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TITLE: THE EFFECT OF LONG-TERM FIXED SEASONAL ROTATIONAL GRAZING ON THE VEGETATION OF THE SOURISH MIXED BUSHVELD

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TRIAL LOCATION: Towoomba ADC.

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ABSTRACT

The study was conducted at the Towoomba Research Station, situated in the Sourish Mixed of the Limpopo Province, South Africa. Changes in the herbaceous component were studied over a sixty five year period under different long-term seasonal rotational grazing treatments. Four grazing systems were involved, namely a one camp system (continuous grazing), a two camp systems, of which one camp is grazed annual1y during winter and the other during spring, summer and autumn, a two-camp system, of which one camp is grazed annual1y during late winter to late summer and the other from late summer to late winter and a three camp system, of which one camp is grazed annually during spring, one during summer and one during autumn and winter. The vegetation of the different camps was surveyed more or less on a ten-yearly basis. Camps that received no summer rest were in a much poorer condition and had lower animal production than camps that received summer rest. A camp that was grazed only during winter was in the best condition but was over rested and had become moribund. Autumn plus winter grazing seemed to have no bad effects on the grass component, while spring grazing only also led to good veld condition and high animal production. Grazing during mid-winter to mid-summer or mid-summer to mid-winter produced the best results overall in terms of veld condition and animal performance. Depending on grazing treatments, tree numbers increased at different rates in different camps, indicating that bush thickening was a phenomenon which occurred naturally, irrespective of rest or grazing treatments that were involved. The rates of encroachment were determined by the intensity of the grazing treatments that were applied.

Key words: Continuous grazing, bush encroachment, grass species composition, spring grazing, veld condition, winter grazing

INTRODUCTION

Towoomba ADC was founded during the early 1930’s as a Departmental research station with the main objective of countering veld deterioration. Grazing trials started on Towoomba in 1934. Four of these trials, the so-called “Maintenance experiments” or “Irvine systems”, started by L.O.F. Irvine in November 1935, are still running. This makes them the oldest veld grazing trials in South Africa. While not designed for statistical treatment, these "Experiments" provide an excellent demonstration of how grazing treatments can change the species composition of the veld.

OBJECTIVES

The objective of the trial was to study the effect of seasonal rotational grazing on veld.
The site was also monitored on an approximate ten yearly basis to determine long term vegetation changes.

EXPERIMENTAL SITE

The experimental site is situated on Towoomba ADC, on the Southern part of the Springbok flats, near Bela Bela in the Limpopo Province (28°21’E, 24°25’S; 1 184m above sea level). The long-term annual rainfall is 630mm per annum. The long-term daily average maximum and minimum temperatures vary between 30.2°C and 17.6°C for December and 21.0°C and 3.0°C for July respectively. The vegetation type of the Irvine systems is classified as Sourish Mixed Bushveld by Acocks (1988). The woody layer of the plant community is dominated by *Dichrostachys cinerea* and *Acacia* species. The grass layer is dominated by *Eragrostis* species (*E.barbinodis* and *E.rigidior*), *Panicum maximum, Themeda triandra* and *Heteropogon contortus*. With the exception of the continuous grazing system (see trial layout), the soil is of the Hutton form (Shorrocks (+) series). Approximately 20%. 60% and 20% of the continuously grazing system is covered by soil of the series Shorrocks (-), Shorrocks (+) and Makatini respectively (MacVicar *et al*. 1977). The continuous grazed system therefore has a higher clay content than the rest of the experimental site (Donaldson & Rootman 1983).

TRIAL LAYOUT

Grazing systems

During 1935, the woody component in all the camps of the Irvine Systems were cleared by hand to resemble “an open savannah” (Louw 1973), and thereafter subjected to different grazing treatments. The grazing treatments involved four different grazing systems, each 7.70 ha in size. The grazing treatments are presented in Table 1 and Figure 1).

Table 1 Grazing treatments applied in the Irvine Systems since 1935.

System Number	**Camp Number**	**Grazing period**							
		Spring		**Summer**		**Autumn**		**Winter**	
1	**1**	■	■	■	■	■	■	■	■
2	**2**							■	■
	3	■	■	■	■	■	■		
3	**4**	■	■	■					■
	5				■	■	■	■	
4	**6**	■	■						
	7			■	■				
	8					■	■	■	■

- System 1 is a one-camp system (camp 1), grazed continuously throughout the year.
- System 2 is a two-camp system, divided into camps of equal size of which one is grazed annual1y during winter (camp 2) and the other during spring, summer and autumn (camp 3).
- System 3 is a two-camp system, divided into camps of equal size of which one camp is grazed annual1y during late winter to late summer (camp 4), and the other from late summer to late winter (camp 5).
- System 4 is a three camp system, divided into camps of equal size that are annually grazed during spring (camp 6), summer (camp 7) and autumn (camp 8) respectively. Initially all three camps were grazed during winter. Since the summer grazed camp failed in practice to provide winter grazing, the steers were later kept in the autumn camp until late winter and then removed to the spring camp, where they remained until the end of spring. During certain years, the autumn camp provided enough grazing for the steers to remain there for the full winter period.

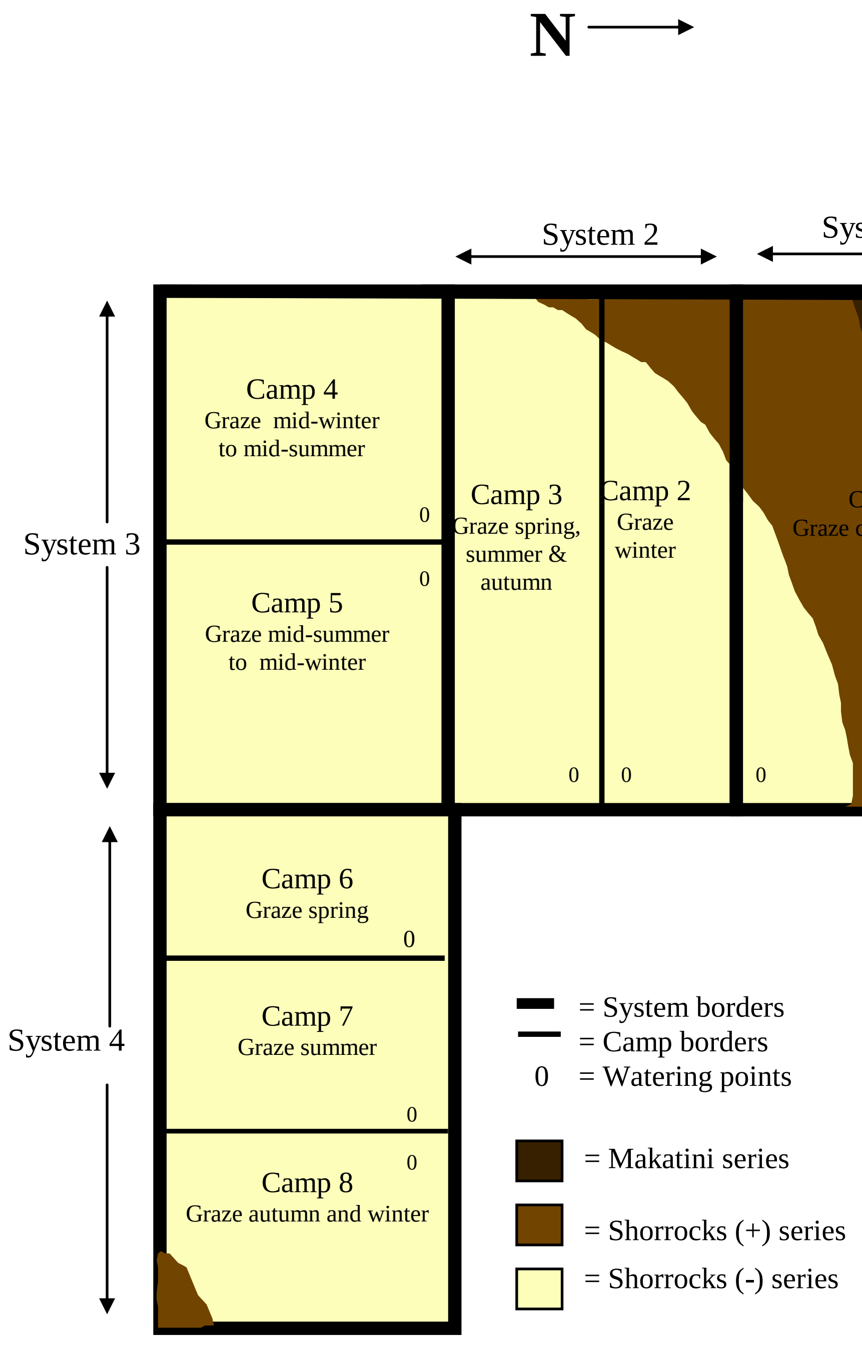


Figure 1 Experimental layout and soil types at the Irvine Systems (Irvine 1940)

Seasons definitions

For experimental purposes the different seasons of the year were defined in accordance with certain growth stages of the vegetation, which in turn depended on prevailing climatic conditions (Irvine 1940). The seasons were defined as follows:

- Spring commences with the opening of leaf buds of *Acacia robusta* and initial greening of unpalatable grasses, particularly *Elyonurus muticus* and *Cymbopogon plurinodis.* The grass growth is usually short lived, being a reaction to increased temperatures and residual moisture rather than to rain. The duration of spring is approximately 12 - 13 weeks.

