CHAPTER 5

UTILISATION OF *ADANSONIA DIGITATA* AND *STERCULIA ROGERSII* BY ELEPHANT IN THE KRUGER NATIONAL PARK

INTRODUCTION

Overwhelming evidence has emerged in the latter part of this century to indicate that elephants are major agents of habitat change. The effect of elephants on the habitat increases in areas where restrictions are placed on their movements and the control of elephant populations becomes necessary. Proper management of elephant populations however requires information on the trends of the populations and especially their patterns of resource utilisation (Ben-Shahar 1993). The effect of elephant utilisation on a tree is dependant on the type of damage, the ability of the tree to recover, the role played by the tree in the plant community and the relationship between the plant community and other ecosystem components (Engelbrecht 1979).

In certain cases, biomass removal by elephant has shown that they prefer particular age groups of certain plant species (Ben-Shahar 1993; Tchamba 1995), while in others, elephant have shown no preference for any size class of tree (Tchamba & Mahamat 1992). The amount of biomass which is removed from trees by browsing elephants also varies considerably in different areas. Ben-Shahar (1993) found that biomass removal from the canopy of trees in northern Botswana was low. Tchamba and Mahamat (1992) found that elephant had browsed 97 % of observed trees belonging to a number of species. Only 53 % of these trees in Kalamaloue National Park, Cameroon, had had less than 75 % of their biomass removed by elephant. In Waza National Park, Cameroon, 55 % of trees were undamaged, 36 % had less than three quarters of the biomass removed and only 9 % more than 75 % of biomass removed (Tchamba 1995).

The aim of this section of the study was to determine the patterns of elephant utilisation of *Adansonia digitata* and *Sterculia rogersii* in the Kruger National Park, to quantify this utilisation and to ascertain whether elephant browsing interferes with the progression of seedlings growing to mature trees.

METHODS

Adansonia digitata

The utilisation of 1314 baobab trees which occur in the study area has been assessed. This was achieved by using two methods. The first was an estimate of the percentage of the total bark which had been stripped from each tree and has been referred to as bark stripping. The second method was to subjectively classify the extent of utilisation into six categories in order to distinguish between superficial and deeper utilisation. This is the depth of utilisation scale, and trees were classified by using the following criteria:

Type 0	Undamaged trees.
Type I	Slightly scarred trees.
Type II	Trees which had been ringbarked, but damage was superficial.
Type III	Deeply scarred trees.
Type IV	Trees whose shape has been radically altered by utilisation.
Type V	Dead trees.

Sterculia rogersii

Similar methods were used to assess the utilisation of 1163 *Sterculia rogersii* trees which occur in the study area. The first method was carried out by determining the percentage of the tree volume from which plant material had been removed. This is the estimated percentage of biomass which was missing from an imaginary intact plant (Ben-Shahar 1993). Due to this species being deciduous (Coates Palgrave 1984; Van Wyk 1984), biomass was only considered missing if the removal of branches and not only leaves had occurred. This has been referred to as biomass removal.

A subjective assessment of the severity of damage was also carried out for this species using a six point classification of the intensity of utilisation. Once again this enabled a distinction to be made between superficial and deeper damage. The categories which were used for the assessment of the depth of utilisation of star-chestnuts were based on the following criteria:

Type 0	Undamaged trees.
Type I	Trees which showed signs of light browsing.
Type II	Trees with entire branches removed by browsing.
Type III	Trees with some but not all stems broken off.
Type IV	Trees with all stems broken off.
Type V	Dead or uprooted trees.

RESULTS

Adansonia digitata

Bark stripping

Bark stripping of baobab trees has been classified into five percent increments and the northern and southern populations compared (Fig. 9). In the northern section, the majority of trees have either none, or only small amounts of bark removed, but in the south trees have generally been stripped of more bark. The difference between the populations is highly significant (Kolmogorov-Smirnov two-sample test, $D_{max} = 0.34$; $P < 0.001$).

The average amount of bark which has been removed from the baobab trees is 18.37 %. On average, baobabs in the southern section (22.96 %) have had more bark stripped than those in the north (9.12 %) (two-sample t-test assuming unequal variances, $t = 15.01$; df = 1201; $P < 0.001$)

The mean percentage of bark stripping of each size class has been plotted against the midpoint of the size class in Figure 10. Trees with a girth larger than 15 m have been lumped together due to the small size of the sample. The relationship between debarking

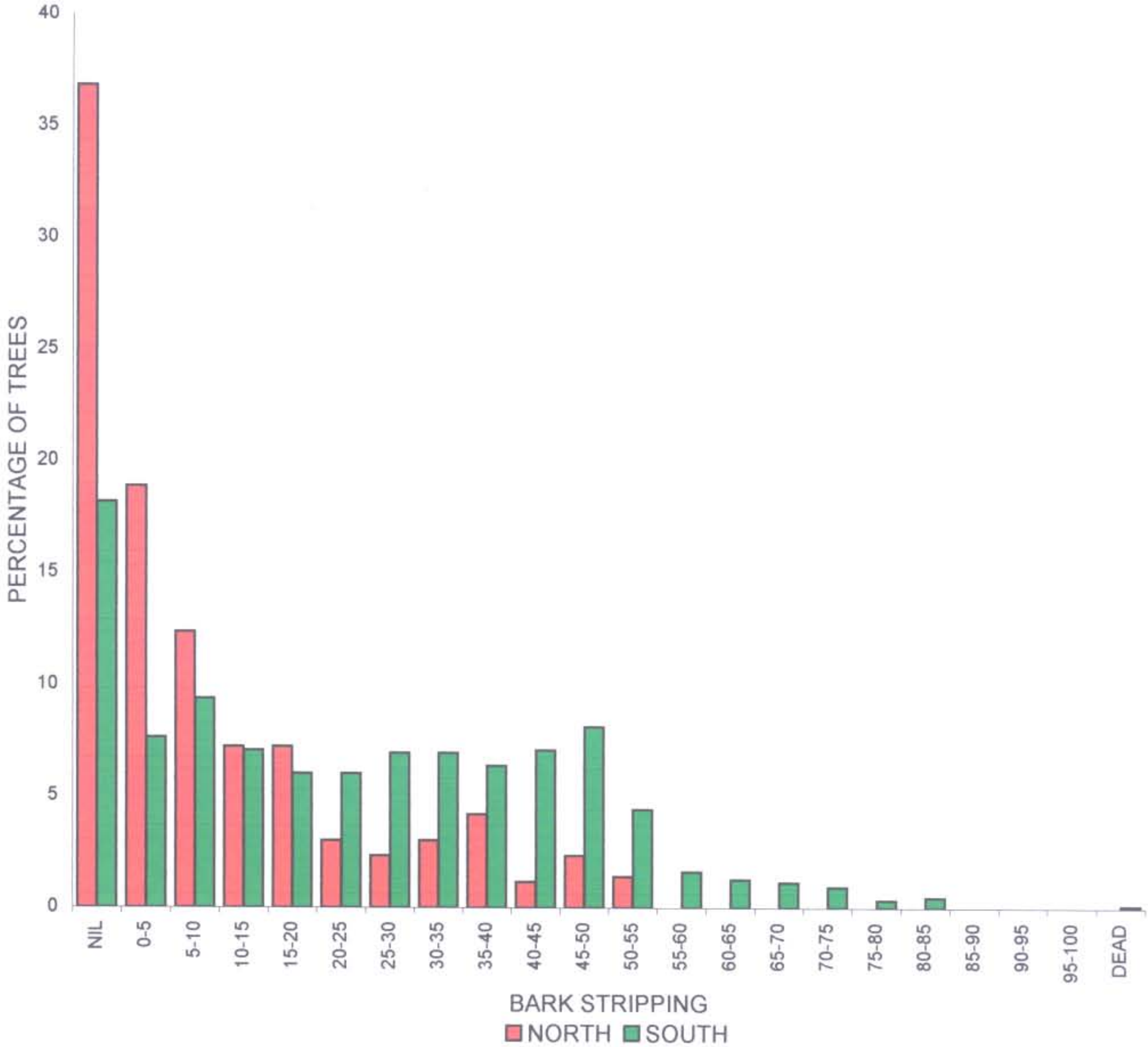


Fig. 9: Bark stripping (%) of *Adansonia digitata* in the northern and southern study sections of the Kruger National Park.

