Fire regime of the Kruger National Park for the period 1980 - 1992

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Fire regime refers to the type and intensity of fire and the season and frequency of burning. In the Kruger National Park it varies according to the source of ignition of the fires. Since 1985 the different ignition sources have been controlled burns (47%), refugees (23%), others (20%) and lightning (10%). The data showed that anthropogenic fires were the most common fires and evidence on a global scale would suggest that the status quo will be maintained even if controlled burning is discontinued as is currently being considered by the National Parks Board. The most common type of fires that occur in the park are surface head fires burning with the wind but back fires and crown fires do also occur. The intensity of the fires is primarily a function of the grass fuel load which is dependent on the rainfall and consequently varies enormously from year to year. The type of fire also influences the intensity and research conducted during 1992 showed that head fires burning under similar environmental conditions were on average 36 times more intense than back fires. Anthropogenic fires generally occurred during the dry, dormant, winter period while lightning fires were more associated with the spring and summer period when dry lightning storms occur. The frequency of burning varied significantly between sourveld and sweetveld. The mean frequency of burning in sourveld areas was triennial and in the sweetveld areas octennial. Finally the general conclusion that can be drawn about the fire regime of the Kruger National Park is that it is highly variable and will continue to be so in the future. This is a very positive feature that ensures a wide diversity of habitat types.

Key words: fire regime, burning, type, intensity, season, frequency, South Africa.

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Introduction

A study of fire ecology in the savanna areas of South Africa has led to the conclusion that the term fire regime comprises and refers to four components, namely, the type and intensity of fire and the season and frequency of burning (Trollope 1984). Research has shown that these different components have unique and individual effects on the ecosystem (Trollope 1993) and it is therefore essential that when considering the ecological effects of fire attention be given to describing all these components of the fire regime. Thus in attempting to describe the fire regime in the Kruger National Park (KNP) these four components will be dealt with separately. However, a complicating factor in describing the fire regime is that it varies according to the source of ignition of the fires and therefore this aspect must also be considered. Finally rotational burns applied on a controlled basis are one of the most important ignition sources of fires in the Kruger National Park. Nevertheless the data will be presented in *de facto* form and no attempt will be made to relate it to the recommended fire regime for the park as this is outside the scope of this paper. The information presented in this paper was obtained from the computerised data base that was established in the KNP in 1980 in which all fires occurring in the park are recorded in terms of date of occurrence, location, ignition source and area burnt. The data presented are for the period 5 May 1980 to the 30 September 1992 and comprise information on 1 137 fires which burnt a total area of 3 041 249 ha which is equivalent to an area 1,6 times the size of the park.

Ignition sources of fires

The different sources of ignition of fires in the KNP for the period 5 May 1985 to the 30 September 1992 are presented in Figure 1.

It is clear from Fig. 1 that the most important ignition source in the park was controlled burning (47%) which is applied on a rotational basis to remove moribund and/or unpalatable grass material and to maintain an optimum balance between grass and tree vegetation. The next most important ignition source were fires caused by refugees (24%) fleeing from Mozambique via the park into South Africa. These people light fires for protection, cooking and warmth, which then spread either by accident or when left unattended. The next most important causes of fires have been grouped under a general heading called others (20%). This includes wild fires caused by poachers, tourists, arsonists, accidents and reasons unknown. Surprisingly lightning (10%) was not a very significant ignition source and the probable reason for this is that ignition from other sources currently have a greater probability of causing fires under the present form of management in the park and political conditions in Mozambique. This concurs with what is occurring on a global scale where, with the significant increase in the human population, the majority of the tropical savannas are being shaped and maintained by anthropogenic fires and the stage has now been reached that in most regions of the world humans have become more important than lightning as sources of ignition (Goldammer & Crutzen 1993).

It is therefore highly unlikely that lightning would become the dominant source of ignition in the KNP if there was a reduction in the application of controlled burns as is currently being considered by the National Parks Board. This is because the other forms of anthropogenic fires are more liable to increase in incidence in the future in view of these fires being unsuccessfully controlled in the past despite efforts by the field staff. The incidence of lightning fires has also probably decreased as is indicated by the fact that data

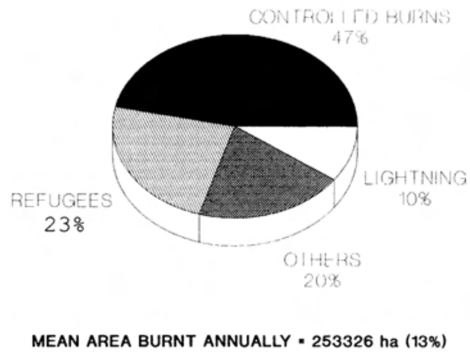


Fig. 1. The proportion of the Kruger National Park that has been burnt by different ignition sources during the period 5 May 1985 – 30 September 1992.