- Early summer commences when the veld begins to grow vigorously; about two weeks after the first good rains have fallen. The duration of early summer is approximately 6 weeks.

- Late summer occurs when the main grasses (e.g. *T. triandra*) are in full flower. It normally occurs six to eight weeks after the beginning of early summer. The duration of late summer is approximately 11 weeks.

- Autumn is recognised by the yellowing of the leaves of *A. caffra*. At this stage grass growth slows down noticeably. The duration of autumn is approximately eight weeks.

- Early winter commences with the first frost, but as this is a rare occurrence it is recognised by cessation of grass growth, which may require experienced judgement. The duration of early winter is approximately six weeks.

- Late winter occurs about six months after late summer. Since the veld is dormant camp changes are determined by the needs of the stock. The duration of late winter is approximately eight weeks.

Animal management

Initially, during 1935, each system was stocked with two Afrikaner type steers with the intention to replace them annually. However, due to the unavailability of animals, it was not possible to replace them annually. The steers were generally introduced into the experiment at the age of two years and replaced after either two, three or four years. The steers were dipped weekly in summer and fortnightly in winter. The steers were weighed every fortnight after an overnight fast of 12 hours.

Withdrawal of animals from camps due to drought or over-utilisation of camps was based on 1ivemass losses in conjunction with the availability of grass herbage. Animals were generally removed after showing a sudden drop in mass of about 15 kg over a two-week period or after a series of successive fortnight1y losses of 5 to 10 kg. The animals had free access to fresh drinking water as well as a lick consisting of salt and bone meal throughout the year.

During 1960/61, as a result of an improvement in the botanical composition of both the camps and excellent animal performance following the previous wet years, the steer numbers in system 3 were raised from two to three. This change in procedure was badly timed since it took place at the beginning of the prolonged drought during the early 1960's. Ten years later it was decided to withdraw the extra steer due to the degeneration of the grass sward. Since the early 1970's, steer numbers have remained at two steers per system.

During the period 1967 to 1976, replacement oxen were often not available, and animals remained in the trial until the age of six years. This led to the decision to use weaner oxen during 1977 to 1986. Since 1987 they were replaced annually. As from 2000, nguni’s were used as replacements on an irregular basis due to the unavailability of animals.

During 2000, the animals were withdrawn from all treatments for four months after a fire and during 2004 for 7 weeks due to water problems. Between April 2007 and January 2008, the whole watering system of the trial site was upgraded and the animals were withdrawn from the trial during this period. During June 2008 to April 2009 animals were withdrawn due to fire. During April 2010, the animals were withdrawn due to fence theft.

Fire history of the different camps

Accidental fires occurred in camps 4 and 5 (system 3) and camp 6 (system 4) during September 1961, camp 1 (system 1) during October 1976, and camps 4, 5 and 6 (systems 3 and 4) during August 1978.

As a result of the above-average rainfall of the 1970's over-accumulation of grass took place in all camps. All grazing systems were temporarily terminated during November 1980. Donaldson and Rootman (1983) attempted to get rid of most of the old grass material by subjecting the camps to high stocking rates during the winter of 1981. Despite the severe grazing treatment most of the camps remained in a moribund condition. All the camps were subsequently burned during October with a controlled, fast and low intensity burn (Donaldson and Rootman 1983). During July 1999, an accidental fire occurred in camps 3, 4, 5, 6, 7 and 8, while camp 2 was subjected to an accidental fire during September 2000. During September 2008, a low intensity accidental fire occurred in all camps.

DATA COLLECTION AND ANALYSES

Tree density

The woody component was monitored during 1962, 1967 and 1972 by Louw (1973), using the point-centred quadrate method of Cottam and Curtis (1956), revised by Morisita (1957) and described by Van Eeden (1966). Forty-five points were randomly placed per camp. At each point, in four opposite directions, the distance from the point to the nearest single stemmed tree, as well as the stem diameter of the relevant trees was determined. Trees were grouped in the following classes:

- individuals with a stem diameter thicker than 7.62 cm (> 3 inches)
- individuals with a stem diameter between 2.54 to 7.62 cm (1 - 3 inches)
- individuals with a stem diameter less than 2.54 cm (< 1 inch)
- multi-stemmed trees and shrubs with a basal diameter less than 0.31 m (1 foot). Other multi-stemmed trees were classed in the three previous classes.

Data of trees with a stem diameter thicker than 7.62 cm were expressed as tree density. Data of trees in the other classes were expressed as the percentage frequency of each species within each class [Percentage frequency = (number of quadrates containing species Z/Total number of quadrates) x100].

During 1977, tree density and percentage frequency surveys were repeated by Robinson (1977). A chain, 3 m in length, was used to attain 28.28 m^2 circular quadrats (Havenga and Stoker 1983). In systems 1, systems 2 and 3 and system 4, 120, 80 and 60 quadrats were systematically distributed per camp respectively, and all trees that occurred in each quadrat were counted. During this survey, single- and multi-stemmed trees and shrubs were not separated. Data of trees with a stem diameter thicker than 7.62 cm were expressed as tree density [28.28 m^2 x the number of quadrates per camp contains Y number of trees; 1 ha contains (10000 m^2/X m^2) x Y number of trees]. Data of trees in the other classes were expressed as the percentage frequency of each species within each class. Different *Acacia* species were grouped as a single species.

Donaldson and Rootman (1983), using the point-centred quadrat method similar to the original monitoring, surveyed the different camps during 1983. Trees were grouped into similar stem diameter classes as in the original survey. The only available data of this survey that could be located, was the percentage frequency of single stemmed trees with basal stem diameters between 2.54 to 7.62 cm (1 - 3") and less than 2.54 cm, and the percentage frequency of multi-stemmed shrubs with basal diameter less than 0.31 m (1').

During 1987, Smit (1988) surveyed the Irvine Systems. The woody component was monitored, using 70 m X 2m strip transects. In camp 1, twenty-seven, and in camps 2 to 8, nine stratified, randomly placed transects were respectively monitored. Trees were divided into the following height classes: 0.0 - 0.5 m, > 0.5 - 1.0 m, >1.0 - 1.5 m, >1.5 - 2.0 m, >2.0 - 3.0 m, >3.0 - 4.0 m, > 4.0 - 5.0 m and > 5.0 m.

During 2000, Jordaan (2004) repeated the survey, using the point-centred quadrat method similar to the original monitoring. Trees were grouped into similar stem diameter classes as in the original survey. Data of trees with a stem diameter thicker than 7.62 cm were expressed as tree density, while data of trees in the other classes were expressed as the percentage frequency of each species within each class.

All data in this study were tested for normal distribution fitting (Statgraphics 1991). Data that fitted a normal distribution were subjected to parametric statistics, while data that were not normally distributed were subjected to non-parametric statistics.

Inter-camp differences in vegetation changes over time in terms of tree density and percentage tree frequency were subjected to summary statistics only. Density of trees with a stem diameter thicker than 7.62 cm were compared by the fitting of sixth order polynomials to the data (Microsoft Excel 1991) and plotting the results to illustrate changes in tree density over time.

Percentage tree species composition

Percentage tree species composition [= (number of points per species/total number of points) x 100] was determined, using data obtained during the tree density surveys. Percentage tree species composition for 1962, 1967, 1972, 1977 and 2000 was based on the total number of trees in all stem diameter classes. Similarly, for the 1983 survey, percentage tree species composition was based on all height classes. Due to the absence of data, percentage tree species composition for the 1983 surveys was ignored. Species composition data were compared, using the Z-index of similarity (Du Toit 1998).

Height distribution

Tree height was only included in the 1987 and 2000 surveys. Height distribution data obtained from the 1987 survey (Smit 1988), was compared to that of the 2000 survey to illustrate changes in the height distribution of the woody component over a period of 13 years. Average tree height data were subjected to the non-parametric Wilcoxon's signed rank analysis (Siegel 1956, Statgraphics 1991).

Percentage canopy cover

During 1987, Smit (1988) determined the percentage canopy cover for each camp, using the method of Westfall and Panagos (1984; 1988). This method of estimating percentage canopy cover is based on the measurement of a randomly selected tree's canopy cover, as well as the distance to the canopy of a neighbouring tree. Ninety tree pairs each for camps 2 to 8 and 270 pairs for camp 1 were surveyed. To select tree pairs, a randomly placed T-shaped iron rod, 20 cm in length with one of the arms painted yellow, was used. The tree nearest to the centre of the T was chosen as the first random tree of which the canopy cover was measured and the tree towards which the yellow arm pointed as the neighbouring tree. The distance between the crowns of the selected two trees was divided by the crown diameter of the first tree. This canopy-to-gap ratio was used to obtain a "percentage canopy cover value", using the Domin-Krajina cover-abundance scale (Westfall and Panagos 1988). The average "percentage values" of all tree pairs represented the percentage canopy cover of the relevant camp. During 2000, the author determined the percentage canopy cover for each camp, similar to the 1988 survey (Smit 1988), using the method of Westfall and Panagos (1984; 1988). Data relating to tree canopy cover was subjected to the non-parametric Wilcoxon's signed rank analysis (Siegel 1956, Statgraphics 1991).