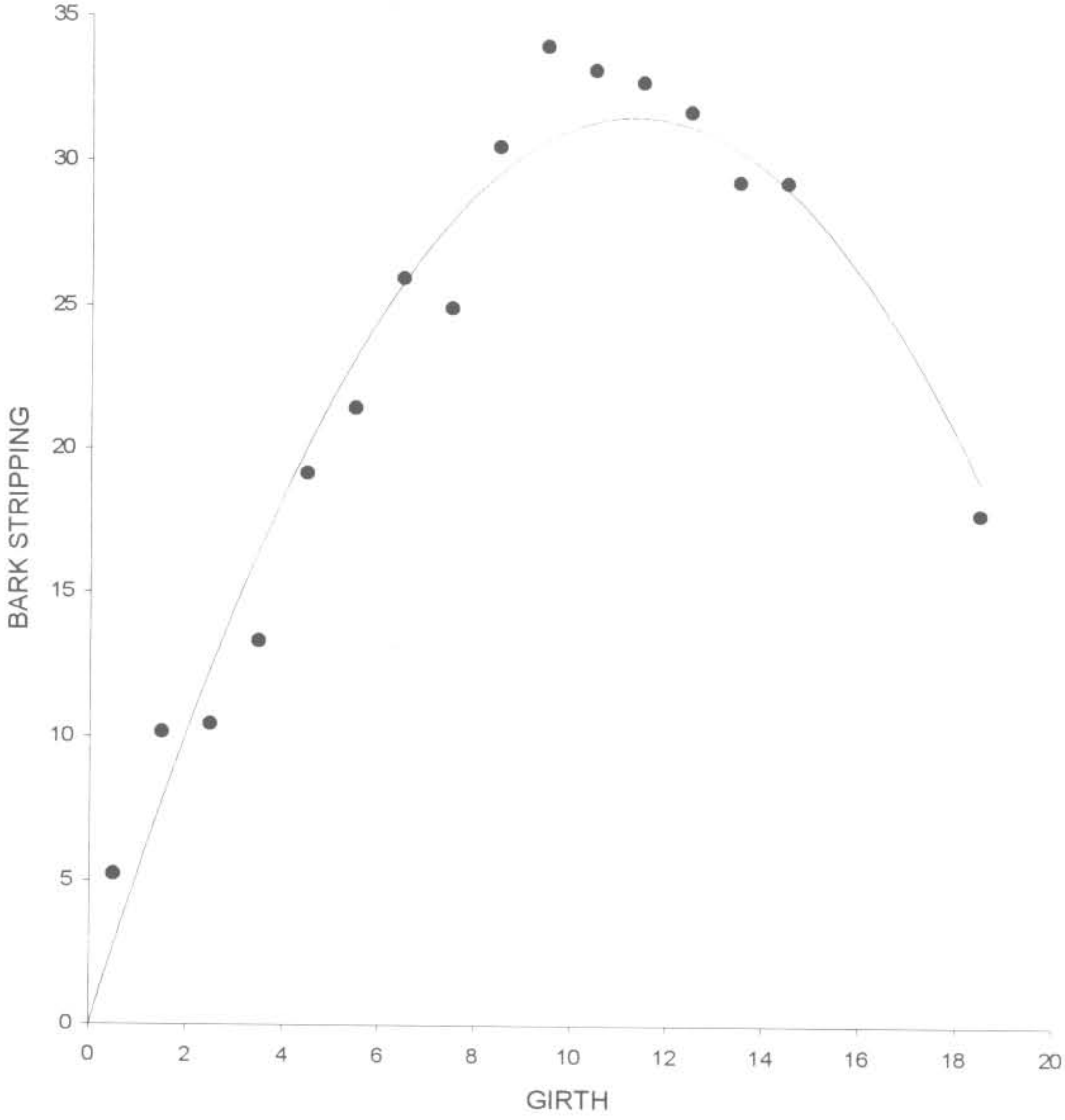


Fig. 10: Bark stripping (%) of *Adansonia digitata* in the Kruger National Park as a function of girth (m). Data for trees with a girth larger than 15 m have been pooled due to the small sample. $y = -0.25x^2 + 5.58x - 0.04$; ($r^2 = 0.96$; $X^2 = 5.15$; $P < 0.05$).

and baobab girth is described by the polynomial regression $y = -0.25x^2 + 5.58x - 0.04$ ($r^2 = 0.96$; $X^2 = 5.15$; $P < 0.05$).

The proportion of freshly debarked trees is 22 % in the northern section, which is considerably higher than the 7 % which have recently been debarked in the south (difference of proportions on freshly debarked trees, $z = 7.92$; $P < 0.001$).

