Long-term changes in the woody vegetation of the Kruger National Park, with special reference to the effects of elephants and fire

W.S.W. Trollope, L.A. Trollope, H.C. Biggs, D. Pienaar and A.L.F. Potgieter

Trollope, W.S.W., L.A. Trollope, H.C. Biggs, D. Pienaar and A.L.F. Potgieter. 1998. Long term changes in the woody vegetation of the Kruger National Park, with special reference to the effects of elephants and fire. *Koedoe* 41(2): 103–112. Pretoria. ISSN 0075-6458.

As part of the investigation reviewing the South African National Parks policy on the management of elephants in the Kruger National Park in South Africa it was decided to assess the current density and structural diversity of the woody vegetation in the park as it is affected by elephants and fire. The management policy used till recently, limited the population to approximately 7000 elephants, based on a conclusion that 6000 elephants (1 per 1.94 km²) was the highest number of elephants that could be carried in the Kruger National Park. The inclusion of the effects and interaction of fire in the investigation arises from the general recognition that elephants and fire can have a highly significant impact on the species and structural diversity of tree and shrub vegetation in African savannas. In the absence of quantitative data describing the condition of the woody vegetation in the Kruger National Park, subjective comparisons of changes in the density of large trees were made for the periods 1940 *vs* 1960 and 1960 *vs* 1986/89 using aerial photographs based on four of the major vegetation landscape units in the park. The results indicate that in the vegetation landscapes in areas with granitic soils there were no significant changes in the density of large trees between 1940 *vs* 1960 whereas a moderate decline occurred in the vegetation in the areas with basaltic soils. Conversely during the period 1960 to 1986/89 there was a dramatic decline in the density of large trees in all four major vegetation landscape units. On-site inspections and botanical surveys suggest that the decline in the density of large trees is the result of the effects of the interaction of elephants and fire. This had arisen because during the period 1960 to 1986/89 systematic burning programs had been introduced at the same time as elephant numbers had risen sharply. The results presented suggest that the changes in the woody vegetation do not involve a decrease in species diversity but rather a change in structural diversity where the woody vegetation is being transformed into a short woodland community interspersed with a low density of large trees. It is concluded that if it is desirable to prevent further structural changes to the woody vegetation then the current density of elephants should not be allowed to increase, the frequency of burning should be significantly reduced and the ignition procedure altered to allow or simulate point ignitions of fires.

Key words: elephants, fire, savanna, Kruger National Park.

W.S.W. Trollope, L.A. Trollope, Department Livestock & Pasture Science, Faculty of Agriculture, University Fort Hare, P.Bag X1314, Alice, 5700, South Africa; H.C. Biggs, D. Pienaar & A.L.F. Potgieter, Scientific Services, Conservation Development, Kruger National Park, Skukuza, 1350, South Africa.

Introduction

As part of the investigation reviewing the South African National Parks policy on the management of elephants in the Kruger National Park in South Africa it was decided to assess the current density and structural diversity of the woody vegetation in the park as it is affected by elephants and fire. The reason for introducing the management policy (used till recently and currently suspended pending possible implementation of an alternative) which limited the population to 7000