Basal cover

To compare changes in basal cover, the stem diameter data obtained during the 1962 (Louw 1973) and 2000 tree surveys were used. Basal cover of trees in the thicker than 7.62 cm (3") stem diameter class were determined by measuring the stem diameter of each tree with a tape measure at ground level. Each individual stem was regarded as a circle, and basal cover determined on an individual basis (basal cover = $\pi \times r^2$). The average basal cover per species was multiplied with the number of trees ha^{-1}, and added to give total basal cover. Basal cover and average stem diameter data obtained during 1962 and 2000 were subjected to a signs test (non-parametric Wilcoxon's signed ranks analysis) (Steel and Torrie 1960, Statgraphics 1991). The 1962, 1967, 1972 and 2000 basal cover, average stem diameter and tree density data (trees with a stem diameter thicker than 7.62 cm) were subjected to correlation analysis (Statgraphics 1991).

Veld condition trends

The method used in this study was developed by Donaldson (1986), in the Sourish Mixed Bushveld, where decreasers are considered unpalatable (Jordaan 1991). The method was tested by Smit (1988), and was found to be as accurate as the ecological classification methods, on which it was based. The WV given to each species is determined on the basis of palatability, stability and production. If the characteristic is present, a species receives a 1, if it is absent, a zero. If a grass species has a one for each characteristic (three ones), the WV given to the species is 10, for two ones 7, for one 4 and for none 1 (similar values as the ecological classification methods). Aloe and forb species are considered unpalatable, and are excluded. The veld condition index and trend are determined similarly to that of the ecological classification methods (Jordaan 1994).

Earlier botanical composition surveys (1935) were conducted on the diagonal of each camp of the Irvine Systems, using the line intercept method. The botanical composition of the herbaceous layer was determined via a 4000 point wheelpoint survey (Tidmarsh and Havenga 1955) per system during 1962, 1967, 1972, 1977, 1883, 1987 and 2000. Data were expressed as percentage grass species composition based on basal cover and the veld condition trends were determined, using the above-mentioned method of Donaldson (1986).

RESULTS AND DISCUSSION

Stocking rate

Due to the layout of the trial, stocking rates and length of stay differed between different systems and camps (Table 2). Stocking rates were applied so that the different systems had the same number of grazing days/ha.

Table 2 The mean long-term stocking rate and grazing days ha^{-1} at the Irvine Systems

System number								
	1	2		3		4		
Camp number								
	1	2	3	4	5	6	7	8
Long-term stocking density (LSU ha^{-1})	0.25	0.49	0.49	0.54	0.54	0.74	0.74	0.74
Mean grazing days ha^{-1}								
Spring	19	-	33	45	-	67	-	-
Early summer	10	-	21	22	-	-	32	-
Late summer	21	-	42	-	42	-	61	-
Autumn	15	-	30	-	30	-	-	45
Early winter	10	20	-	-	20	-	-	30
Late winter	14	30	-	30	-	45	-	-
Total	89	50	126	97	92	112	93	75
Average grazing days ha^{-1}	12	11		12		12		

The effect of fires on the woody component of the Irvine Systems

Donaldson and Rootman (1983) reported that the fire that occurred during September 1961 had a minimal effect on the woody component of the burned camps, as did the 1976 fire in camp 1. Continuous grazing led to a low fuel load, which resulted in a “cold” fire. However, the 1978 fire had marked effects on the woody component of the camps in which the fires occurred (Robinson 1977). In camps where high fuel loads were present (camps 4, 5 and 8), a marked reduction in the population of large plants occurred. Simultaneously, the fire stimulated coppice growth, resulting in increases in multi-stemmed trees at the expense of single-stemmed trees in the thinner stem diameter classes. The fires thus succeeded in opening up the vegetation of the relevant camps. In situations where low fuel loads were present (i.e. camp 7, 1999), the woody component was not affected. The “cold” fire applied by Donaldson and Rootman (1983) during 1981 was successful in that it resulted in an even clean burn with minimum damage to the woody plants. The basal cover of the grass layer was temporarily reduced by approximately fifty percent. The 1999 fire in systems 3 and 4 and the 2000 fire in camp 2 had a similar effect to the 1978 fire. Again, the fires stimulated coppice growth, resulting in increases in multi-stemmed trees, at the expense of single-stemmed trees in the thinner stem diameter classes. The vegetation in the burned camps was again opened up. The 2008 fire had no effect on the woody component.

Tree density and percentage frequency

Botanical data relating to density and frequency changes of the woody component between camps are presented Annexure A (Table A1 to A20).

Louw (1973) reported that, over the short term, bush encroachment was detected within two years after the initial monitoring of the woody component in the camps of the Irvine Systems that were subjected to summer grazing. During the period 1962 to 1973 leguminous species had increased in camps 1 and 3, whereas more stable conditions prevailed in the other camps. In accordance, this study indicates that trees with a stem diameter thicker than 7.62 cm further increased in all camps over the long term. Increases escalated during the last 13 years (Figure 6.12).

Smit (1988) indicated that increases in bush density in the Irvine Systems were highly correlated with both veld condition and the occurrence of summer rest. In accordance with both Louw (1973) and Smit (1988), big long-term increases occurred in camps that were subjected to long term continuous grazing during the active growing season. In camps 1, 3 and 7, trees with a stem diameter thicker than 7.62 cm increased by 2230%, 1573% and 1277%, respectively. In camps 2 (+1119%) and 6 (+1563%), which both received long rest periods during the active growing season, large increases were also encountered, but tree density remained lower than in camps 1 and 3. Camps 4, 5 and 8 (Tables A2.9 and A2.13) were subjected to lesser encroachment.

Similarly, smaller trees and shrubs also increased in percentage frequency in all camps Leguminous species (*Acacia* species and *D. cinerea*) were the main increasers, in all stem diameter classes. General broad-leaved increasers included *Ehretia rigida, Diospyros lycioides, Rhus leptodictya*, *Z. mucronata* and *Grewia* species.

Rates of bush encroachment

Trees increased in all camps of the Irvine Systems, irrespective of the grazing treatment that the different camps received over time.

Where trees with a stem diameter thicker than 7.62 cm are concerned, until 1987, the biggest increases in total bush density occurred in camps subjected to continuous summer grazing. Camps 1, 3 and 7 were the only camps that had bush densities that exceeded 500 trees ha^{-1}. Camps that received a rest period during the active growing season (camps 2, 4, 5 and 6) were less affected. The camps where the smallest increases in the total number of trees occurred, namely camps 4 and 5, had both received rest periods during a part of the active growing season, but had also been subjected to the highest fire frequency. During 2000, camps 1, 3 and 7 had reached bush densities exceeding 1000 trees ha^{-1} (Figure 2).

However, during the last 13 years of the trial (1987 to 2000) bush also increased in camps that received rest periods during the active growing season. It appears as if the rate of encroachment differed in camps 2, 6 and 8 as well. In the long term, this resulted in all three camps being under-utilised (specifically where camps 2 and 6 were concerned but to a lesser extent in camp 8), indicating that under-utilisation of the grass component also promoted bush encroachment.

It appears as if the bush encroachment rate in camps 4 and 5 was influenced by the higher fire frequency in these camps. Both camps were fairly open during 2000, but despite the sporadic occurrence of hot fires, bush encroachment rates differed even between camps 4 and 5. During 2000, camp 4 (mid-winter to mid-summer grazing) had a slightly higher tree density than camp 5 (mid-summer to mid-winter grazing). The reason might be explained as follows:

- Since the beginning of the experiment, the period of occupation for camp 4 included the last part of the dormant season and the early part of the growing season, accompanied by a rest period during the main growing period (Figure 4.2).

- In comparison, the period of occupation for camp 5 included the main growing period and an early winter rest. Camp 4 thus received "spring grazing", while camp 5 received "summer grazing", which might explain the difference in bush encroachment rates.

Polynomials fitted to density data of trees with a stem diameter thicker than 7.62 cm (Figure 2, Annexure B; Table B1) give the impression that limited bush encroachment took place before 1972. It generally appears as

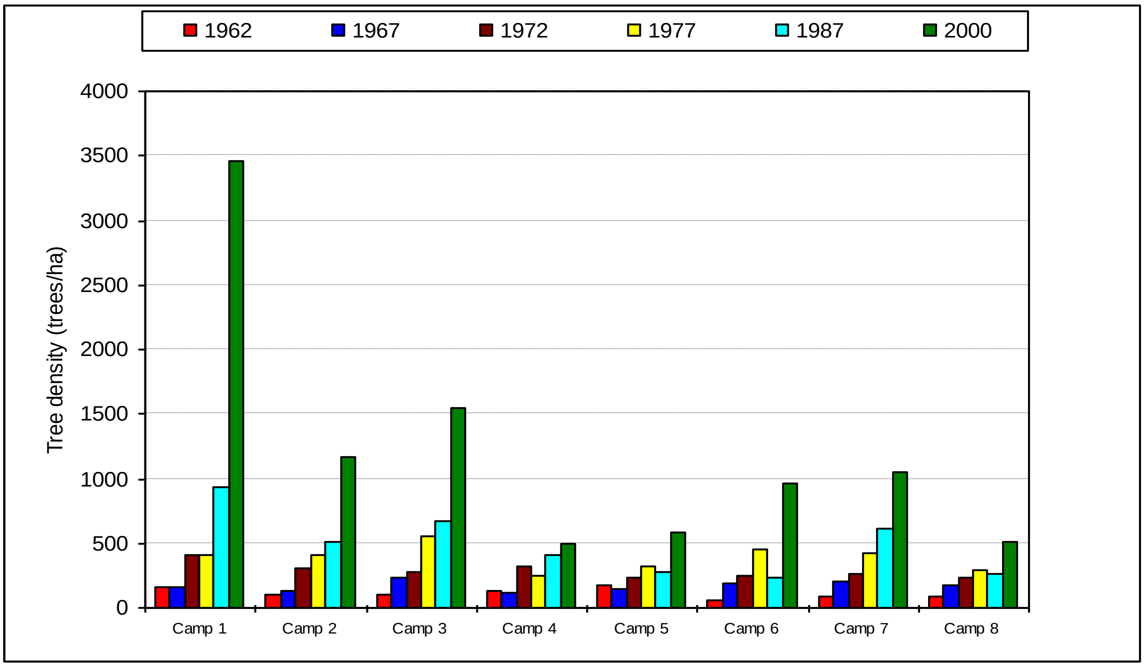


Figure 2 Long-term changes in tree density (trees with a stem diameter thicker than 7.62 cm) in the Irvine Systems