Depth of utilisation

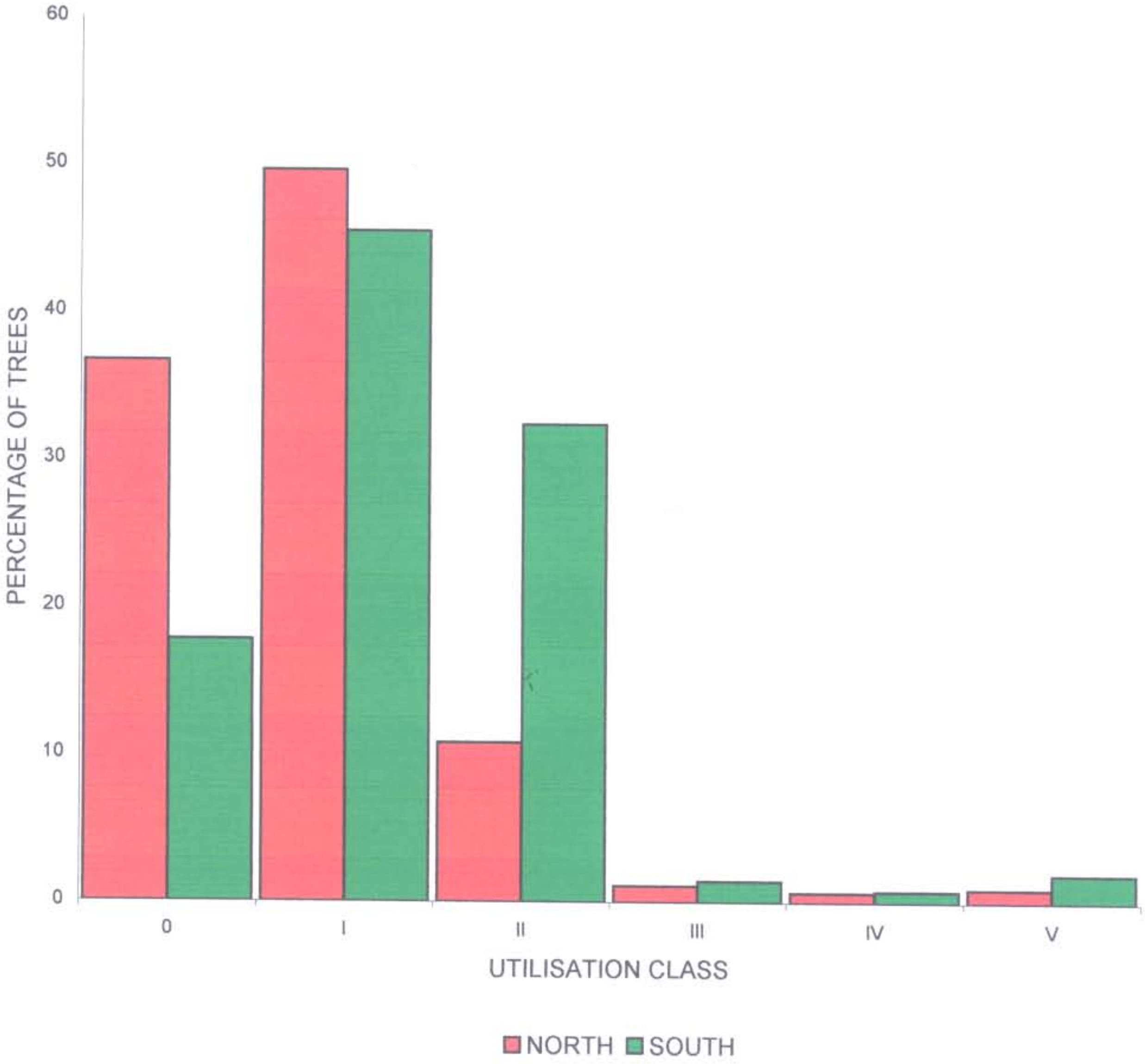
The depth of utilisation classification shows that the highest proportion of trees have been slightly scarred (Type I), with the intensity of utilisation dropping drastically into the more severe categories (Fig. 11). Utilisation is significantly different in the two study sections (Kolmogorov-Smirnov two-sample test, $D_{max} = 0.23$; $P < 0.001$).

In the northern section, 37 % of baobab trees show no signs of utilisation, but far fewer trees (18 %) in the south are unutilised (difference of proportions on the percent undamaged, $z = 7.53$; $P < 0.001$).

This depth of utilisation scale has also been used to express the total amount of damage incurred by baobab trees in each region by using a damage score system (Swanepoel 1993). Each tree has been allocated a score from 0 (undamaged) to 5 (tree dead) based on utilisation. A damage score has then been calculated for each region and expressed as a percentage of the maximum possible score which could be attained in that region. Damage scores have been calculated using the following equation:

$$\text{Damage score} = (\text{sum of individual damage scores} \div \text{total possible damage score}) \times 100$$

The damage score for the baobab population in the entire study area is 22.54, with 16.44 and 25.54 the scores for the northern and southern section respectively. The damage score for the southern section is significantly higher than the score for the northern section (difference of proportions, $z = -8.29$; $P < 0.001$).



0: TREE UNDAMAGED.
I: TREE SLIGHTLY SCARRED.
II: TREE RINGBARKED, BUT DAMAGE SUPERFICIAL.
III: TREE DEEPLY SCARRED.
IV: TREE SHAPE RADICALLY ALTERED BY UTILISATION.
V: TREE DEAD.

Fig. 11: Depth of utilisation of *Adansonia digitata* in the northern and southern study sections of the Kruger National Park.

The severity of utilisation as a function of girth at breast height has also been determined using the damage score system described above. Due to the small number of trees in the data set with a girth larger than 15 m, these trees have all been placed in one size class. As no size data is available for dead trees, these trees have been excluded from these calculations. The scale therefore only has five points and thus the maximum score allocated to any tree is four. The damage scores for the various size classes are given in Table 2.

Regression analysis was used to determine if the degree of utilisation is affected by tree size (Fig. 12). The regression of the midpoint of each size class on the damage score of the size class has been calculated and shows that the relationship between baobab circumference and the severity of utilisation can be described by the polynomial regression: $y = -0.20x^2 + 4.86x + 10.01$ ($r^2 = 0.94$; $X^2 = 2.22$; $P < 0.05$).

Sterculia rogersii

Biomass removal

Biomass removal of *Sterculia rogersii* has been classified based on five percent increments of the percentage of biomass which had been removed from each tree. There are also categories for unutilised trees and dead or recumbent trees (Fig. 13).

In the northern section, the largest proportion of trees (21.65 %) has had less than five percent of the biomass removed. In the south, the largest proportion of trees (17.83 %) show no signs of utilisation. Only 13.25 % of trees in the north are unutilised. The distributions of utilisation of these two populations does however not differ significantly (Kolmogorov-Smirnov two-sample test, $D_{max} = 0.057$; $P > 0.05$).

In the northern section, the amount of biomass which has been removed from trees has a mean of 18.54 % and in the southern section 21.05 %. The difference between these two means is not significant (two-sample t-test assuming unequal variances, $t = -1.91$; df = 1112; $P > 0.05$)

Table 2

Damage scores of tree size classes

ADANSONIA DIGITATA		*STERCULIA ROGERSII*	
GIRTH(m)	DAMAGE SCORE	GIRTH (m)	DAMAGE SCORE
0-1	10.76	0.00-0.25	2.08
1-2	19.42	0.25-0.50	15.79
2-3	20.57	0.50-0.75	22.50
3-4	24.19	0.75-1.00	24.38
4-5	27.68	1.00-1.25	29.12
5-6	28.71	1.25-1.50	34.92
6-7	34.14	1.50-1.75	33.71
7-8	34.64	1.75-2.00	36.15
8-9	35.92	2.00-2.25	34.13
9-10	42.31	2.25-2.50	30.23
10-11	41.95	2.50-2.75	32.53
11-12	38.75	2.75-3.00	42.18
12-13	38.16	3.00-3.25	35.42
13-14	34.38	3.25-3.50	34.09
14-15	38.64	3.50-3.75	35.14
>15	32.69	3.75-4.00	41.67
		>4	32.24