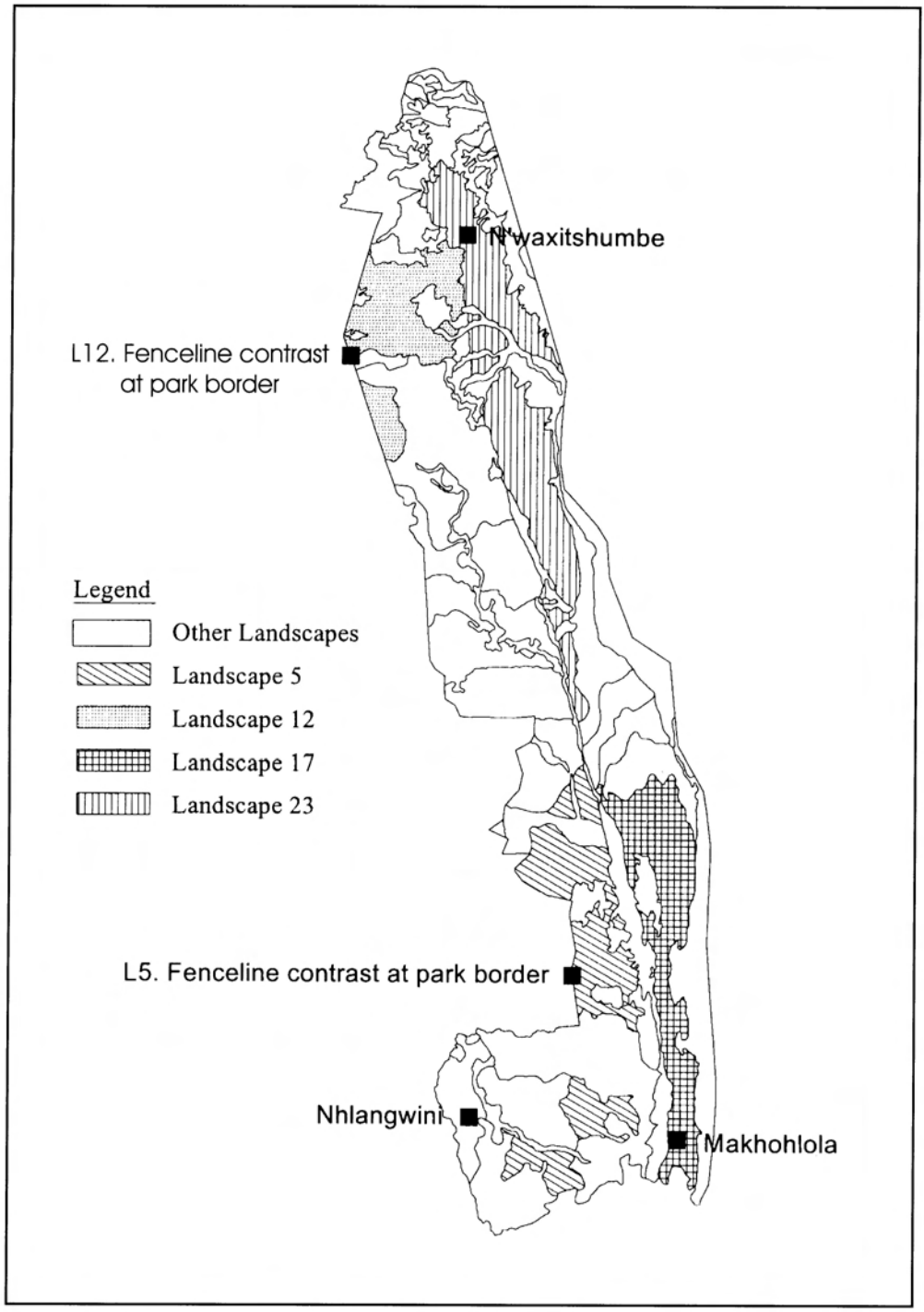

Fig. 1. The location of study sites and vegetation zones in which sampling was undertaken in the Kruger National Park.

elephants (± 6000-8500) (Joubert 1986), were the findings by Pienaar, van Wyk & Fairall (1966). They concluded that 6000 elephants (1 per 1.94 km²) was the highest number of elephants that could be carried in the Kruger National Park "if the total destruction of the vulnerable areas near water is not to result". This finding was embodied in the policy applicable to high density animal species which permits the manipulations of artificially high densities of animals due to spatial limitations of the Kruger National Park, that may materially change the structure and/or composition of the woody element of the vegetation (Joubert 1986). The inclusion of the effects of fire in the investigation resulted from the recognition that both elephants and fire as single or interactive factors can have a highly significant impact on the species and structural diversity of tree and shrub vegetation in African savannas. This is well illustrated by the numerous reports on the effects of elephants and fire on woody vegetation in the Tsavo National Park, Kenya (Glover 1963; Sheldrick 1992), Serengeti National Park, Tanzania (Pellew 1983; Dublin 1995), Murchison Falls National Park, Uganda (Wheater 1971), Luangwa Valley, Zambia (Hanks 1979) and the Kruger National Park, South Africa (van Wyk 1971).