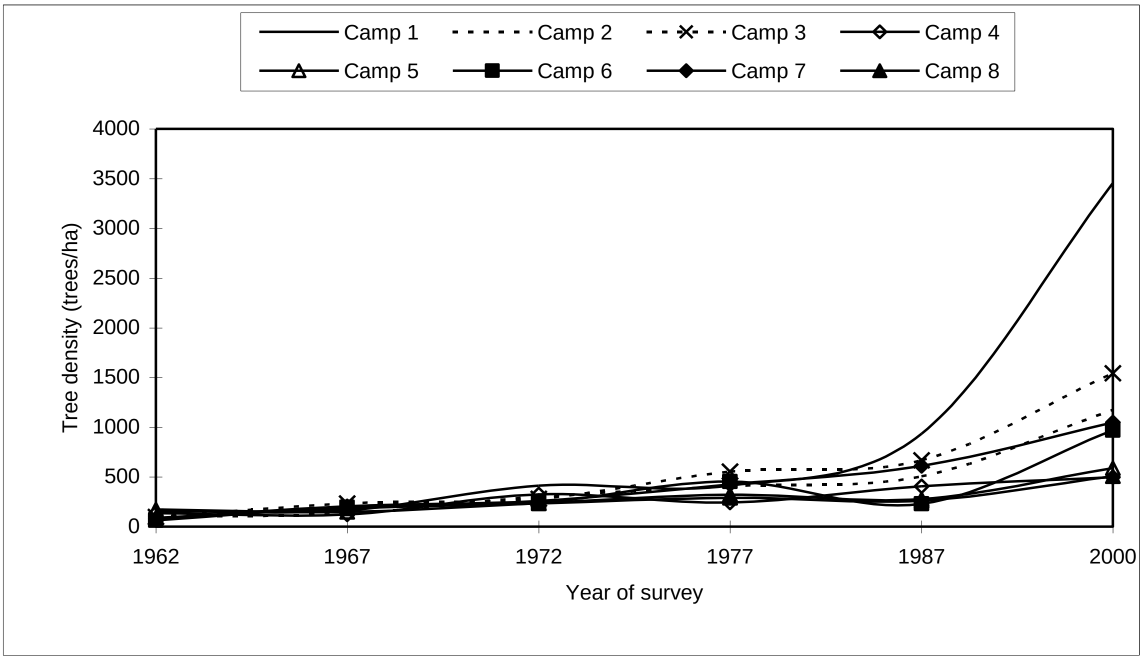


Figure 3 Polynomials fitted to tree density data (trees with a stem diameter thicker than 7.62 cm) in the Irvine Systems

if little increases occurred before 1983, with the rates of encroachment escalating thereafter, differing between grazing treatments. The observed differences in the time and rates of establishment are accordance with results obtained by Louw (1973) and Smit (1994) and involved mainly *Acacia* spp. and *D. cinerea.*

Although abundant information is available on the growth rates of different *Acacia* spp, little literature could be found relating to their age. Carr (1976) reported known tree ages of 22, 15 and 17 years for *A. karroo, A. haematoxylon* and *A. senegal*, respectively, while Coates Palgrave (1977) mentioned *A. erioloba* trees that were more than 100 years old. However, based on unconfirmed verbal reports, it is suggested that the average life expectancy of most *Acacia* species and *D. cinerea* varies between 30 and 50 years. The time period between 1935 and 1977 in Figure 16.3 thus resembles 37 years during which the woody component recovered after being cleared to the point where bush encroachment presented a problem again. During this period, tree-on-tree competition was absent and large trees were able to reproduce freely. The degree of grass-on-tree competition differed periodically and depended on rainfall and grazing treatment. Small trees that remained after clearing matured to a reproductive stage. Eventually, a new tree generation was established that was adequate in numbers to produce enough offspring for bush encroachment to escalate as from 1987, the rate depending on climate, grazing treatments and the occurrence of fires.

Percentage tree species composition

Tree species compositions of different camps are presented in Annexure A (Tables A17 to A20). Comparing the different surveys with one another, similarity indices clearly indicate that major changes occurred in percentage tree species composition during the 65-year trial period (Annexure A, Table A21). Two periods of major change in percentage tree species composition were identified, both following major ecological "catastrophes". The first occurred during the period 1962 to 1967, which coincided with the middle to latter part of the 1960's drought. The second major period of change was approximately ten years later, during 1977 to 1987. This period involved followed the wet period of the 1970's, and was also the time when the trial site was subjected to the highest fire frequency, the most intense fires and accelerated increases in bush density. During the earlier surveys, changes in percentage tree species composition were mainly due to fluctuations in the occurrence of *Acacia* spp. and *D. cinerea*, while later changes (1987 and 2000) are attributed to increases in broad-leaved species and decreases in the leguminous part of the woody component.

Tree height

The average tree height decreased non-significantly ($p > 0.05$; Table B2) in all camps during the 13-year period that elapsed between the 1987 and 2000 surveys, except for camps 2 and 8 (Figure 4, Tables A22 to A29). The reasons for the decreases in tree height might be due to the overall increase of small trees in the Irvine Systems as well as the occurrence of fire, which reduced tree height. This is also reflected by a relatively high correlation between tree density (trees thicker than 7.62 cm) and tree height during 1987, which decreased during 2000 (Table B6).

The reason why tree height increased in camps 2 and 8 is not clear. One can only speculate, but the absence of tree-on-tree competition due to lower bush density (Figure 4) might have favoured bigger trees that occurred in camps 2 and 8, leading to better growth conditions and increased tree height.

Height distribution

During 1987, 56.52% of the trees in all camps occurred as individuals lower than 1.0 m. During that survey, the camps of the Irvine Systems could subjectively be classed into three groups (Smit 1988; Figure 5, Tables A22 to A29).

- The first group consisted of camps 2 and 8 and represented camps that received a full growing season's rest. Smit (1988) reported that they were both relatively open at that stage and had similar height distributions, with individuals up to 1 m in height contributing to 67% and 68% of the total number of individuals, respectively. The large percentage of small and the relatively low percentage of big trees that occurred, however, indicate that there was enough space for individuals to establish at this point and indicate an accelerated rate of bush encroachment.

According to Smit (1988), the second group consisted of camps 4, 5 and 6. These were the camps that received the highest fire frequency and the hottest fires during the late 1970s and represented camps that received a rest period during a part of the growing season. These camps had approximately 50% trees that were smaller than 1.0 m, while higher trees were more dominant.

- The third group consisted of camps that were grazed during summer, namely camps 1, 3 and 7 (Smit 1988). These camps had the highest percentage of trees higher than 3.0 m (11.7%, 9.4% and 5.8%, respectively), but were intermediate where trees smaller than 1.0 m were concerned. Camps 1, 3 and 7 had between 50% and 57% trees smaller than 1.0 m.