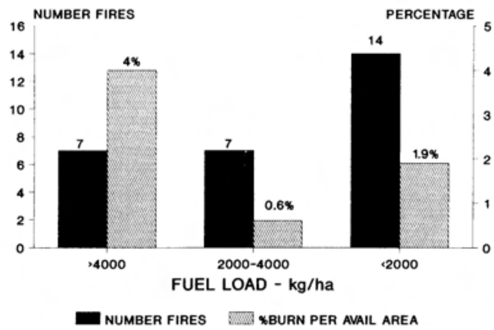


Fig. 2. The relationship between the percentage area burnt by lightning in the Kruger National Park and the fuel load of grass expressed in kg/ha.

collected since 1989 during the annual assessment of the condition of the veld in the park (Zambatis 1992), showed that the majority of fires caused by lightning (66%) occurred under conditions where the grass fuel load was low (< 2 000 kg/ha). Furthermore because the overall standing crop of grass in the park was also generally low, there was less of an opportunity for these fires to spread and burn a greater area. Support for this possibility is illustrated in Fig. 2 where the percentage of area burnt by lightning fires was higher (4% vs. 0,6 – 1,9%) in situations where the fuel load of grass was > 4 000 kg/ha than where it was < 4 000 kg/ha. It is therefore possible that under conditions that may have existed in the past, lightning was a more important source of ignition of fires in the savanna areas currently occupied by the Kruger National Park than is the situation at present.

Fire Regime

Type of fire

The most commonly occurring types of fires in the park are *surface fires* burning in the grass sward either as *head fires* with the wind or *back fires* against the wind. *Crown fires* do occur when the aerial portions of trees and shrubs occasionally ignite during fierce high intensity head fires but these are the exception rather than the rule. No data are available on what proportion of the burns caused by the different ignition sources occur as the aforementioned types of fires. Suffice it to say that the rotational burns applied up until 1990 occurred mainly as head fires because of the procedure used in igniting the areas to be burnt. The procedure is illustrated in Fig. 3.

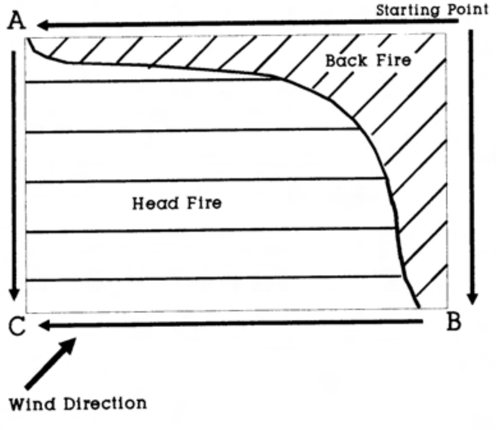


Fig. 3. The procedure used in applying controlled rotational burns in the Kruger National Park.

Up until 1990 the burning program comprised dividing the park up into 456 burning blocks which were burnt on a rotational system according to certain prescribed criteria. As a result of the burning blocks being relatively small (mean = 4 800 ha) the procedure of igniting the perimeter of the block tended to cause the development of a central coalescing smoke plume that set up convection currents which drew the flame fronts inwards from around the perimeter resulting in the burns being predominantly head fires burning with the wind. This was concluded to be ecologically undesirable because having the area burnt mainly by one type of fire, this was probably causing a relatively uniform effect on the vegetation therefore reducing biodiversity and the range of different habitat types. In an effort to introduce a more natural type of fire regime the 456 burning blocks were combined into 88 larger burning units in 1991. These larger areas are still being ignited around the perimeter but because the burning units are significantly greater the areas burn for much longer i.e. days rather than hours, during which time the fire front fragments into separate fires and is driven in different directions in response to changes in the wind. The diurnal variations in the atmosphere during the extended burning period also result in different fire behaviour causing the controlled burn to have a greater range of effects on the vegetation. Thus it is hypothesised and anticipated that the current rotational burns will comprise a greater range of types of fires than was previously the case.