It is the object of this paper to present an overview of the effects of elephants and fire on the density and structural diversity of trees and shrubs in the Kruger National Park. This will be based on available data and will comprise determining the changes that have occurred over time and a preliminary field investigation of the interaction of these two environmental factors on the woody vegetation.

Methods

Changes in the woody vegetation

The condition of the tree and shrub vegetation in the Kruger National Park is being monitored using aerial photography and a series of fixed point photographs that are taken during the wet and dry season each year. Viljoen (1988) conducted an initial preliminary survey using the aerial photographs to determine changes in the density of large trees in two areas of the *Sclerocarya birrea/ Acacia nigrescens* savanna landscape in the Kruger National Park viz. the Satara and Lower Sabie areas. In the current investigation it was decided to adopt the same approach to assess changes that may have occurred in the woody vegetation of the park since 1940. However, due to the urgency of the matter it was decided to restrict the investigation to the four major vegetation landscape units (Fig. 1) as described by Gertenbach (1983) occurring in the Kruger National Park viz.:

- Landscape 5: Mixed *Combretum/ Terminalia sericea* woodland occurring on sandy granite derived soils;
- Landscape 12: *Colophospermum mopane/ Acacia nigrescens* savanna occurring on sandy granite derived soils;
- Landscape 17: *Sclerocarya birrea/ Acacia nigrescens* savanna occurring on clayey basalt derived soils;
- Landscapes 23: *Colophospermum mopane* shrubveld on basalt occurring on clayey basalt derived soils.

Because of time constraints it was also not possible to estimate the quantitative changes that may have occurred in the density of large trees in these landscapes. It was therefore decided that the most practical procedure would be to subjectively compare aerial photographs of randomly selected sites in the aforementioned vegetation landscapes using the criterion of whether there had been no (or negligible) or a marked (moderate or greater) decline or increase in the density of large trees with a canopy diameter of >5 m.

In addition to the sites randomly selected within the four landscape vegetation units two sites were chosen on adjacent sides of the western boundary fence of the park in Landscapes 5 and 12. In both cases the adjacent areas to the park represented rangeland under a communal grazing system in the absence of elephants and without any form of active cultivation for crop production being evident. No documented fire history is available from the communal side of these contrasts, though it is clear that fires at times burnt there.

The comparisons were done for the years 1940 vs 1960 and 1960 vs 1986/89 by the resident research botanist and the results were tested by presenting a statistically large enough sample of the same data to two independent assessors. To improve objectivity, these evaluations were done without the observers knowing which image in the sequence was the earlier and which the later scene. There was highly satisfactory concordance between the results of the test-

run comparisons of the three assessors in that the results of statistical analyses on all three agreed. Also, it is notable that no single site was recorded by any observer as having shown an increase in the density of large trees over time. Consequently the data generated by only one of the assessors (the research botanist) was used to describe the changes that had occurred in the density of large trees in the different landscape vegetation units.

Effects of interactions of elephants and fire on the woody vegetation

To obtain quantitative botanical data on the effects of elephants and fire on the density and structural diversity of the woody vegetation in the Kruger National Park, bush surveys were conducted inside and outside of exclosures that had been protected from elephants but subjected to controlled burning for extended periods of time (Fig. 1) viz.:

- the N'waxitshumbe Exclosure located in Landscape 23: *Colophospermum mopane* shrubveld on basalt in the northern arid savannas near Shingwedzi; established 1967; size = 309 ha;
- the Nhlangwini Exclosure located in Landscape 1: Lowveld Sour Bushveld in the southern moist savanna near Pretoriuskop; established 1973; size = 269 ha;
- the Makhohlola Exclosure located in Landscape 17: *Sclerocarya birrea/Acacia nigrescens* savanna in the southern arid savannas near Crocodile Bridge; established 1974; size = 2 ha.