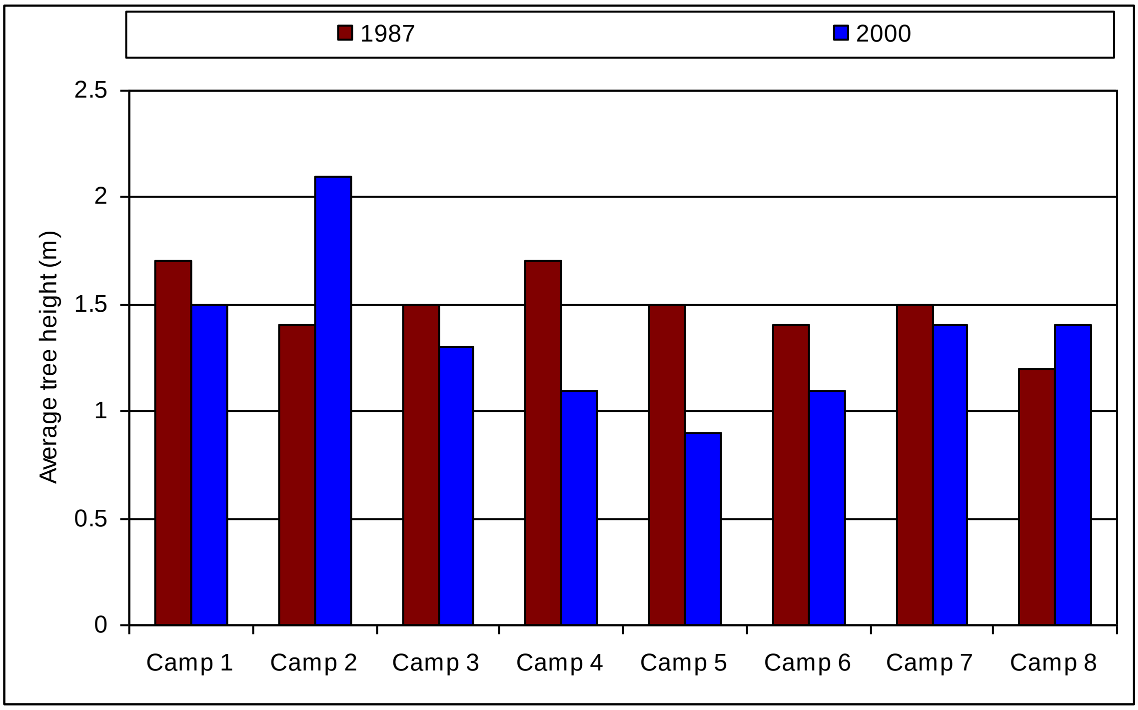


Figure 4 Average tree height (m) in the Irvine Systems

Small trees increased in all camps during the 13-year period that elapsed between the 1987 and 2000 surveys (Figure 6). The subjective grouping of camps remained the same as indicated by Smit (1988), but differences were less evident. During 2000, trees in the lower than 0.5 m height class dominated in all camps, the general average being approximately 65%. During 2000, 54% of the trees in camp 2 appeared in the 0.0 - 0.5 m height class, which is characteristic of veld that is busy recovering from a recent hot fire (Jordaan 1995). Similarly, camps 4, 5, 6, 7 and 8, which had been burned during the winter of 1999, were dominated by trees in the 0.5 - 1.0 m height class (general average 28%). Most of these trees had coppice growth. The camps that received no recent fire (camps 1 and 3) had an equal percentage of trees occurring in the 0.0 - 0.5 m height class (46%) while no coppice growth due to fire was present. Camps 4, 5 and 6, which received the highest fire frequency and the hottest fires during the late 1970s, had less than 50% trees that were smaller than 1.0 m, while taller trees were more dominant.

Tree-on-tree competition

Spacing

The average distances between trees as observed during the point-centred quadrate surveys, are presented in Figure 7 for the 1962 and the 2000 seasons. In all camps, average distances between trees and sample points decreased significantly ($p < 0.05$; Table B6), indicating increases in the number of trees ha^{-1} [$r = -0.30$ ($p < 0.05$; d.f. = 14) during 1962 and $r = -0.86$ ($p < 0.05$; d.f. = 14) during 2000]. The smallest changes occurred in camps that were less dense, namely camps 4, 5 and 8, where the average distances between trees and sample points decreased by 48.8%, 52.3% and 54.4%, respectively. In the other five camps, the average distances between trees and sample points decreased by between 68.8% and 83.9%, indicating a faster rate of encroachment compared to camps 4, 5 and 8.

Percentage canopy cover

The changes in canopy cover during the 13-year period that elapsed between the surveys were not significant ($p > 0.05$; Table B3, Figure 8). However, as in the case of tree height, camps could be classified into three subjective groups in terms of changes in percentage canopy cover:

- The first group included camps 2 and 8, in which the total percentage canopy cover increased by 17.2% and 16.5%, respectively, during the period 1987 to 2000. Similarly, as in the case of tree height, it appears as if enough space was available for individuals to establish. Furthermore, lesser competition probably led to more favourable conditions for trees in camps 2 and 8.
- The second group consisted of camps 1 (+3%), 3 (+3%), 6 (-2%) and 7 (+0.5%), where the percentage canopy cover stayed relatively constant. Except for camp 6, the other three camps were heavily encroached, which indicates that tree on tree competition must have played a role in suppressing increases in percentage canopy cover.
- The third group included camps 4 and 5, which received the highest fire frequency and the hottest fires during the late 1970s and during 1999. The survey was done only a year after the last occurrence of fire, which led to a 16% and 21% reduction in the percentage canopy cover in camp 4 and 5, respectively.

During 1987 the total percentage canopy cover and tree density (trees thicker than 7.62 cm) were highly correlated ($r = 0.81$; $p < 0.05$; d.f. = 14; Table B6). This relationship decreased over time [$r = 0.62$ ($p < 0.05$; d.f. = 14) during 2000]. As in the case of tree height, the increase in small trees (trees thinner than 7.62 cm) must have had an influence on the percentage canopy cover. Camps that were subjectively classified into the above-mentioned classes reacted similarly.

Basal cover

The total basal cover ($m^2\ ha^{-1}$) increased highly significantly ($p < 0.01$; Table B4) in all camps during the trial period (Figure 9, Tables A30. A32, A34, A36). The biggest increases occurred in camps 1 (continuous grazing), 2 (winter grazing) and 6 (spring grazing). According to Figure 6.12, these camps were subjected to the biggest increase in bush density over time. Similarly, increases in total basal cover were highly correlated with increases in bush density (Table B6 and B7), the lowest correlation being in camp 4, which was the camp where the least encroachment occurred ($r = 0.906$; $p < 0.05$; d.f. = 3).

Stem diameter

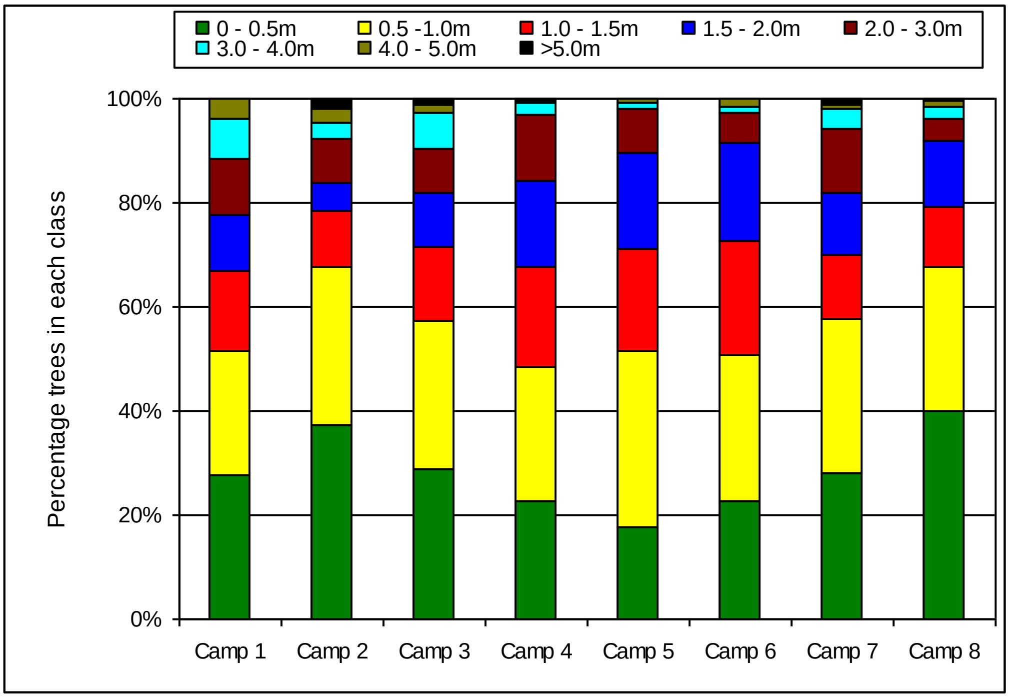
Except for camp 5, the average basal stem diameter decreased significantly ($p < 0.05$; Table B5) during the experimental period (Figure 10, Tables A31, A33, A35, A37). Similarly, in all camps except camp 5, where a weak positive correlation existed, the basal stem diameter was negatively correlated with tree density (Table B6 and B7). In camp 5, the random inclusion of two very large trees (*A. mellifera* and *A. tortillis* tree with stem diameters of 90 cm and 60 cm, respectively) probably led to the increase in the average basal stem diameter during the 2000 survey.

Camps 6, 7 and 8 had the lowest bush density (trees with a stem diameter thicker than 7.62 cm) during 1962 (62, 82 and 89 trees ha^{-1}, respectively), compared to the other camps, where the bush densities were higher than 98 trees ha^{-1} ($\approx > 100$ trees ha^{-1}). Accordingly, trees in camps 6, 7 and 8 had larger stem diameters than trees in the other camps (Figure 10). Camps 6, 7 and 8 were the camps where the largest decreases in basal stem diameter occurred as bush density increased over time.