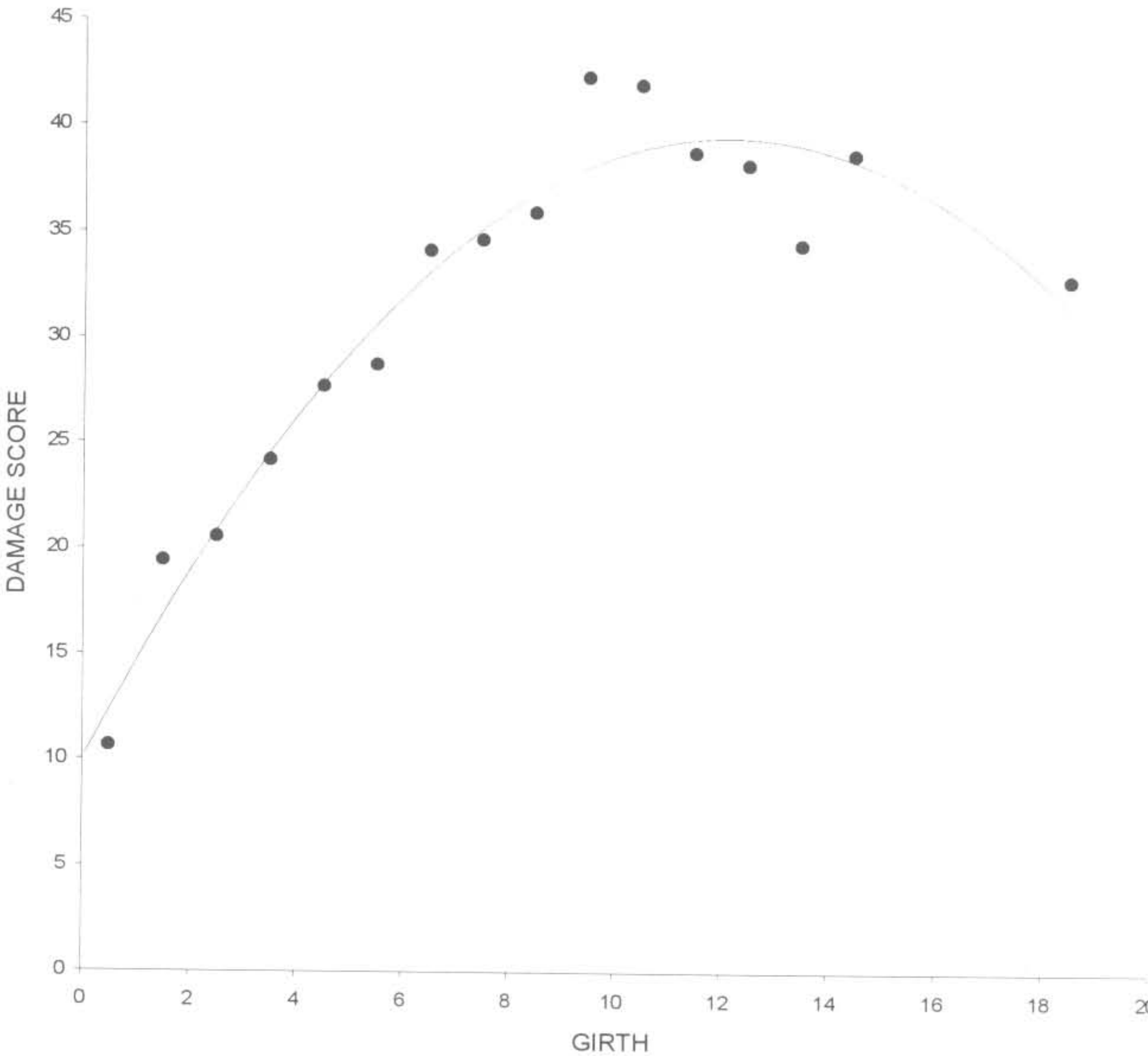


Fig. 12: Damage scores of *Adansonia digitata* in the Kruger National Park as a function of girth (m). Data for trees with a girth larger than 15 m have been pooled due to the small sample. $y = -0.20x^2 + 4.86x + 10.01$; ($r^2 = 0.94$; $X^2 = 2.22$; $P < 0.05$).

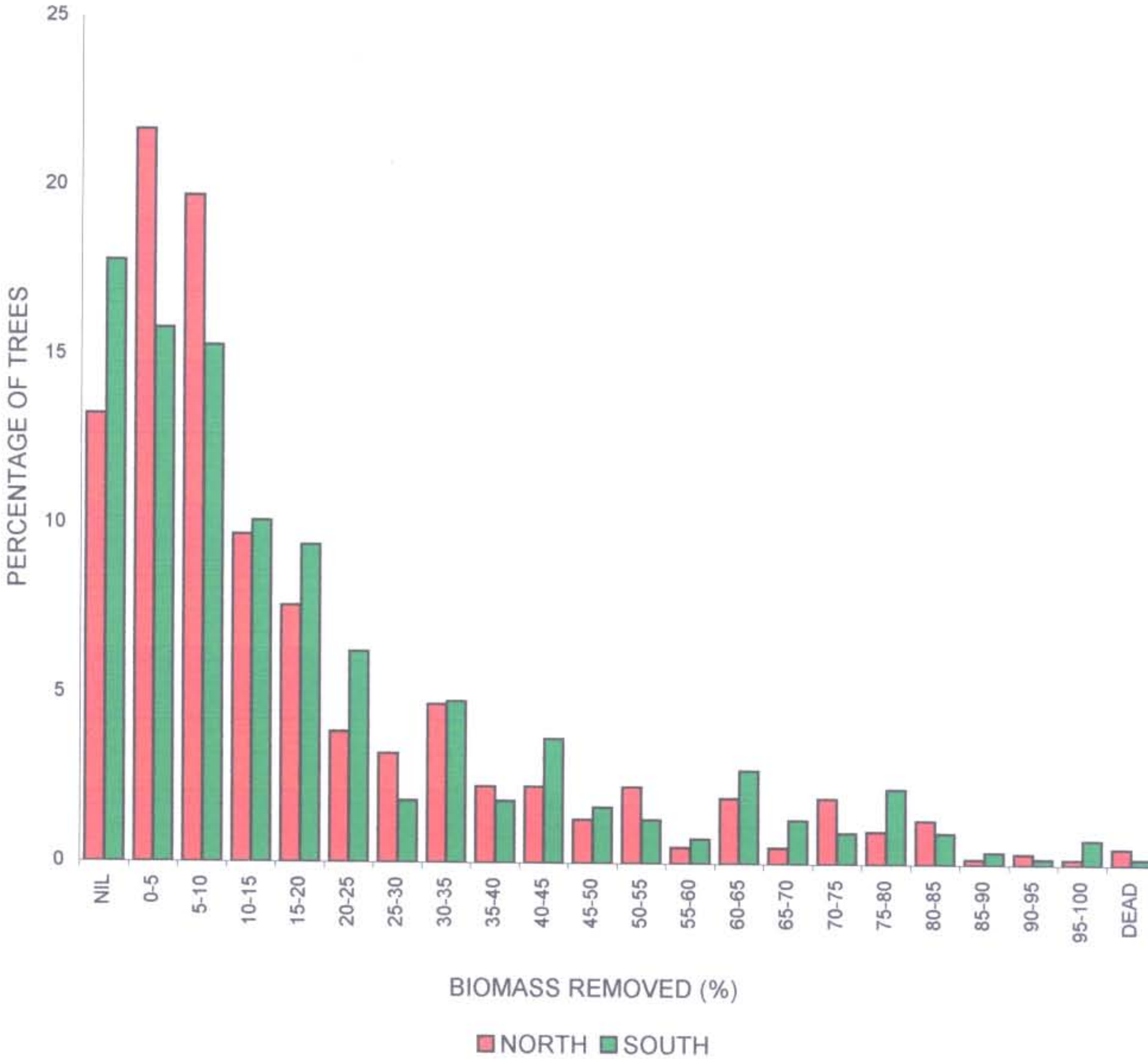


Fig. 13: Utilisation of *Sterculia rogersii* in the northern and southern study sections of the Kruger National Park.

The mean percentage of biomass removed per tree in each size class has been plotted against the mean girth of tree in the size class in Figure 14. Trees with a girth larger than 4 m have been lumped together due to the small size of the sample in this size category. The regression analysis of mean percentage biomass removed on mean girth shows that a logarithmic relationship exists between tree size and amount of browsing ($r^2 = 0.69$; $X^2 = 12.69$; $P < 0.05$).