No quantitative data are available on the relative proportions of the different types of fires caused by the other ignition sources. It is hypothesised though that because these ignition sources result in fires developing from a single point, the burns will comprise a greater range of types of fires because with the fire front spreading and increasing outwards from the ignition point, it will be continually influenced by changes in the wind from all directions.

Fire intensity

Research on fire behaviour in the Kruger National Park by Trollope & Potgieter (1985) led to the conclusion that fire intensity as defined by Byram (1959) is the parameter best suited for describing the general behaviour of fires in the park and provides a convenient means for formulating guidelines for controlled burning. Based on these data and research conducted in the eastern Cape by Trollope (1983) a fire intensity model was developed using a multiple regression analysis for surface head fires burning in grassveld and savanna areas. The model was based on the effects of fuel load, fuel moisture, relative humidity and wind speed on fire intensity. Air temperature was considered but not included in the model because it is significantly correlated with relative humidity. Slope was also excluded because the experimental fires were all applied to relatively flat terrain. The multiple regression analysis showed that the independent variables all had a statistically significant effect on fire intensity but that fuel load and fuel moisture influenced fire intensity to the greatest degree.

The resultant multiple regression equation for predicting the intensity of surface head fires based on these is:

$$FI = 2729 + 0{,}8684x_1 - 530\sqrt{x_2} - 0{,}1907x_3^{\,2} - 596\frac{1}{x_4}$$

where:

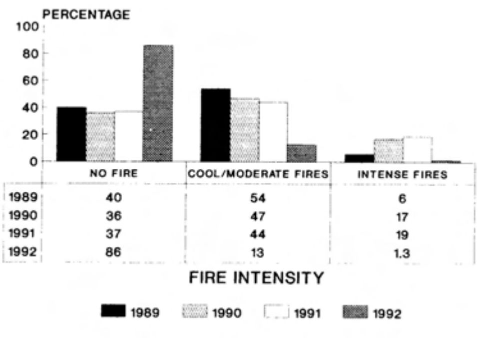
FI = fire intensity - kJs^1m^1
x_1 = fuel load - kg/ha
x_2 = fuel moisture - %
x_3 = relative humidity - %
x_4 = wind speed - m/s

The regression equation is based on the following statistics:

Number of cases = 200
Multiple correlation coefficient (R) = 0,7746 ($P \leq 0{,}01$).

The model was tested with independent fire behaviour data and was found to be highly significant ($r = 0{,}7486$; $df = 33$; $P \leq 0{,}01$).

Recognising that fuel load and fuel moisture have the greatest effect on fire intensity it is possible using the aforementioned fire intensity model, to estimate the potential of the rangeland in the Kruger National Park to support fires of different intensities. Assuming that fires burn mostly during the dry season when the fuel moisture does not exceed 20% the model indicates that intense fires (> 3 000 kJs^1m^1) occur when the fuel load of grass is > 4 000 kg/ha and cool to moderately intense fires (< 3 000 kJs^1m^1) when the fuel load is < 4 000 kg/ha. Field experience also indicates that when the grass fuel load is < 2 000 kg/ha fires will generally not spread because of the discontinuity



	NO FIRE	COOL/MODERATE FIRES	INTENSE FIRES
1989	40	54	6
1990	36	47	17
1991	37	44	19
1992	86	13	1.3

Fig. 4. The potential intensity of head fires in the Kruger National Park as determined by the fuel load of grass during the period 1989 to 1992.

Table 1
The mean, maximum and minimum intensities of head and back fires recorded during the SAFARI'92 project conducted in the Kruger National Park during August and September 1992. Data are expressed in kJs^{1}m^{1}

Type of fire	Mean	Maximum	Minimum
Head fire	2810 ± 893	8845	22
Back fire	77 ± 29	160	20

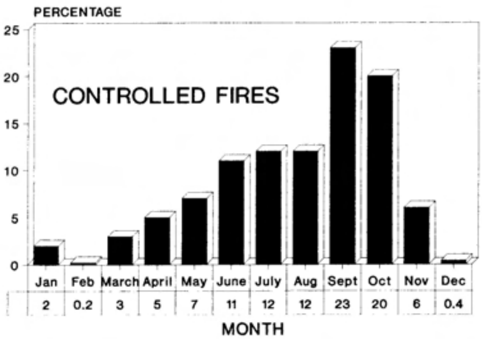


Fig. 5. The percentage area burnt by controlled rotational burns during the different months of the year in the Kruger National Park for the period 1980 to 1992.