The long-term relationship between veld condition and tree density

Indices of similarity in Tables A2.38 to A2.41 indicate that, during the first 30 to 40 years of the trial, big fluctuations occurred in the veld condition in all camps of the Irvine Systems. It appears as if the veld

1987



2000

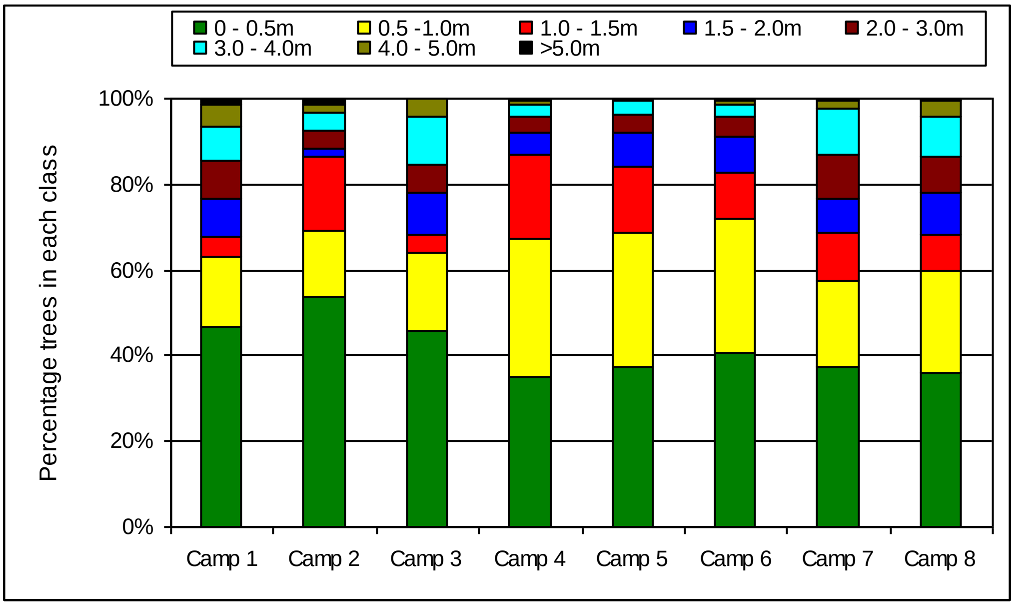


Figure 6 Percentage trees in different height classes during 1987 and 2000 in the Irvine Systems

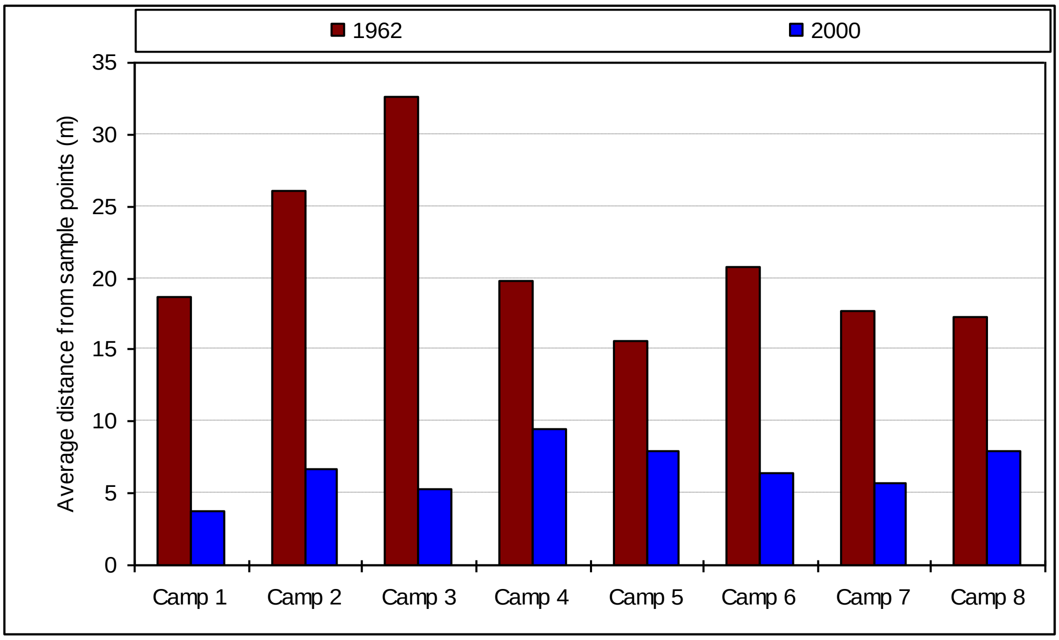


Figure 7 Average distances of trees with a stem diameter thicker than 7.62 cm from randomly chosen sample points in the Irvine Systems; 1962 vs. 2000

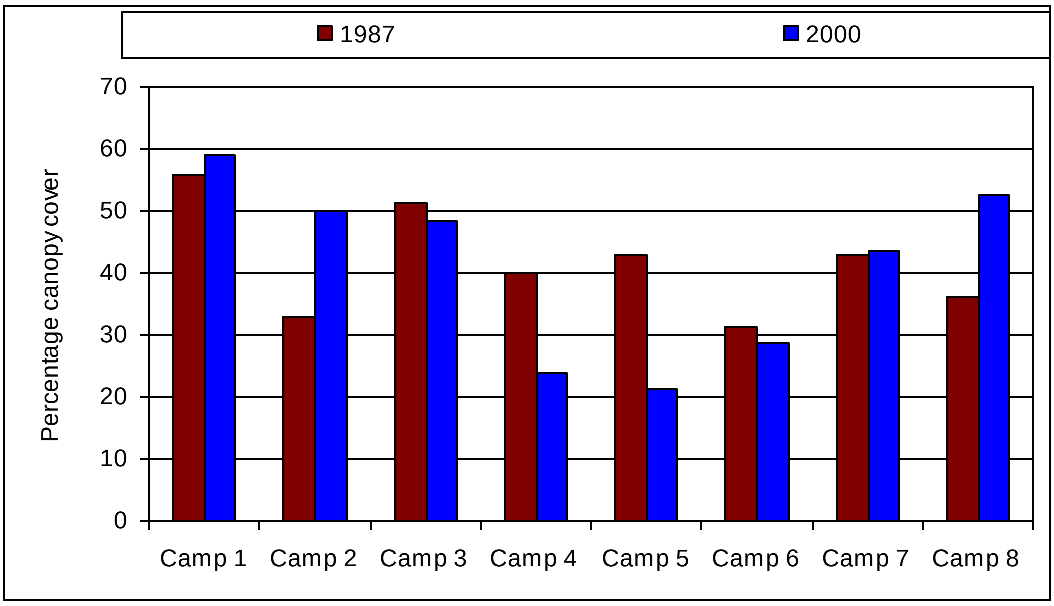


Figure 8 Total canopy cover of trees in the Irvine Systems; 1987 vs. 2000

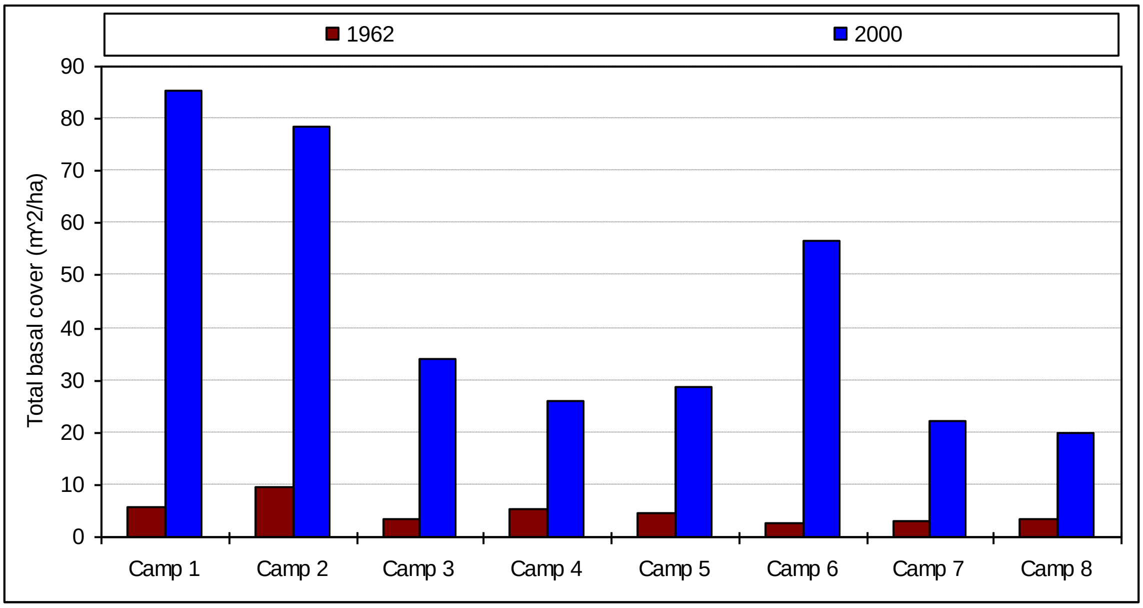


Figure 9 Changes in the total basal cover (m^2 ha^{-1}) of trees with a stem diameter thicker than 7.62 cm in the Irvine Systems; 1962 vs. 2000