The proportion of freshly utilised trees is 8.56 in the northern section, but only 2.76 in the south (difference of proportions on freshly utilised trees, $z = 4.21$; $P < 0.001$).

Depth of utilisation

Classification according to the depth of utilisation scale shows that the majority of star-chestnuts have been lightly browsed (Type I utilisation), while only a small proportion of trees fit the heavier utilisation categories (Fig. 15). The severity of utilisation shows significant differences in the two regions (Kolmogorov-Smirnov two-sample test, $D_{max} = 0.106$; $P < 0.005$).

In the southern section, 18 % of trees show no signs of utilisation, but only 13 % in the north are unutilised (difference of proportions on the percent undamaged, $z = -2.16$; $P < 0.05$).

Each tree has been allocated a score from 0 (undamaged) to 5 (tree dead or uprooted) based on this scale. The damage score system which has already been described has then been used to compare the severity of utilisation in the various regions.

The damage score for the entire study area is 25.95. Trees in the northern section (24.75) are not as severely damaged as those in the southern section (27.32) (difference of proportions, $z = -2.23$; $P < 0.05$).

The depth of utilisation as a function of girth has also been determined using the damage score system. Due to the small number of trees in the data set with a girth larger than 4 m,

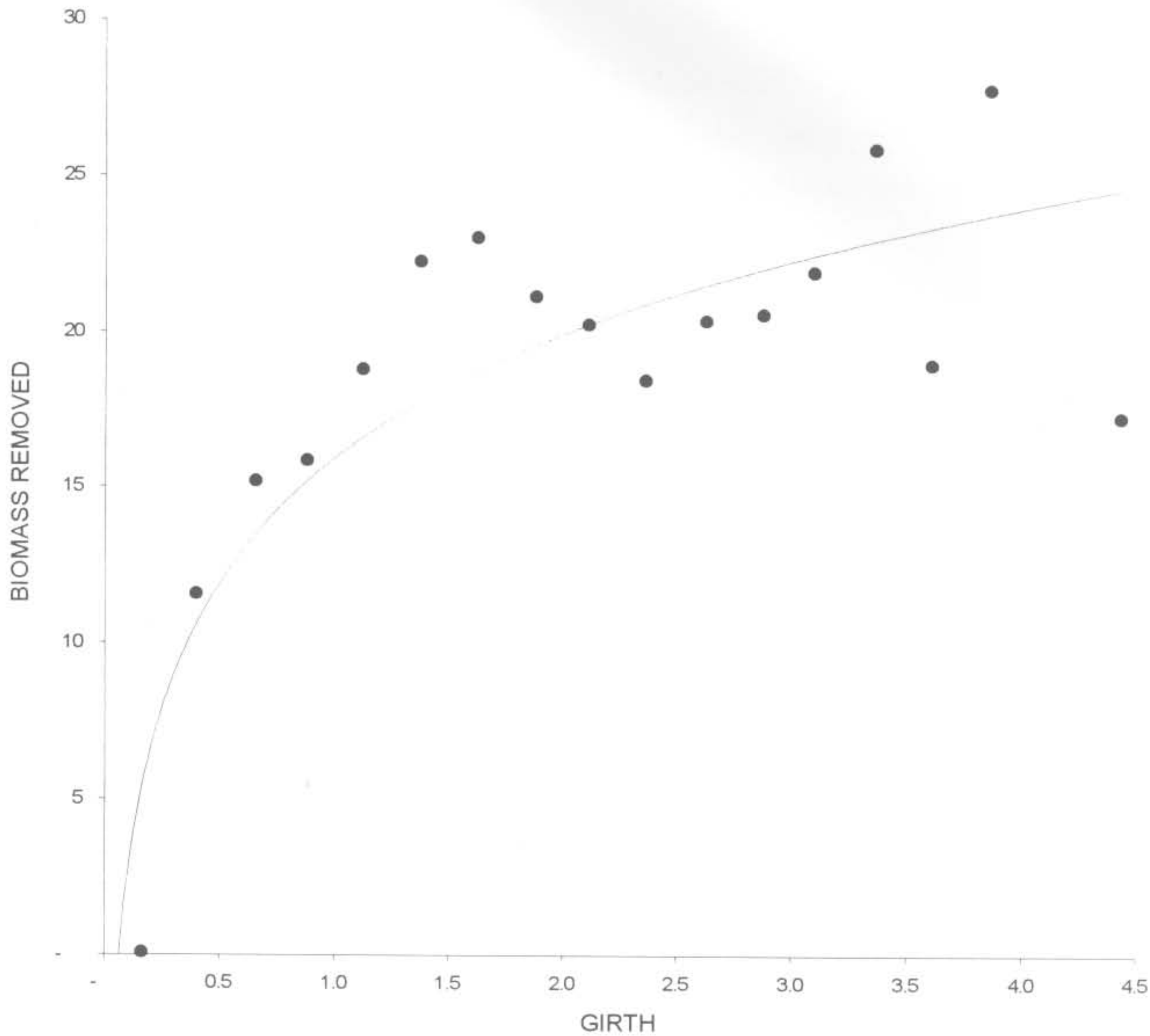
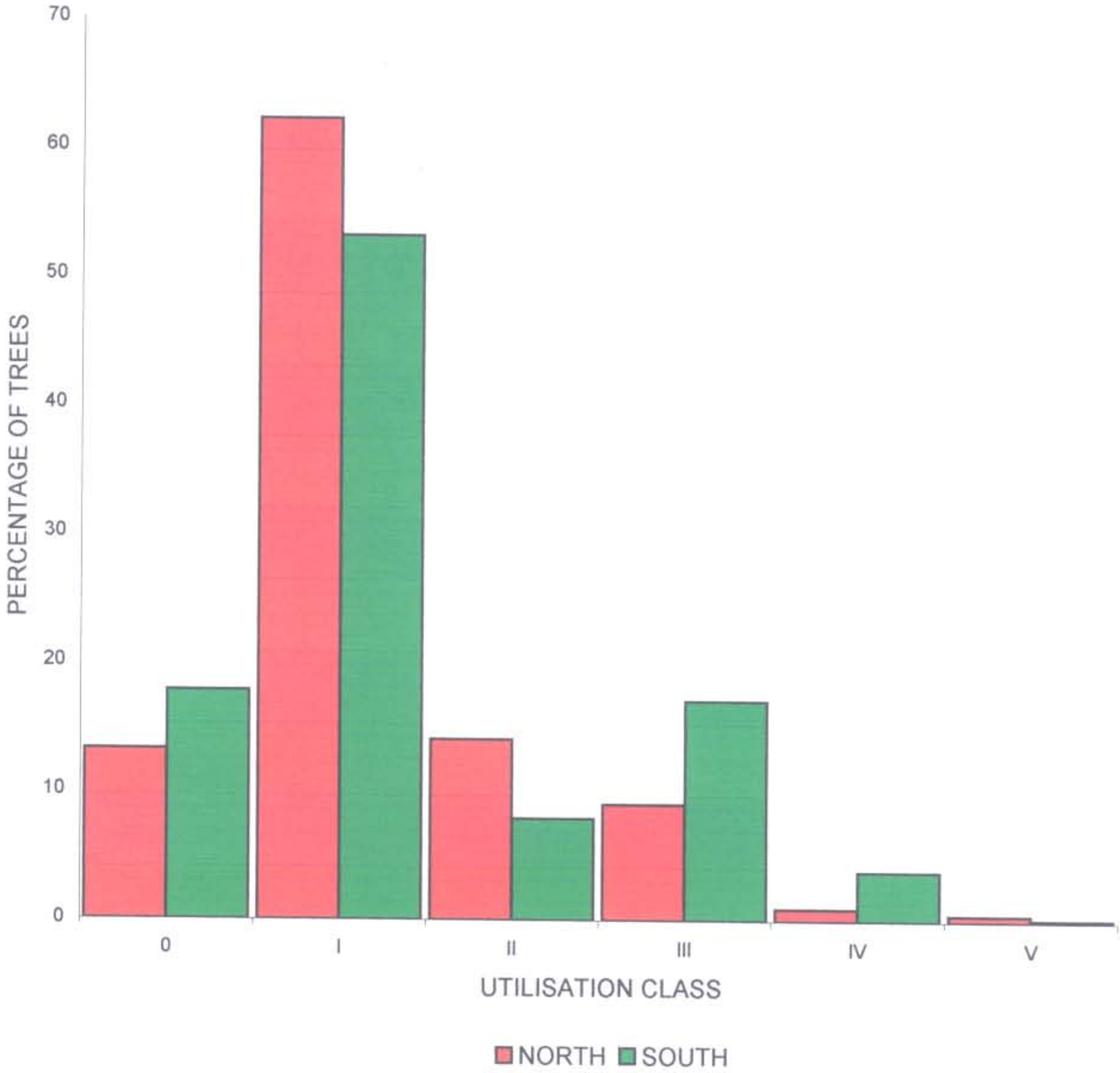