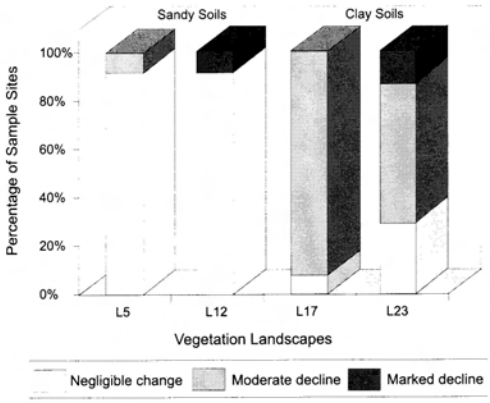

Fig. 2. The changes in the density of large trees with a canopy diameter of >5 m in the vegetation landscapes 5,12,17 and 23 in the Kruger National Park during the period 1940 to 1960.

The bush surveys comprised recording the presence of tree and shrub species rooted within a 2 m wide transect located in stratified random transects inside and outside the aforementioned elephant exclosures. The height of each plant species was recorded and the data were expressed as plants per hectare (P/ha) and tree equivalents per hectare (TE/ha). A tree equivalent is an index of the phytomass of bush and is equivalent to a tree or shrub that is 1.5 m high (Trollope *et al.* 1990). Differences in the density and phytomass of bush occurring within the different exclosures were analysed using a Student t test.

Results

Changes in the woody vegetation

The results of the comparisons of the aerial photographs for the period 1940 *vs* 1960 in the four vegetation landscapes are presented in Fig. 2. The graph data are presented as the percentage of the number of comparisons that indicated the type and degree of change that had occurred in the density of the large trees at the different sample sites in the four vegetation landscapes.

The results in Fig. 2 indicate that during the period 1940 to 1960 the changes in the density of large trees were negligible in Landscapes 5 (Sign Test: NS, n=13) and 12 (Sign Test: NS, n=13) (sandy granitic soils). Conversely a moderate decline in tree density generally occurred in Landscapes 17 (Sign Test: P=0.0005, n=15) and 23 (Sign Test: P=0.0044, n=14) both of which are on clayey basaltic soils. This was particularly so in the latter landscape where in one sample site there was a marked decline in the density of large trees. These trends continued during the period 1960 to 1986/89 and are clearly illustrated in Fig. 3 where generally moderate declines in density of large trees occurred in Landscapes 5 (Sign Test: P=0.0077, n=13) and 12 (Sign Test: P=0.0026, n=12) whereas moderate to marked declines occurred in Landscapes 17 (Sign Test: P=0.0003, n=15) and 23 (Sign Test: P=0.0009, n=14).

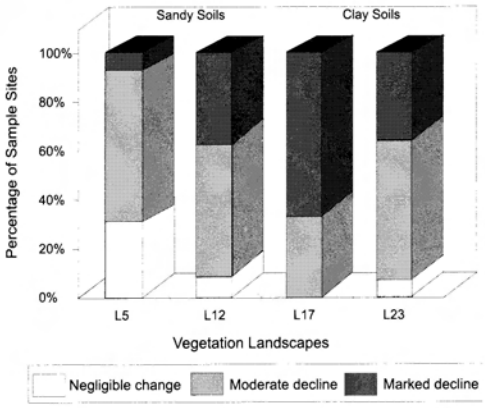

Fig. 3. The changes in the density of large trees with a canopy diameter of >5 m in the vegetation landscapes 5,12,17 and 23 in the Kruger National Park during the period 1960 to 1986/89.

Data are not available for that small portion of the Kruger National Park which has moist savannas, but the above results are believed to represent the 95% of the park's surface area consisting of arid savannas in the following general way :

- that since 1940 there has been a marked decline in the density of large trees particularly in the eastern portion of the park which is characterised by soils with a high clay content (basalt);
- that the major decline in tree density occurred during the period after 1960.

The results of fence-line contrasts on the western boundary of the park are shown in Table 1. These are based on only two sites each and are thus presented as such, with no statistical inference being made. The results indicate that the changes in tree density were negligible in the communal grazing area for the entire period 1940 to 1986/87 while in the Kruger National Park a marked decline in tree density occurred in Landscape 12 between 1960 and 1987. No change occurred in Landscape 5.