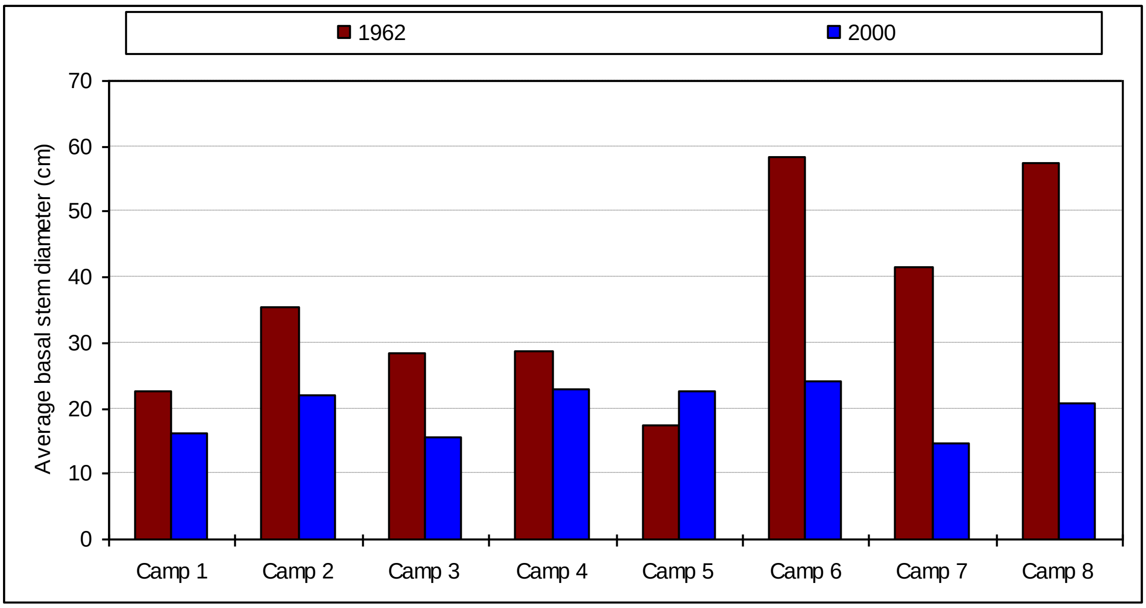


Figure 10 Changes in the stem diameter (cm) of trees with a stem diameter thicker than 7.62 cm in the Irvine Systems; 1962 vs. 2000

condition of the different camps, especially those that were subjected to summer grazing or grazing during the early part of the growing season was severely affected by droughts and the absence of trees on the trial site. Veld condition indices stabilised, irrespective of grazing treatments, in all camps from 1977 onwards, which corresponded with the beginning of the increases in the density of large trees (Figure 3). This is due to increases in *P. maximum* (Table B8), a palatable and high producing grass species known to be associated with trees (Trollope *et al.* 1988, Jordaan 1991, Jordaan 1992, Smit *et al*. 993a and 1993b, Smit and Van Romburgh 1993).

Grass species composition and veld condition

The grass species composition and veld condition indices of the grass component are represented in Annexure A (Tables A38 to A41) and in Figures 11a to 11h. The grasses were classified into Decreasers (species that decrease with overgrazing, like *T.triandra*), Increasers Ia (species that increase with moderate under grazing, like *Cymbopogon plurinodis*), Increasers IIa (species that increase with moderate overgrazing, like *P.maximum*), Increasers IIb (species that increase with overgrazing, like *E.rigidior*) and Increasers IIc (species that increase with severe overgrazing, like *Tragus berteronianus*) (Vorster 1982; Friedel and Blackmore 1988, Smit 1988).

Continuous grazing (no rest)

The continuously grazed camp (Figure 11a) was characterised by an increase in Increaser Ia and Increaser IIc species, while Decreasers declined. Much of the vegetation cover was sparse, with *C. plurinodis* tufts interspersed with annual and weak perennial species such as *T. berteronianus*. Increaser IIb and Increaser IIa species were also prominent. At the end of the experiment, the veld condition was bad.

Camps grazed during summer (autumn and winter rest)

The camps grazed during summer Figures 11c and 11g) were dominated by Increaser IIb species. The grass was always short and more forb species occurred and veld was in a bad condition. The reaction of the grass component was similar to continuous grazing.

Camps grazed during the dormant season (spring and summer rest)

Despite the fact that winter grazing only is regarded as the best possible treatment a camp could get (Low 1975), the camps that was grazed during winter only (Figure 11b and 11h) has over the years had an abundance of Increaser IIa and IIb species. Rethman (1971) reported that grasses (*T. triandra*) become moribund if not defoliated. This was a situation which often occurred in this camp. The result was that, despite being in a good condition, grass tufts were large, coarse and often moribund, leading to low quality grazing.

Camps that grazed during a part of the growing season.

In general, these camps were in a continuous good condition. The Increaser IIb species have decreased and the Increaser IIa species have increased in the camp that was grazed from mid-winter to mid-summer (Figure 11d). Increaser IIb species have decreased and the Increaser IIa species have increased in the camp that was grazed from mid-summer to mid-winter (Figure 11e), but not as dramatically as in the other camp. Despite theoretically getting the same amount of rest, Camp 5 produced less grass and was in a poorer condition than Camp 4. One can only speculate as to the reason for rest in the early part of the summer being less effective than rest in the late part of the summer. The reasons might well be found in the beliefs that grass growth is expected to be better in the second half of the season, the late rains are usually more reliable and that grazing the last growth before the winter is considered bad for the accumulation of root reserves.

Grazing during spring was, up till now, considered detrimental to grass growth. During the early growing season, grasses are extremely vulnerable to defoliation. Early growth after dormancy requires large amounts of root reserves, stored during the previous growing season. If a grass tuft is defoliated at a stage where photosynthesis is slow and root reserves restricted, growth is seriously affected. Adding the fact that the commencement of growth, at this stage, depends on the availability of soil moisture, which in turn depends on the previous years' rainfall, veld degradation is ominous when proper grazing management is absent. However, long-term spring grazing (short grazing periods and long rest periods, Figure 11g) led to high producing veld, where Increaser IIb species have decreased and Increaser IIa species have increased and the veld is in a good condition.

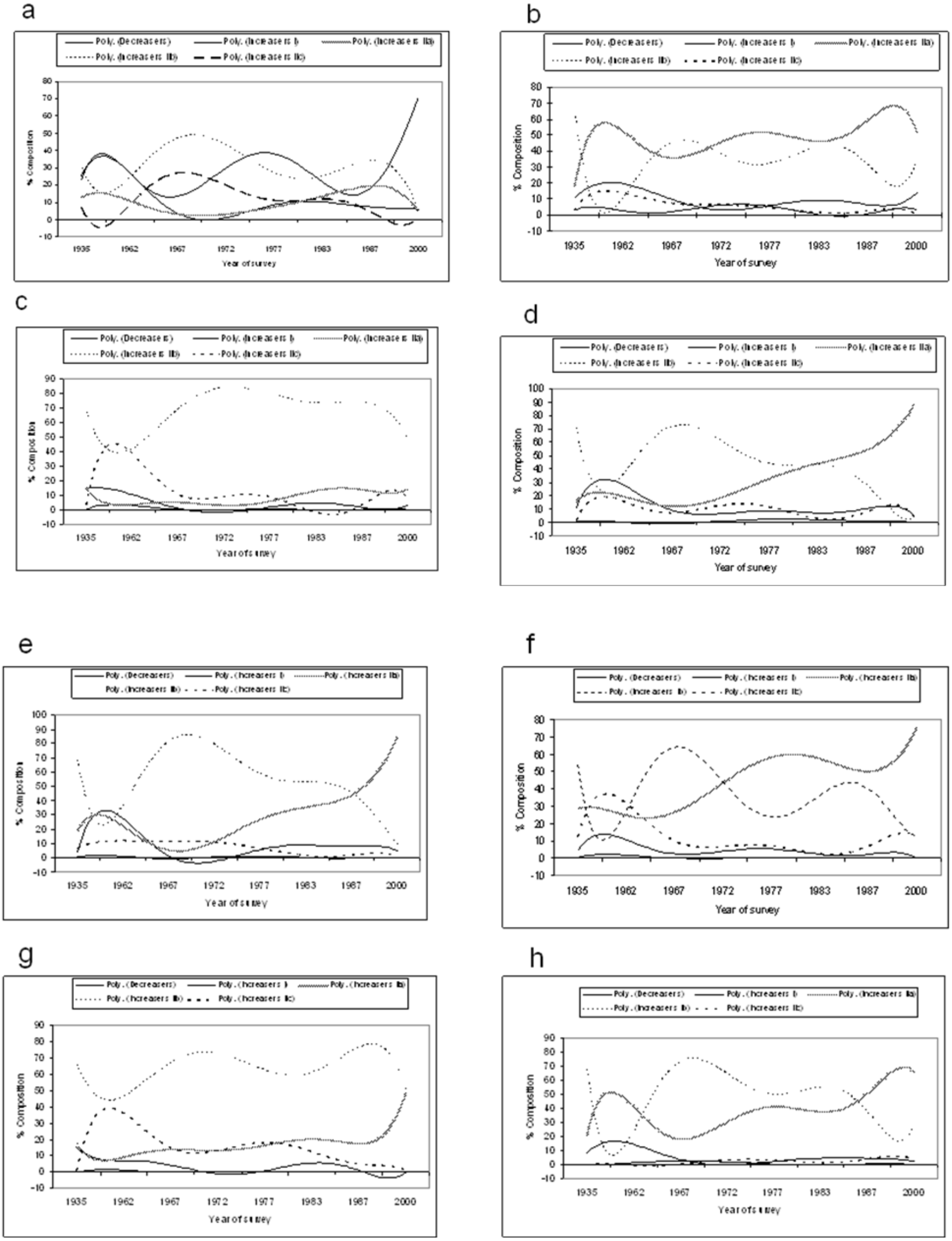


Figure 11a to 11h Grass species composition changes in the Irvine Systems

Long-term animal performance

What must be kept in mind is that none of the four grazing systems was strictly speaking rotational grazing, since the long grazing periods of specifically camps that received no summer rest did not differ significantly from continuous grazing. What is also important is the fact that a pre-determined, fixed stocking rate was hosted during the entire duration of the experiment.

From the data in Tables 3 to 5 it is clear that long-term continuous grazing had a negative effect on animal production. System 1 (camp 1) has resulted in a steady decline in livestock production over the years, due to the degradation of the grass sward (grass production and vigour), combined with bush encroachment.