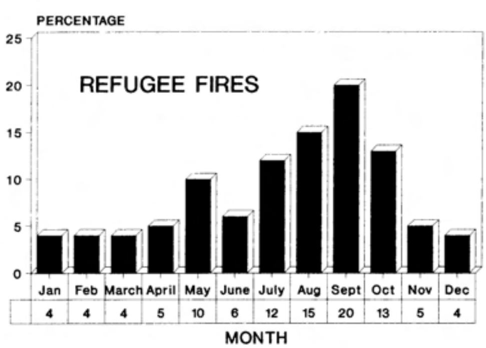


Fig. 6. The percentage area burnt by fires caused by refugees during the different months of the year in the Kruger National Park for the period 1985 to 1992.

of the fuel bed. Using the estimates of the standing crop of grass measured with a disc meter that have been recorded annually in the park since 1989 it is possible using the aforementioned criteria to determine what proportion of the rangeland will support fires of different intensities.

The data in Fig. 4 illustrate the important influence fuel load has on the potential fire intensity of the rangeland in the park and the effect of the devastating drought experienced during 1992 is clearly shown by the high proportion of the park (85%) that could not have supported a fire.

Obviously it is not logistically possible to monitor the intensities of the fires that occur in the KNP annually. However, the intensities of the fires that were recorded during August and September 1992 as part of the SAFARI'92 project, give a representative indication of the range of fire intensities that occur in the park under field conditions.

The data in Table 1 indicate that head fires are generally far more intense than back fires but that they are more variable. These results corroborate the behaviour of head and back fires that has been observed during the application of controlled burns on a field scale in the Kruger National Park.

Season of burning

Data are available on the month of the year that fires caused by controlled rotational burning, refugees, lightning and other causes have occurred in the Kruger National Park since 1980. The areas burnt by these fires, expressed as a percentage, are presented in Figs. 5, 6, 7 and 8.

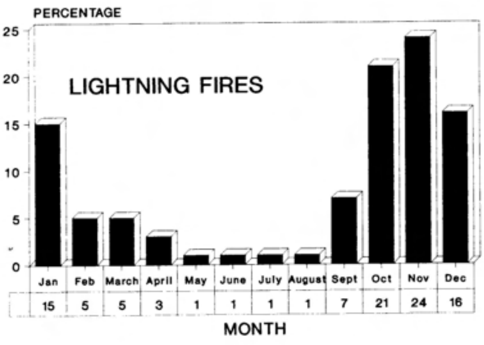


Fig. 7. The percentage area burnt by fires caused by lingtning during the different months of the year in the Kruger National Park for the period 1980 to 1992.

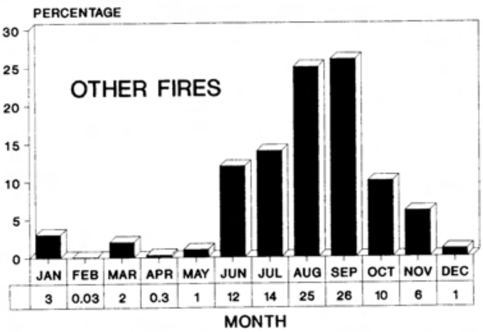


Fig. 8. The percentage area burnt by fires caused by "other" causes during the different months of the year in the Kruger National Park for the period 1980 to 1992.

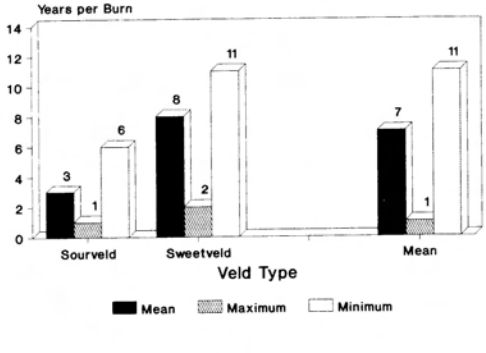


Fig. 9. The mean, maximum and minimum number of years that elapsed between burns occurring in sourveld and sweetveld areas in the Kruger National Park during the period 23 April 1981 and 24 September 1992.

The data in these figures show that, except for lightning, the majority of the fires occurred during the dry, dormant winter period. Of course fires caused by lightning also happen when the grass sward is dry but the data would suggest that these fires are associated with dry lightning storms that are prevalent from October through to January.