Effects of interactions of elephants and fire on the woody vegetation

The density and phytomass of bush occurring inside and outside of the exclosures in the Kruger National Park are presented in Table 2. The results are that:

- there were no significant differences between the densities of bush (P/ha) occurring inside and outside of the different exclosures.
- In contrast the phytomass of bush (TE/ha) was significantly greater ($P< 0.05$) inside than outside the Makhohlola and N'waxitshumbe exclosures located in arid savanna (500 mm; 446 mm) and on clayey basaltic soils. There were, however, no significant differences in the phytomass of bush inside and outside the Nhlangwini exclosure located in moist savanna (722 mm) and on sandy granitic soils.
- The small to large bush ratio (height class 0-3 m versus >3 m) : in all cases the there

Table 1

The effect of different systems of land use, comprising nature conservation inside and communal grazing outside the western boundary of the Kruger National Park (KNP), on the density of large trees with a canopy diameter of >5m in vegetation landscapes 5 and 12 during the periods 1940 - 1960 and 1960 - 1986/87

Landscape	Location	Period1940 - 1960	Period1960 - 1986/87
Landscape 5	Inside KNP	Negligible change	Negligible change
	Outside KNP	Negligible change	Negligible change
Landscape 12	Inside KNP	Negligible change	Marked decline
	Outside KNP	Negligible change	Negligible change

Table 2

The density and phytomass of bush occurring inside and outside the N'waxitshumbe, Makhohlola and Nhlangwini exclosures in the Kruger National Park where elephants have been excluded for extended periods of time but which have been subjected to controlled burning at different frequencies

Exclosure	Rainfall mm/ pa Soil Type	Fire Frequency Yrs/Fire	Bush Survey	Transect Length m	Density P/ ha	Phytomass TE/ha	Small:Large Bush Ratio 0-3m: >3 m %
N'waxitshumbe-1973	722	4.0	Inside	400	6463[a]	5377[a]	64: 36
Landscape 1	sandy	2.3	Outside	400	4900[a]	3037[a]	78: 22
Makhohlola - 1974	500	8.5	Inside	400	3625[a]	2634[a]	60: 40
Landscape 17	clayey	3.0	Outside	400	2575[a]	1320[b]	92: 8
Nhlangwini - 1967	446	3.6	Inside	1500	982[a]	1243[a]	67: 33
Landscape 23	clayey	4.3	Outside	1500	847[a]	786[b]	81: 19

[a,b] Tree density and phytomass values denoted with different alphabetical letters were significantly different from one another at the 5 % level of significance.

was a higher proportion of trees inside than outside the three exclosures in the >3 m height class. This manifested itself in a clearly defined two-tier structure in the woody vegetation outside the exclosures with the majority of the bush occurring in the lower height class.

Discussion and conclusions

At the macro-scale, the data obtained from subjectively comparing the density of large trees observed on aerial photographs for the periods 1940 *vs* 1960 and 1960 *vs* 1986/89 provide strong indications that there has been a marked decline in the density of large trees in the major arid landscapes of the park since 1960. These data support earlier findings by Viljoen (1988) who reported that there had been significant decreases in the density of large trees in Landscape 17: *Sclerocarya birrea/Acacia nigrescens* savanna during the period 1940 - 1981. This also provides support to the concern about the decline in the number and recruitment of aesthetically and ecologically important species of large trees like *Adansonia digitata* (baobab), *Sclerocarya birrea* (marula), *Acacia nigrescens* (knobthorn), *Combretum imberbe* (leadwood) and *Pterocarpus angolensis* (kiaat). However, these data are only qualitative, and thus it is absolutely imperative that the comprehensive database that already exists in the Kruger National Park in the form of aerial and fixed point photographs be quantitatively analysed in the near future to provide further evidence in this important area of investigation. Serious consideration should also be given to expanding the annual assessment of veld condition of the grass sward to include bush surveys on the same sample sites, possibly using analytical techniques such as those described in Teague *et al.* (1981).

The results in Figs. 2 & 3 are of particular ecological interest as they clearly illustrate the fact that the sandy soils of granitic origin are more favourable for the growth of trees than the clay soils of basaltic origin. The sandy soils retain less moisture in the upper soil layers but permit the infiltration of moisture down to greater depths in the soil profile than the clay soils thus favouring the deeper rooted woody vegetation more than the more shallow rooted grass sward. This phenomenon is also described by Knoop & Walker (1985).