System 2 (camps 2 and 3) has maintained its productivity in terms of animal production. Livestock usually lost mass during spring, but performed fairly well during summer and autumn. Currently, camp 2 is in a good and camp 3 in a poor condition. The fact that this system is still in a good, productive state is due to abundant, high quality winter grazing in camp 2, which counter-acts the effect of the poor grazing that is available in camp 3 during the active growing season.

Table 6.15 Mean stocking rate of cattle in the Irvine Systems for the period 1934 to 2009, expressed in ha LSU^{-1}

	1934-36	1937-1946	1947-1956	1957-1966	1967-1976	1977-1986	1987-1995	1996 - 2000	2000 - 2005	2006 - 2009	Mean
System 1	4.23	4.77	4.18	4.38	3.22	5.33	5.51	7.38	6.78	4.27	5.01
System 2	4.12	4.55	4.38	4.29	3.10	6.21	6.08	6.56	6.29	4.19	4.98
System 3	4.00	4.33	3.95	2.69	2.61	4.94	4.83	6.16	5.81	3.64	4.30
System 4	4.00	4.12	4.10	3.68	2.86	5.08	4.83	6.22	5.91	3.78	4.46

Table 6.16 Live mass of cattle in the Irvine Systems for the period 1934 to 1995, expressed as kg $animal^{-1}$

	1934-36	1937-1946	1947-1956	1957-1966	1967-1976	1977-1986	1987-1995	1996 - 2000	2000 - 2005	2006 - 2009	Mean
System 1	420	368	388	398	614	243	250	468	502	863	451.4
System 2	406	346	413	387	584	298	285	529	554	867	466.9
System 3	428	394	444	470	598	330	340	564	603	1069	524.0
System 4	438	420	423	488	684	318	339	561	596	973	524.0

Table 6.17 Live mass gains of cattle in the Irvine Systems for the period 1934 to 1995, expressed as kg ha^{-1}

	1934-36	1937-1946	1947-1956	1957-1966	1967-1976	1977-1986	1987-1995	1996 - 2000	2000 - 2005	2006 - 2009	Mean
System 1	22.83	23.89	24.37	19.68	31.33	19.83	12.24	19.54	20.32	14.63	20.87
System 2	24.53	23.48	25.89	23.06	21.66	26.82	21.18	26.39	23.00	16.96	23.30
System 3	12.31	28.56	30.92	33.19	28.64	22.12	34.52	33.14	33.31	22.85	27.96
System 4	11.12	16.13	40.55	36.46	35.19	41.47	37.84	32.74	31.86	21.66	30.51

System 3 (camps 4 and 5) where each camp receives half a growing season's rest, produced the highest livemass gains up until the dry years of the 1980's and 1990's, which resulted in a decline. The high fire frequency has probably also lowered the overall animal performance in the system. Jordaan (1991) indicated that climax grass species such as *T. triandra* are less palatable, while Jordaan (1995) showed that this climax grass species increased when veld is burned. Besides the fact that a large part of the grass component in system 3 currently consists of *T. triandra* and *H. contortus*, the fires have also led to withdrawal periods and times where little grazing was available, thereby negatively influencing animal performance. In System 4 (camps 6, 7 and 8) cattle performed exceptionally well, despite the poor condition of the summer grazed camp. The system's animal production improved after the implementation of a recommendation by Irvine (1940) during the early 1970's, namely that the autumn camp should provide all the winter grazing. Currently, the system consists of two camps whose veld is in a good condition (6 and 8) and one whose veld is in a poor condition (camp 7, grazed for approximately four months of the year). The system has improved from the worst producing system in 1935 to the best in 1995 (Table 6.17).

CONCLUSIONS

In terms of bush encroachment, the following points conclude the main findings of this study:

- Bush density increased in all camps of the Irvine Systems, including camps that received a long-term summer rest. This indicates that bush establishes naturally, irrespective of grazing or rest treatments. This is similar to the results obtained by O'Connor and Crow (1999).
- Bush established faster in areas where the grass component receives no summer rest, while areas that were rested in summer were subjected to a lower rate of encroachment. This corresponds to results obtained by Smit (1988).
- Overall, bush encroachment has a negative effect on the herbaceous component (veld condition) and leads to lower animal production. Similar results were obtained by Van Eck (1984), Coetzer (1985), Moore and Van Niekerk (1987), Moore and Odendaal (1987) and Smit (1994).
- Woody plants compete against one another. As bush density increases, trees grow closer together and adjust their growth form accordingly.
- The recovery period of the woody component after being cleared to a point where the newly established tree generation enabled accelerated establishment, appears to be between 30 and 40 years. The period in between is characterised by the establishment of tree seedlings with small trees continuously adding to the encroachment rate while maturing.
- Change in tree density and species composition is a continuous process that is drastically altered by ecological events such as fire, droughts and low temperatures.

In terms of the grass component, the following points were illustrated by this study:

- The different camps of the Irvine Systems can be classified according to the following long-term grazing treatments (Smit 1988), namely :

  1. Camps that received an annual rest during the active growing season (camps 2, 6 and 8). These camps were generally characterised by a good veld condition, high grass production, intermediate bush encroachment and good animal production (Robinson 1996).
  2. Camps that received an annual rest during a part of the active growing season (camps 4 and 5). Due to a higher fire frequency compared to other camps in the experiment, these camps were generally characterised by good veld condition, high grass production, moderate bush encroachment and high animal production (Robinson 1996).
  3. Camps that received no rest during the active growing season (camps 1, 2 and 7). These camps were generally characterised by a poor veld condition, low grass production, severe bush encroachment and relatively low animal production, compared to other camps in the experiment (Robinson 1996). However, these camps remained relatively productive throughout the experimental period. It therefore appears as if, even though detrimental to veld and animal production in the long term, animal production can be maintained under continuous grazing at realistic stocking rates. Continuous overgrazing appears to be the main cause of concern where short-term veld degradation is concerned.

In terms of a grazing management system, the following can be concluded:
Improved grazing management can be successfully applied if the following three major strategies are adhered to:

- The separate utilisation of different veld types or plant communities. This is a practice that is not questioned by researchers. Various researchers recorded the influence of grazing on unseparated veld types in the past, and it is clear that, to prevent selective overgrazing, separation of veld types is of the utmost importance (Kirkman and Moore 1995).
- The inclusion of a full active growing seasons rest period. Adequate rest can be defined as a prolonged period of absence of livestock, long enough for the veld to overcome the effect of previous grazing treatments in terms of both grass production and seed production (vitality) (Van de Pol and Jordaan 2008). In order to be seen as "vitality rest", it was reported that a period of absence of more than eight weeks is needed to overcome the effects of grazing (Low 1975). However, Barnes and Dempsey (1992) indicated that an eight-week period of

absence is too short. Until the long-term results of this study become available, little is known to indicate what the length of an effective rest period should be. From this study it is clear that a full growing season is needed for grasses to recover after defoliation. It is also clear that grazed veld which receives no rest, progressively deteriorates over time.

- Maintaining a stocking rate that falls within the carrying capacity of the veld. O'Reagain and Turner (1992) revealed that the carrying capacity of veld could be increased by rotational grazing during the first season of grazing, where after grass vitality and veld condition decreased over time. The general belief that by applying high stocking rates, carrying capacity is increased due to a higher grass production as a result of the continued stimulation of grass species was regarded as unfounded. According to Van de Pol and Jordaan (2008) the available grass material determines grazing capacity (and therefore stocking rate). This, in turn, depends on climatic conditions (mainly rainfall), veld type and veld condition. Accordingly, in this study, the 1980s and 1990s drought and the gradual deterioration of the grass component in camps 1, 3 and 7 had an effect on animal production in all four systems. However, regardless of management, the veld in all camps is currently still productive.

IMPACT OF THE STUDY ON BENEFICIARIES

- Over a period of 75 years, the trial had been the source of extremely valuable long-term veld data. Several studies were conducted at the trial site, resulting in various journal publications which included veld management (Louw 1973), survey techniques (Jordaan *et al.* 1991), veld condition assessment (Friedel & Blackmore 1987), rangeland ecology (Smit & Van Romburgh 1993), animal performance (Robinson 1996) and soil studies (Donaldson, 1986). Several congress presentations (Jordaan 1992, Robinson & Jordaan 2000,), MSc dissertations (Smit 1988, Jordaan 1991) and PhD theses (Jordaan 2004) as well as the Mara and Fodderbank Grazing Systems (Van der Pol & Jordaan 2008) also originated out of this trial.
- The trial was an excellent demonstration of the effect of different veld utilization strategies, i.e. long-term during the active growing season vs. continuous overgrazing. Long term treatments led to drastic changes that can be observed with the naked eye and no botanical surveys are needed to illustrate veld condition changes over time. Approximately 100 farmers, researchers, students and extension officers visited the trial site annually for training purposes.

REASONS FOR CLOSING THE TRIAL

The long term trial was one of the flagship trials at Towoomba. However, continuous vandalism of fences, watering points and vegetation and arson has reduced the value of this trial to the extent that it is deemed unfit for future research. Grazing treatments were only applied for short periods and little data collection on both livestock production and the vegetation were done during the last three years. Wood theft has had a major impact on the vegetation, and future monitoring actions would give a false image future vegetation changes that might occur. The trial was therefore stopped in April 2010.

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