Frequency of burning

The frequency of burning in the KNP is highly variable and is influenced by the annual rainfall and the grazing pressure exerted by the wildlife populations that fluctuate from year to year. This is clearly illustrated in Table 2 where the total area burnt by different ignition sources for the period 1981 to 1992 is presented.

The data presented in Table 2 clearly illustrates the great variation in the total area burnt annually in the KNP. For example in 1981, 37,3% of the park was burnt as a result of high fuel loads accumulating after a period of above average rainfall, whereas only 1,5% burnt in 1992 as a result of the devastating drought severely depressing grass production. A further analysis of the data showed that the frequency of burning was greater in sourveld areas than in sweetveld areas i.e. high and

Table 2

The total area burnt by different ignition sources in the Kruger National Park during the period 1981 to 1992. Data expressed in hectares and as a percentage

Year	Controlled	Refugees	Lightning	Others	Total	%
1981	509 114	0	118 074	100 649	727 837	37,3
1982	108 434	0	98 316	68 815	275 565	14,1
1983	4 689	0	41 281	14 926	60 896	3,1
1984	46 984	0	3 279	3 888	54 151	2,8
1985	242 997	141 557	30 849	110 392	525 795	27,0
1986	76 166	55 530	43 734	65 438	240 868	12,3
1987	62 492	30 449	17 714	31 247	141 902	7,3
1988	82 429	90 390	2 523	38 527	213 869	11,0
1989	60 702	22 137	13 823	16 517	113 179	5,8
1990	200 117	24 673	21 553	50 487	296 830	15,2
1991	169 786	72 458	54 404	61 667	358 315	18,4
1992	4 084	15 910	5 577	4 157	29 728	1,5
Mean	130 666	56 638	37 594	47 226	253 245	13,0

low rainfall areas respectively. The data were analysed by recording the number of times that the different burning blocks in the park were burnt between the 23 April 1981 and the 24 September 1992. The analysis was limited to those burning blocks that were at least 1 000 ha in size and where at least 50% of a burning block had been burnt during a fire. This constituted a sample area of 1 562 035 ha which is 80,1% of the total area of the Kruger National Park and involved a total of 605 fires.

Results

The results, presented in Figure 9, show that on average the sourveld areas were triennially burnt and the sweetveld areas octennially burnt. This is a credible result as the quality of the grass forage in the sourveld areas declines significantly over time due to the high rainfall leaching out the soluble chemical fractions of the plant material. Therefore at the end of three years the protein level of the herbage is generally so low (± 3%) that the veld is largely avoided by grazing animals, causing a high accumulation of grass fuel. Conversely in sweetveld areas, which receive a low rainfall, the quality of the grass forage does not decline to the extent that the herbage becomes unpalatable to grazing animals, even when the grass is dry and dormant during winter. Therefore the level of utilisation of grass forage is much higher in these areas and the accumulation of adequate fuel loads of grass only occurs during above average rainfall years when the grazing capacity of the veld far exceeds the stocking rate of grazing animals.

Discussion and conclusions

It is clear from the foregoing results that the fire regime of the Kruger National Park is very complex and is in a continual state of flux as a result of the different sources of ignition that cause fires. For example fires caused by refugees from Mozambique are the second most important source of ignition and the frequency of these fires will vary according to factors beyond the control of the park authorities. Furthermore, fires caused by "other " ignition sources such as poaching and arson, are also very variable and difficult to predict. If the variation in the fire regime that is caused by oscillations in climate are also considered as they effect fires caused by controlled burning and lightning, then the general conclusion must be drawn that the fire regime of the KNP is inherently variable and will continue to be so in the future. The positive aspect of this conclusion is that an inherently variable fire regime will have a variable effect on the ecosystem of the park thus ensuring a wide range of habitat types and therefore promoting biodiversity. However, the one component of the fire regime that must be monitored very closely is the frequency of burning. This is because preliminary results from the long term burning experiment in the park indicate that, as the frequency of fire increases, so the intensity of grazing by wild ungulates increases. This increase in grazing pressure apparently leads to the eventual reduction of the grass sward to a pioneer condition which is unproductive in terms of providing forage for grazing animals and which has a lower diversity of perennial plant species. These preliminary results emphasise the necessity of having a comprehensive program for monitoring the condition of the vegetation and lend support to the current intensive monitoring of veld condition in the Kruger National Park.

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