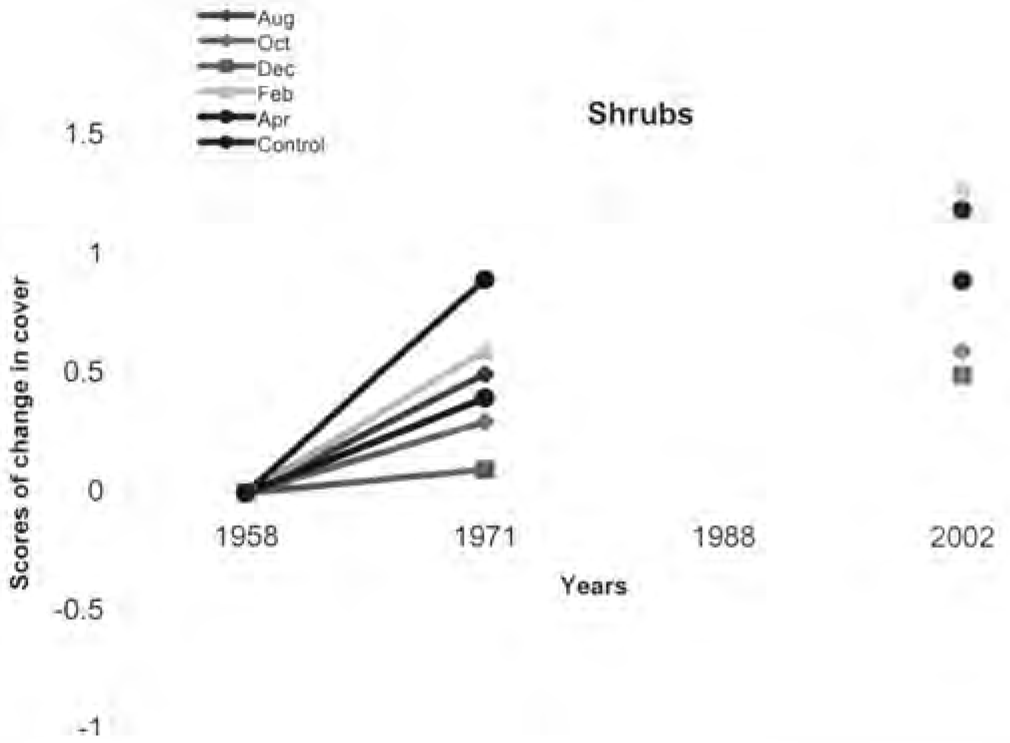

Figure 4. b. The effect of month of burn on shrub cover over the period 1958-2002 in Numbi, Shabeni and Kambeni

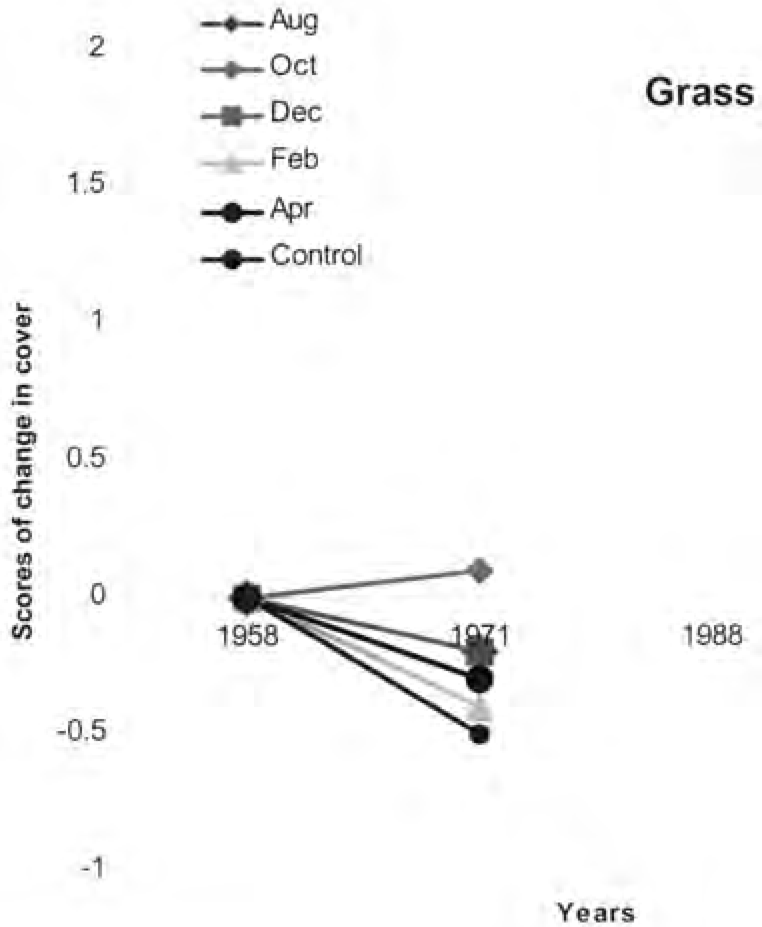

Figure 4. c. The effect of month of burn on grass cover over from 1958-2002 for Numbi, Shabeni and Kambeni.