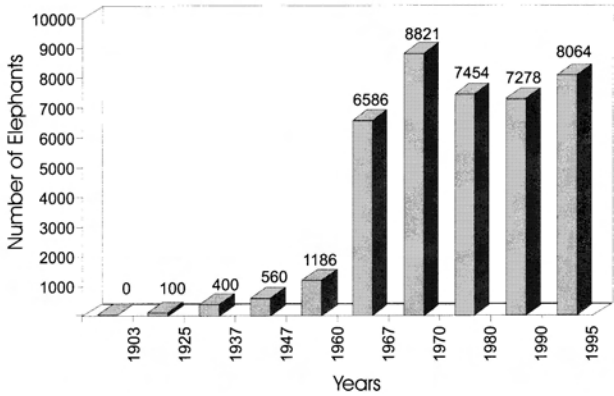

Fig. 4. The estimated elephant population in the Kruger National Park for the period 1903 to 1995.

The comparisons of the density of large trees on either side of the western boundary of the Kruger National Park clearly suggest that the decline in the tree density in landscape 12 is as a result of conditions within the park and not factors having an overall influence on the region irrespective of the system of land use (see Table 1). A further important result here is the lack of change in tree density in the adjacent communal grazing area at both sites (and in landscape 5 just within the park) for the entire period, which suggests that the overall climatic environment may have been similar over time and both inside and outside the Kruger National Park. The unknown fire histories on the communal sides, however, do pose an interpretive problem.

The exclosure data suggest that neither fire nor the interaction of elephants and fire had any significant effect on the overall density of the bush in the three vegetation landscapes. The data did not support field observations that there has been a significant decline in the density of preferred bush species like *Sclerocarya birrea* as a result of the interaction of fire and elephants. This may be the result of insufficient data and these field observations deserve further detailed research attention. The results also suggest that elephants in combination with fire have significantly reduced the phytomass of bush in the arid vegetation landscapes but not in the moist vegetation landscape. This would indicate that bush is more adversely affected by the interaction of elephants and fire where moisture is limiting and that the drier landscapes favour the development of open savanna or grassland. No exclosures were available in moist savanna occurring on clayey soils in order to determine the effect of rainfall under edaphic conditions similar to the exclosures in the arid savannas, although subjective observations (*pers. obs.*) made in the Shitlave area near Pretoriuskop situated in the same moist savanna landscape as the Nhlangwini exclosure, showed that moist savanna vegetation growing on clayey soils derived from gabbro was also highly sensitive to the effect of elephants and fire. In an area that had been subjected to a recent high intensity fire during 1995 the vegetation had been converted from a dense stand of *Dichrostachys cinerea* (sickle bush) dominated savanna to a physiognomically open grassland with virtually all the shrubs coppicing at ground level. This observation would suggest that soil type rather than rainfall is the dominant factor influencing the effect of the interaction of elephants and fire on the phytomass of bush in the Kruger National Park. The overall picture that emerges from these exclosure plots is that neither fire nor elephants and fire had any significant effect on the density of the woody vegetation in the three landscapes.

Conversely the interaction of elephants and fire caused a significantly marked reduction in the phytomass of bush in areas with clay soils irrespective of rainfall. This interaction, however, did not occur in areas with sandy soils where the rainfall is high. The impact of elephants (in combination with fire) on the woody vegetation is also clearly illustrated by the ratio of small to large bushes, where elephants are circumstantially linked to the two-tier structure (with few large trees in the upper tier) outside exclosures, compared to the more even spread of woody vegetation structure inside, where no elephants occur.