Fig. 14: Utilisation (%) of *Sterculia rogersii* in the Kruger National Park as a function of girth (m). Data for trees with a girth larger than 4 m have been pooled due to the small sample. $y = 5.76\text{Ln}(x) + 15.92$; ($r^2 = 0.69$; $X^2 = 12.69$; $P < 0.05$).



0: TREE UNDAMAGED.
I: TREE LIGHTLY BROWSED.
II: TREE WITH BRANCHES REMOVED BY BROWSING.
III: TREE WITH SOME STEMS BROKEN OFF.
IV: TREE WITH ALL STEMS BROKEN OFF.
V: TREE DEAD OR UPROOTED.

Fig. 15: Depth of utilisation of *Sterculia rogersii* in the northern and southern study sections of the Kruger National Park.

these trees have all been placed into one size class. As no size data are available for dead trees, dead trees have been excluded from these calculations. Therefore, the scale once again only has five points and thus the maximum score allocated to any tree is four. The damage scores for the various size classes are given in Table 2.

The regression of the midpoint of each size class on the damage score of the size class has been calculated (Fig. 16). This regression analysis shows that a logarithmic relationship exists between the size of *Sterculia rogersii* trees and the severity of utilisation ($r^2 = 0.84$; $X^2 = 9.35$; $P < 0.05$).

DISCUSSION

Adansonia digitata

Bark stripping is greater in the southern section than in the north. Most trees in the northern section have had either none or only small amounts of bark stripped from them, while trees in the south have generally been more heavily utilised. Between the early 1930's, when elephant elephant first began to recolonise the area, until 1969, when the northern section was proclaimed as part of the Kruger National Park, elephant numbers were greater in the south. The trees in the southern section have thus been exposed to elephant utilisation for a longer period than those in the north. It is therefore to be expected that trees in the southern section would have been more heavily utilised. Utilisation of baobabs such as debarking results in scarring of the trees. The scars are noticeable even after new bark has covered the damaged area. These scars persist for a long time, and in many if not all cases outlive the trees themselves. Much of the scarring which has been recorded occurred when elephant densities were greater south of the Luvuvhu River. The evidence of utilisation during this era is still present on the baobab trees today.

The average amount of bark stripped from baobabs is almost 20 %. Although some trees appear to have had their stems completely stripped of bark, in many cases, these trees have been regularly used over time, with the trees of similar size around them, not being utilised at all. Elephants tend to concentrate their foraging on particular trees (Swanepoel 1993).

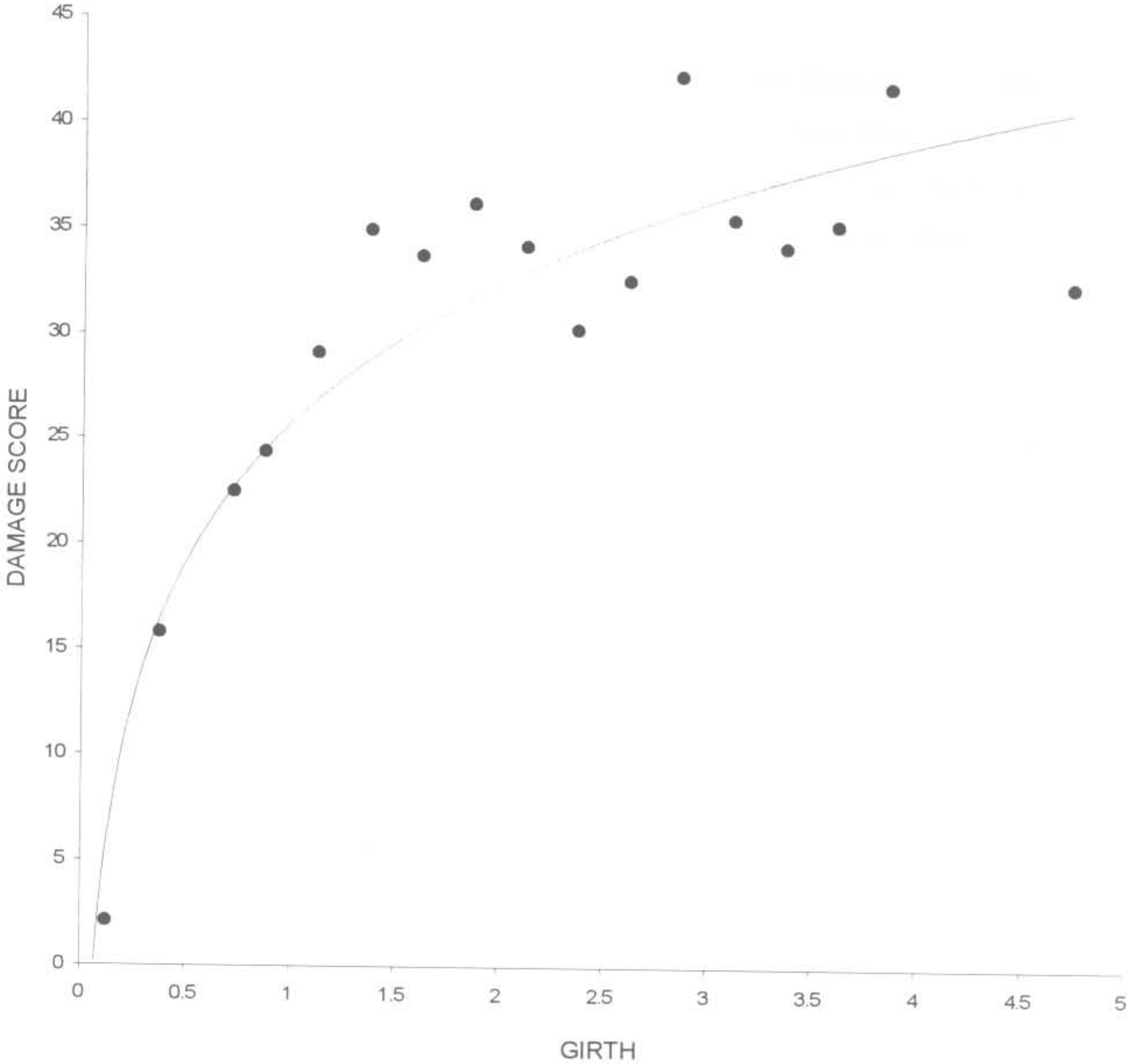


Fig. 16: Damage scores of *Sterculia rogersii* in the Kruger National Park as a function of girth (m). Data for trees with a girth larger than 4 m have been pooled due to the small sample. $y = 9.48\mathrm{Ln}(x) + 25.78$; ($r^2 = 0.84$; $X^2 = 9.35$; $P < 0.05$).