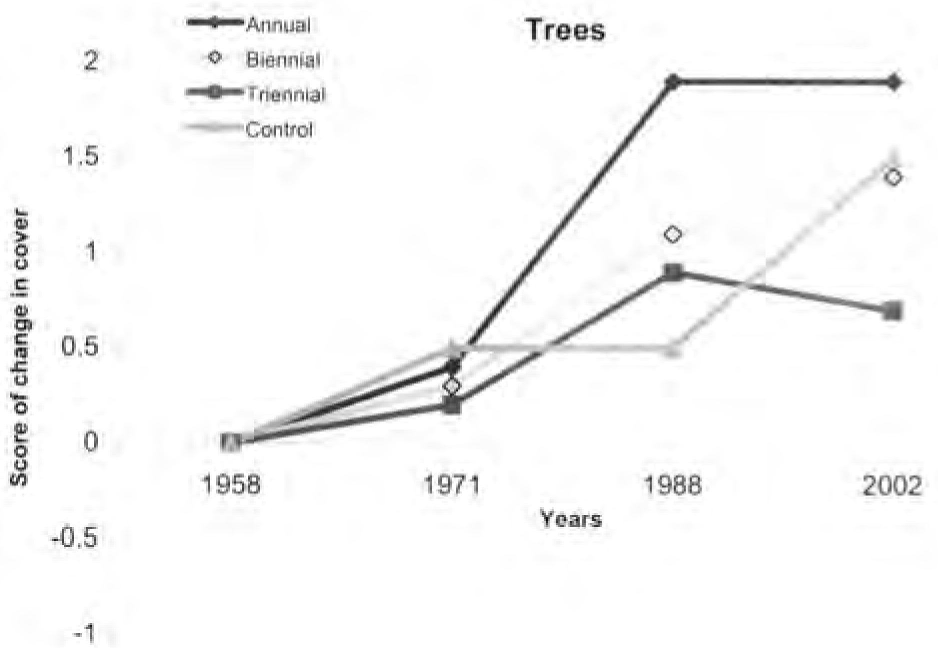

Figure 5. a. The effect of the burn interval on the tree cover over the period 1958-2002 in Numbi,Fayi, Kambeni and Shabeni.

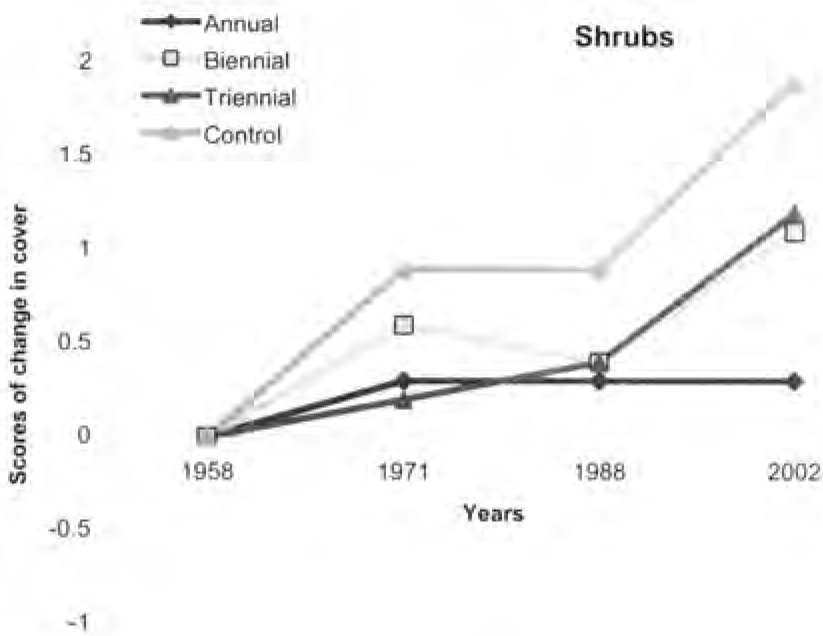

Figure 5. b. The effect of the burn interval on the shrub cover over the period 1958-2002 in Numbi,Fayi, Kambeni and Shabeni.