The results from the exclosures therefore provide strong indications that the reason for the decline in the density of large trees is the interaction of elephants and fire. This is believed to be the case because these two factors changed dramatically during the post 1960 period. Firstly, there was a dramatic increase in the elephant population in the Kruger National Park between 1960 and 1970 (Braack 1997) which is illustrated in Fig. 4. The reason for the dramatic increase in the elephant population during the 1960s is not completely known but is thought to be partly due to immigration from Zimbabwe and Mozambique during that period and partly due to the successful build-up of populations inside the Kruger National Park. The rise in numbers between 1960 and the first reliable census in 1967 is believed to be steeper than was actually the case or was even possible, the explanation being given that the 1960 value was an underestimate by perhaps half. In any event, this increase led to Pienaar *et al.* (1966) concluding that 6000 elephants (1 per 1.94 km²) was the highest number of elephants that could be carried in the Kruger National Park "if the total destruction of the vulnerable areas near water is not to result". Secondly, a controlled burning program was implemented in the park in 1954 and has been maintained in one form or another until 1991 (Trollope *et al.* 1995). Investigations by Trollope *et al.* (1995) led to the conclusion that the veld was being burnt too frequently based on the present condition of the grass sward. This partly forms the basis for the introduction of the current lightning burning program to reduce the previously high frequency of burning. Therefore the situation has developed that since 1960 there has been both an increase in the number of elephants and the incidence of fire, both factors which are known to have a negative influence on the development and structure of woody vegetation.

At the micro-scale the data from the exclosure plots also suggest that the interaction of elephants and fire have had a marked effect on the structure of the woody vegetation in arid landscapes but have no effect on the density of woody vegetation. It is not possible to separate the effect of elephants and fire per se on the woody vegetation as there are no quantitative examples of situations where only elephants were present and no fire. Nevertheless the results from the exclosures in the arid landscapes indicated that fire alone had significantly less effect on the structure of the woody vegetation than when it was combined with elephants, suggesting that elephants are the major contributing factor in the interaction. Quantitative data are required to substantiate this conclusion and highlights the necessity for field experiments specifically designed to determine the individual effects of elephants together with their interactive effects with fire. Some indication of the effects of elephants on the woody vegetation in the absence of fire could be obtained from surveying the control (i.e. nonburnt plots) of ± 7 ha in the long-term burning experiment that is replicated in all the major vegetation types in the park. Fire has been excluded in these plots for 44 years and the significantly greater phytomass of bush in these plots is in stark contrast to the more open structure and lower phytomass of bush in the plots that have received annual, biennial and triennial burning treatments. Woody vegetation in the Wolhuter Circle at Pretorious Kop (*pers. obs.*), situated in moist savanna on sandy granitic soils, which has been protected from fire since 1954 but which is open to elephants and other wild herbivorous ungulates

has developed into a closed canopy and is again in clear subjective contrast to the significantly more open adjacent burning blocks that have been subjected to a fire frequency of 1-3 years since the proclamation of the Sabi Game Reserve in 1898. It is also strongly recommended that additional exclosures (5-10 ha) be established in several major landscape units for monitoring purposes to further assist unravelling the interacting effects of elephants and fire on the structure of the woody vegetation.

All the aforegoing discussion has led to the postulation of the following hypothesis to explain the mechanisms involved in the reduction in the density of large trees and the development of a lower growing tree stratum in the arid vegetation landscapes of the park. Firstly, elephants have been primarily responsible for the topkill of trees > 3 m in height as research in the park has shown that trees > 3 m tall are generally resistant to fire. An accelerated rate of destruction of large trees occurred with the significant increase in the population of elephants post-1960 and the recruitment of large trees was prevented by an increase in the frequency of burning arising from the introduction and development of a triennial burning program implemented in 1957. This frequency of burning proved to be too high, not only in terms of altering the structure of the woody vegetation, but possibly also caused a decline in the condition of the herbaceous component of the vegetation in terms of species diversity and potential forage production. The recruitment of large trees was further exacerbated by the ignition procedure used in the application of the controlled burns where the burning blocks were ignited around the perimeter. This caused the rangeland to be burnt by mainly intense head fires resulting from the converging fire fronts being drawn towards the centre of the burning block by the well developed fire convection column. Based on the reasoning used in the postulation of this hypothesis, it is firmly believed that if it is desirable to prevent further structural changes to the woody vegetation then the current density of elephants should not be allowed to increase, the frequency of burning should be significantly reduced and the ignition procedure altered to allow or simulate point ignitions of fires. This conclusion is drawn mindful of the fact that the current management practice of limiting the elephant population to approximately 7000 has not prevented a decline in the structural diversity of the woody vegetation in the Kruger National Park. It highlights the interactive role of fire in the dynamics of the woody vegetation and the necessity to take a holistic view of the ecosystem when attempting to analyse changes that have occurred over an extended period of time.