This phenomenon may be linked to genetic differences present in these trees (Wickens 1982). Although some trees show signs of heavy utilisation, the large number of unutilised or slightly utilised trees results in a mean bark stripping value of 18.37 %. Although this seems a substantial amount, much of this is damage from which the trees appear to have recovered.

The age of utilisation of trees has been recorded in four categories based on the current appearance of the damaged plant parts. The oldest category (Class D) consists of scars on the tree, where damage has been completely covered by new bark. The tree has thus recovered fully from this damage. In a study of elephant impact on *Sclerocarya caffra* trees, Coetzee *et al.* (1979) recorded trees with old debarked areas which had been completely covered by new bark, as unscarred. Many baobabs which occur outside of game reserves, in areas where elephant are absent also show class D utilisation. This indicates that these scars are vestiges of a bygone era when elephant still occupied these regions. Elephant have probably been absent from some of these areas for more than 100 years, providing some indication of the length of time these scars persist on the trees. More than two-thirds of bark stripping is classified as class D utilisation.

For these reasons, class D utilisation has been omitted and the calculations repeated. The mean percentage of bark stripped from baobabs is then only 6.06. The southern study section (6.55 %) is still more heavily utilised than the north (5.07 %) (two-sample t-test assuming equal variances, $t = -2.87$; df = 1291; $P < 0.005$). The difference in the amount of bark stripping in the two sections is not as great. This is further evidence to indicate that these differences are due mainly to utilisation in the past when elephant densities in the two sections differed. Bark stripping of baobabs is therefore not very severe, even less so when their ability to recover from this utilisation is taken into consideration.

Baobabs have a remarkable ability to recover from damage (Wickens 1982), quickly replacing lost bark (Coates Palgrave 1956). Their robustness and vitality is legendary (Coates Palgrave 1956; Piearce *et al.* 1994). Baobabs readily withstand mechanical injury inflicted by the carving of inscriptions or harvesting of their bark (Piearce *et al.* 1994). Trees do not die even when ring-barked (Barnes 1980). While some baobabs are able to survive considerable damage, the resources required for recovery could have a negative effect on the long-term survival of these trees (Swanepoel 1993). Trees from which large amounts of bark have been removed are more noticeable than unutilised trees and thus, to the casual observer, the population may appear to be subjected to more utilisation than is actually the case. This perception may also stem from observations being made from roads, where elephant damage is perceived to be greater (Coetzee *et al.* 1979).

The proportion of freshly debarked (class A) trees in these two regions indicates that in recent times, the situation has changed drastically. Bark stripping of these trees, would have occurred not more than a year prior to the study, as extended exposure of scar tissue to sun and rain causes a loss in colour, making older damage discernible from new damage. The amount of bark which has recently been removed from trees in the northern section is significantly higher than in the southern section. This indicates that elephant foraging is now concentrated in the northern section of the study area.

Elephants tend to congregate around permanent water during the dry season (Van Wyk & Fairall 1969). The northern section is flanked by both the Luvuvhu and the Limpopo Rivers, and most of this section is therefore, relatively close to perennial water. In contrast, much of the larger southern section is a considerable distance from water, and during the dry season, elephants foraging in these parts will have to travel long distances to obtain water. This resultant higher elephant density is the likely explanation for the higher incidence of fresh bark stripping in the northern section. Swanepoel (1993) found that elephant foraging on baobabs is related to the position of the trees relative to perennial water, with trees further from water being less affected. The utilisation of baobabs relative to water is discussed in Chapter 8.

Independent studies in Lake Manyara and Ruaha National Parks, Tanzania both found an increase in bark damage with increasing baobab circumference (Weyerhauser 1985). Weyerhauser (1985) does not indicate whether older scars were included in the studies or not. The damage , which is expressed as a percentage of circumference, may or may not therefore, be cumulative. Swanepoel (1993) could not find any indication that elephants in Mana Pools National Park, Zimbabwe concentrate on any particular size of tree. The results of this study indicate that elephants in the Kruger National Park concentrate their foraging on the larger baobab trees. The severity of elephant damage and the amount of bark stripping both increase with an increase in the girth of trees. This trend is similar to that shown in the Tanzanian parks mentioned.

The top parts of the larger baobabs are not available to elephants as they are out of reach. Therefore, once a baobab reaches a certain height, the amount of bark an elephant can strip from it, in proportion to its size, reaches a limit. Any further growth of the tree thus results in a decrease of the proportion of bark which has been removed from the tree. This relationship causes the curve which plots bark stripping as a function of girth to dip after peaking at the 9 - 10 m size class. The presence of plant material on the larger trees which is unavailable to elephants causes the curve to dip. The relationship between bark stripping and size could therefore, be different to that indicated by the regression analysis. A repeat of the regression analysis of the mean percentage of bark stripping on baobab girth has therefore been carried out, this time only using data from trees with a girth of 10 m or less. Trees in the 9-10 m size class have the greatest percentage of bark removed and this is where the curve peaks. As expected, this regression shows a strong linear relationship between girth and bark stripping ($r^2 = 0.98$; $n = 10$; $P < 0.001$), and indicates a trend shown by elephants of selecting larger trees.

The more severe utilisation of the larger trees could be as a result of these trees providing an opportunity for more than one elephant to forage simultaneously (Swanepoel 1993). During the hottest part of the day, elephants often stand under shady trees to escape the heat (Smithers 1983). Baobabs, although deciduous, provide good shade in summer, and thus provide elephants with a resting place. While escaping the heat, these animals also have ample opportunity to forage on the trees. Only the large baobabs provide this opportunity, thus resulting in a trend of increased bark stripping of and more severe damage to larger trees.

By concentrating their foraging activities on the larger baobab trees, elephant are having a smaller influence on the regeneration class. This situation is less damaging to the long-term survival of the baobab population in the Kruger National Park which is dependant on regeneration.

The assessment of utilisation depth shows that utilisation of baobabs by elephants in the Kruger National Park is generally superficial with very few trees being severely damaged. Damage to most baobabs therefore, consists only of bark stripping, which is not severe enough as to threaten the survival of either individual plants or the population. Baobabs are generally able to recover well from this superficial damage. As with bark stripping, the damage scores of baobabs also indicate that trees in the southern section have been more severely damaged than those in the north. Here again, the land use history of the two sections provides a plausible explanation. For this reason, utilisation depth in the two sections have been compared, omitting the oldest (class D) utilisation. The utilisation of baobabs does not differ significantly in the two regions (Kolmogorov-Smirnov two-sample test, $D_{max} = 0.06$; $P > 0.05$).