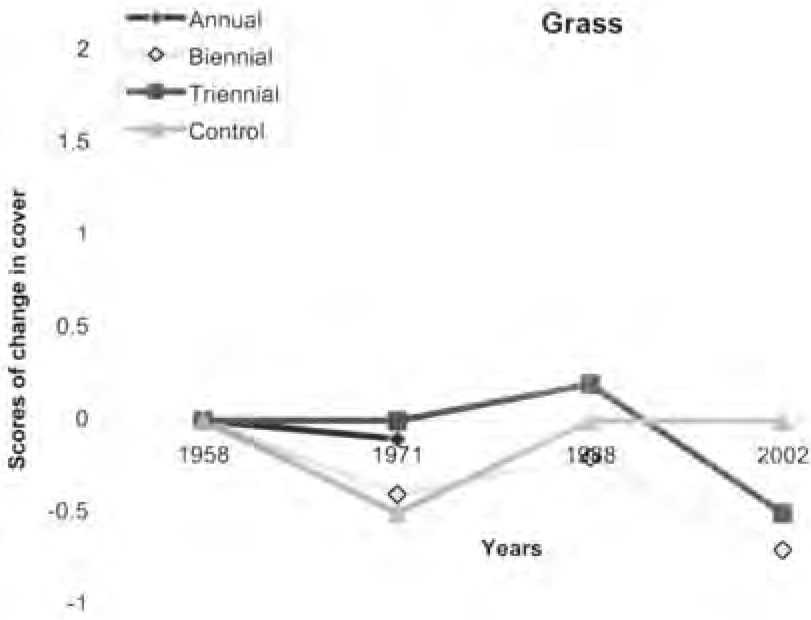

Figure 5. c. The effect of the burn interval on the grass cover over the period 1958-2002 in Numbi,Fayi, Kambeni and Shabeni.

Table 2. The effect of fire regimes on change in tree cover from 1958-2002. -0.5- -1=small decline, -1.5 - -2=significant decline, 0= no change, 0.5- 1=small increase, 1.5 2=significant increase, 2.5=outstandingly significant increase

	Decrease	0	0.5	1	1.5	2	2.5
FAYI		Apr3 Oct3 Dec3	Aug3 Oct2	Aug2	Feb2 Feb3	No burn Apr2 Aug1 Dec2	
SHABENI		Aug3 Oct2	Apr2 Aug1 Aug2 Dec2 Dec3	Feb2 Feb3 Apr3 Oct3			
NUMBI		Feb2 Aug1 Oct3 Dec2 Dec3	Apr3 Aug3	Apr2 Oct2	No burn Feb3		

Table 3. Effect of fire regimes on change in shrub cover from 1958-2002. -0.5- -1=small decline, -1.5 - -2=significant decline, 0= no change, 0.5- 1=small increase, 1.5 - 2=significant increase, 2.5=outstandingly significant increase

	-1.5	-1	-0.5	0	0.5	1	1.5	2	2.5
FAYI		Feb2 Apr2		Dec3	Apr3	No burn Aug1 Aug2 Oct2	Dec2	Aug3 Oct3	Feb3
SHABENI				Dec3	Aug1 Aug2	Feb3 Apr2 Aug3 Oct2 Oct3		Feb2 Apr3 Dec2	
NUMBI			Oct3	Dec3	Aug1 Oct2 Dec2	Feb2 Apr3 Aug3	No burn	Apr2	Feb3

Table 4. Effect of fire regime on change in grass cover from 1958-2002. -0.5- -1=small decline, -1.5 - -2=significant decline, 0= no change, 0.5- 1=small increase, 1.5 - 2=significant increase, 2.5=outstandingly significant increase

	-2	-1.5	-1	-0.5	0	0.5	1	1.5
FAYI	No burn Dec2	Oct3	Feb3 Aug2	Aug3 Oct2	Apr2 Apr3 Aug1	Feb2 Dec3		
SHABENI	Apr3 Dec2		Feb2 Aug1	Oct3 Aug3 Apr2 Oct2 Aug3	Feb3	Dec3		
NUMBI		Feb3 Apr2	No burn	Aug3 Oct2	Feb2 Apr3 Aug1 Dec2	Dec3	Oct3	

Figure 7. a.1958 picture of Feb2 fire regime at Fayi

Figure 7.b. 1971 picture of Feb2 fire regime at Fayi

Picture 7. c.1988 picture of Feb2 fire regime at Fayi

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Figure 7. d.2002 picture of Feb2 fire regime at Fayi