Acknowledgements

The successful conducting of this investigation has been made possible by the willing and co-operative efforts of numerous people and we would like to pay special tribute to the valuable assistance provided by Mike Peel, Naledi Mare, Nick Zambatis, Albert Viljoen, Ian Whyte, Brian Harris, Wickus van der Walt, Kobus Kruger, Kim and Penelope Trollope.

References

BRAACK, L.E.O. 1997. Options for the management of the Kruger National Park elephant population. Pp. 118–139. *In:* A revision of parts of the management plan for the Kruger National Park. Vol. III: Policy Proposals Regarding Issues Relating To Biodiversity Maintenance, Maintenance Of Wilderness Qualities And Provision Of Human Benefits. Skukuza: Scientific Services, Kruger National Park. Unpublished.

DUBLIN, HOLLY T. 1995. Vegetation dynamics in the Serengeti-Mara Ecosystem: The role of elephants, fire and other factors. Pp. 71–90. *In:* SINCLAIR, A.R.E. & PETER ARCESE (eds.). *Serengeti II: Dynamics, management and conservation of an ecosystem.* Univ. Chicago Press.

GERTENBACH, W.P.D. 1983. Landscapes of the Kruger National Park. *Koedoe* 26: 9–121.

GLOVER, J. 1963. The elephant problem at Tsavo. *East African Wildlife Journal* 1: 30–39.

HANKS, J. 1979. *A struggle for survival - the elephant problem.* Cape Town: Struik.

JOUBERT, S.C.J. 1986. Masterplan for the management of the Kruger National Park. Unpublished memorandum. National Parks Board, Skukuza.

KNOOP, W.T. & B.H. WALKER. 1985. Interactions of woody and herbaceous vegetation in a southern African savanna. *Journal of Ecology* 73, 235–253.

PELLEW, R.A.P. 1983. The impacts of elephant, giraffe and fire upon the *Acacia tortilis* woodlands of the Serengeti. *African Journal of Ecology* 21: 41–74.

PIENAAR, U. DE V., P. VAN WYK & N. FAIRALL. 1966. An aerial census of elephant and buffalo in the Kruger National Park and the implications thereof on intended management schemes. *Koedoe* 9: 40–107.

SHELDRICK, DAPHNE. 1993. Vegetation changes in the Tsavo National Park. Pp. 350–361. *In:* CORFIELD, T. *The Wilderness Guardian.* Nairobi: Longman.

TEAGUE, W R., W.S.W. TROLLOPE & A.J. AUCAMP. 1981. Veld management in the semi-arid bushgrass communities of the Eastern Cape, *Proceedings of the Grassland Society of southern Africa* 16: 23–28.

TROLLOPE, W.S.W., L.A. TROLLOPE & O.J.H. BOSCH. 1990. Veld and pasture management terminology in southern Africa. *Journal of the Grassland Society of South Africa* 7(1): 52–61.

TROLLOPE, W.S.W., H.C. BIGGS, A.L.F. POTGIETER, & N. ZAMBATIS. 1995. A structured *versus* a wilderness approach to burning in the Kruger National Park in South Africa. *Proceedings of the V th International Rangeland Congress, Salt Lake City, U.S.A.*

VAN WYK, P. 1971. Veld burning in the Kruger National Park—An interim report of some aspects of research. *Proceedings of the Tall Timbers Fire Ecology Conference* 11: 9–31.

VILJOEN, A.J. 1988. Long term changes in the tree component of the vegetation in the Kruger National Park. Pp. 310–315. *In:* MACDONALD, I.A.W. & R.J.M. CRAWFORD (eds.). *Long term data series relating to southern Africa's renewable natural resources.* Pretoria: Council for Scientific and Industrial Research, National Scientific Programmes Unit. (South African National Scientific Programmes report; no. 157.)

WHEATER, R.J. 1971. Problem of controlling fires in Uganda National Parks. *Proceedings of the Tall Timbers Fire Ecology Conference* 11: 259–275.