Baobab trees which have been very severely damaged often show a remarkable ability to survive. Fallen trees have the ability to form new growth from the prostrate plant, and even felled trees are able to grow bark which covers the exposed stump and new shoots then arise from the periphery and centre of the stump (Wickens 1982). The comparison between the two study sections is therefore, affected by the scars left by utilisation which occurred when elephants only inhabited the area south of the Luvuvhu River. The results of the scoring system also show that fresh damage is higher in the northern section, once again indicating that this area was, at the time of the study supporting a higher concentration of elephants.

Sterculia rogersii

This plant species is known as an important source of nourishment for elephants (Van Wyk 1974), but in both sections of the study area, the majority of common star chestnut trees are either undamaged, or have only been lightly browsed. Of the entire population, 34 % of trees have had less than five percent of the biomass removed from them. There is also a very small proportion of trees with more than 50 % of their biomass removed. The differences in utilisation in the two sections are not significant, indicating that utilisation has been the same in these two areas. Observations of star-chestnuts which, have been made in Messina Nature Reserve, an area which is not inhabited by elephant, indicate that these trees are a favoured browse item for other large herbivores such as kudu (*Tragelaphus strepsiceros*), giraffe (*Giraffa camelopardalis*) and eland (*Tragelaphus oryx*). While no trees were seen in this reserve which had not been utilised at all, the vast majority of trees had only been lightly browsed, with 76 % of trees having had less than 10 % and 96 % of trees having had less than 15 % of their biomass browsed. This compares with figures of 52 % and 62 % in the Kruger National Park respectively. Much of the browsing of this tree species can therefore, be attributed to herbivores other than elephant, although the more destructive utilisation is almost certainly due to elephant. The absence of unutilised trees and the higher proportion of trees fulfilling the smaller utilisation categories in the Messina Nature Reserve are as a result of higher stocking rates of non-elephant browsers in this reserve. Clearly, browsers other than elephant are responsible for consuming a considerable amount of *Sterculia rogersii* browse.

The differences in the numbers of unutilised trees in the northern and southern study sections is not necessarily due to elephants. Where only small amounts of the tree have been browsed, no differentiation can be made between elephant utilisation and the utilisation by other herbivores. These trees can therefore, not be classed as unutilised. Other herbivores also browse on star-chestnuts and their foraging, affects the number of unutilised trees in the area.

The depth of utilisation scale shows that the majority of *Sterculia rogersii* trees in the study area have only been lightly browsed (Type I utilisation), and that trees with Type I and Type 0 utilisation constitute 73 % of the population. Type I utilisation can probably be attributed to browsers other than elephant and is unlikely to have any long term effect on the tree. Differences in the depth of utilisation in the two study sections are due to the larger proportion of trees in the south with Type III utilisation. Observations on trees in Messina Nature Reserve showed that 14 % of trees had Type III utilisation. There are two possible reasons why some trees in this area have had stems broken off. The first is that the stems have broken off during strong winds, or die due to infection or as a result of consumption by arthropods and not as a result of browsing. The second explanation is that this damage is extremely old and was inflicted on the trees sometime in the past when elephant still inhabited the area. When the oldest (class D) utilisation is omitted, less than three percent of the trees have Type III utilisation. This indicates that the more severe damage to these trees in Messina Nature Reserve occurred a number of years back. Although elephant have probably not been resident in the area since the mid 1800's, elephants were known to pass through the area now occupied by the reserve until the 1970's when it was proclaimed and fenced. The damage to *Sterculia rogersii* trees could thus be attributed to elephant presence in the reserve during this period.

The breaking of large branches and stems and the uprooting of trees can be attributed to the elephant population. The historic distribution and density of elephant in the two study sections in the Kruger National Park can be used to explain the higher proportion of trees which have Type III and IV utilisation in the southern section. The southern section also has a higher damage score than the north. The system used to determine these scores allocates a different number of points to different types of damage. A greater number of points are allocated to severely damaged trees and thus the south study section has a high total. Here again, omitting the utilisation data from the oldest (class D) utilisation category presents a very different scenario. In both the northern and southern sections, each category of the utilisation scale is occupied by similar proportions of trees and the damage scores for the two sections of 14.60 (north) and 16.14 (south) are no longer significantly different (difference of proportions $z = -1.62$; $P > 0.05$). The difference in utilisation of these two areas can therefore, be attributed to elephant with the higher damage score in the south a result of the higher elephant density in that section between 1931 and 1969. Utilisation of these trees has however been more intense in the northern section in recent times as is shown by the damage score (2.46) for the most recent (class A) utilisation which is considerably larger than the score for the southern section (0.92) (difference of proportions $z = 4.47$; $P < 0.001$). Once again this can be attributed to the higher herbivore density and increased utilisation of browse, due to the proximity of permanent water.

Both the proportion of biomass removed from and the damage score of *Sterculia rogersii* trees shows an increase with an increase in girth, indicating that browsers concentrate their foraging on the larger trees. The seedlings and regeneration class of trees are therefore, not as likely to be affected by browsing as are the older trees. This is a favourable situation with regards to long term survival of the population, especially when considering that for the same foraging effort, a smaller tree would suffer more injury than a larger one. The resources which are required for a smaller tree to recover are greater and the risk of the tree not surviving is consequently greater.

As with baobabs, the star-chestnuts possess a remarkable ability to recover from browsing induced damage. New bark covers areas which have been exposed by browsing and where branches or stems have been broken off. Some trees have been so severely damaged that all their stems had been broken off at ground level, leaving only the subterranean parts of the plant. These trees are still able to survive and coppice from the remaining parts of the tree, effectively forming a new plant. Many plants can be seen growing from the prostrate stem of a tree which had been pushed over in the past and from which new shoots emerged. Despite being severely injured, these trees still manage to survive.

The remarkable survival ability of these trees even under heavy herbivore pressure would indicate that, to determine the sustainability of the population, the causes and rates of mortality of the trees should be investigated. The amount and intensity of utilisation does not provide any clues in this regard. Browsers have been concentrating their foraging efforts on the larger trees which tend to recover from browsing and not the regeneration classes and so, although there is a lack of smaller trees in the Kruger National Park, it is most likely from the evidence presented here that elephant are not solely to blame if at all for the poor number of trees being recruited into the Kruger National Park population.

Unfortunately the effect of fire on *Sterculia rogersii* trees did not form part of this study as it is likely that an increase in the frequency of fire has hampered recruitment and regeneration of this species. The susceptibility of small trees to fire may be the cause of the poor recruitment of trees into the population. The effect of fire on the population structure of this species has been discussed in more detail in Chapter 4.

CONCLUSION

Utilsation of both tree species (*Adansonia digitata* and *Sterculia rogersii*) has taken place in the Kruger National Park. This has been greater in the southern study section as a result of higher elephant densities being present in this area for most of this century. In all cases, utilisation increases with an increase in girth. However, both species show an ability to recover from even severe damage and utilisation is therefore, unlikely to kill trees. Utilisation may, however, lower the resistance of plants to drought-induced or other forms of stress. This could not be determined during this study. Monitoring of mortality rates would be a better indicator of the potential of these populations to survive than monitoring utilisation. A reduction in the utilisation of common star-chestnuts will only be achieved if the stocking rates of all the larger herbivores are reduced.