BUSH ENCROACHMENT: WITH REFERENCE TO THE OCCURRENCE, DIE-BACK AND REGENERATION OF ACACIA MELLIFERA SUBSPECIES DETINENSE IN NAMIBIA

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ABSTRACT

In terms of increased grass production it is feasible to control bush. Methods of bush control will depend on the density of the bush and species composition. In stands with a high density initial control with herbicides is recommendable. Fire and incorporating the Boer Goat can serve in an after-care programme. Incorporating the Boer Goat must be done with caution. Controlling bush with herbicides, an increase in grass production can be achieved even when the rate of success (bush mortality rate) is low. A prolonged spell of low rainfall has an overriding influence on dry-material grass production irrespective of bush density. The distribution of the rainfall during a rainy season, also influence the grass production dramatically. Research done in the past shows that in the Thorn Tree Savanna it is not possible to control *Acacia mellifera* with the Boer Goat, and that one can aggravate the problem, rather than solving the problem. Harvesting the problem bush to produce charcoal is a possibility, however surveys in the field shows that only eight percent of the total bush population is normally removed. Considering that 45% to 60% of the remaining bush are smaller than one meter, an after-care in one or other form will be necessary.

Bush encroachment occurs in various degrees of densities species composition and structure. The variation in density and species composition can be attributed mainly to soil type and rainfall. A major feature is the natural die-back of *Acacia mellifera* in the Thorn Tree Savanna. The die back results in relatively low bush densities in the Thorn Tree Savanna. Coinciding with the lowest bush densities recorded the highest percentage mortality of *Acacia mellifera* occurs in the Thorn Tree Savanna. The percentage mortality of *Acacia mellifera* varies from as low 10% on some sites to as high as 80% on others. The overall average would be in the order of 30% mortality. The stand structure in the Thorn Tree Savanna averages two meters in height, however, on some sites where *Acacia mellifera* dominates the majority of the bushes are smaller than one meter in height. This is attributed to the fact that the larger trees have already died back. On other sites due to virtually no regeneration of *Acacia mellifera* the younger generation only contributed 5.26% to the population.

Along with the natural die-back other factors such as fire and low rainfall result in a change in stand structure. On a site where no fire had occurred *Dichrostachys cinerea* bushes larger than one meter declined by 55% while the percentage re-growth was in the order of 50%. Where a veld fire occurred the population of *Dichrostachys cinerea* bushes smaller than one meter increased in the form of re-growth by 70.00%. In the Hochland Savanna, *Acacia reficiens* increased from 1998 to 2002 by 2.80% in the height class smaller than one meter, 22.14% between one meter and two meters and by 4.48 percent in the height class two meters to four meters high. During the 1998 survey no bush larger than two meters high were recorded. No bush larger than four meters were recorded in any of the surveys. However in the latter two height classes mortality was recorded.

INTRODUCTION

Agriculture in Namibia is largely livestock production that is dependent on natural grazing. Bush encroachment remains one of the major causes for a decrease in grass production and red meat production. Since the 1960's bush densities increased dramatically and bush densities as high as 21000 bush per hectare have been recorded in the Karstveld Savanna. Large areas of bushes have been cleared by chemical control. During the early 1980's natural die-back of blackthorn resulted in further open stands. This phenomenon resulted in a change in the blackthorn situation. Not only blackthorn but other woody species also show a die-back. In the latter case the die-back can be ascribed to prolonged low rainfall. One of the most important questions centred round the future of these open stands. How long will stands remain open and what will the re-infestation rate be? Can or will blackthorn re-infest these open stands or will other woody species take the place of blackthorn through re-infestation? Both, bush encroachment or an opening in dense stands will influence future livestock production. Emanating from above, a bush encroachment programme was launched during 1998.

The objectives of the programme are to;

- investigate the current status of bush encroachment in Namibia,
- determine whether die-back is confined to blackthorn or is also occurring in stands of other woody species,
- determine the health status of bushes in blackthorn stands,
- determine the regeneration of bushes in blackthorn stands cleared by natural die-back or other means.

BUSH ENCROACHMENT IN NAMIBIA: AN OVERVIEW

Bush encroachment is no new phenomenon in Namibia or even in Southern Africa. It is generally accepted by the agricultural sector that the combination of the 1960 drought and the foot and mouth disease out-break, contributed dramatically to the bush encroachment problem in Namibia. The causes of bush encroachment have been reviewed in many papers presented over time. This paper does not attempt to discuss the causes of bush encroachment, but rather, to indicate what has been done in the past regarding the issue of bush encroachment. Data presented is either, results from projects or data obtained through case studies. Vegetation types in the text are from Giess (1970).

1 Total Bush Eradication

As early as the 1950's the government was already aware of the issue of bush encroachment and therefore it received attention. A project was launched to determine the influence of different control treatments on the bush/grass ratio in the so -called Damaraland Thorn Tree Savanna (Joubert, 1966).
On four (20m x 20m) plots bush was eradicated manually, while on four control plots the bush was not eradicated. The bush density per hectare in the four control plots where no bush had been eradicated is presented in Table 1. Bush density surveys were initially done during 1957 and at the end of the trial in 1960.

Table 1. Bush densities per hectare of Black Thorn (*Acacia mellifera*) in the four control plots in which no bush had been eradicated (1957 and 1960).

Years	Bush densities per hectare			
	Plot 1	Plot 2	Plot 3	Plot 4
1957	3185	6133	11674	3809
1960	3432	6596	10028	2851

The average bush density of the four plots for the years 1957 and 1960 was 6200 bush per hectare and 5727 bush per hectare. The results presented in Table 1 show an increase in bush density in plot 1 and plot 2 from 1957 to 1960, while plots 3 and 4 showed a decline in densities per hectare. Overall there was a decline of 473 bush per hectare from 1957 to 1960. It is clear that there was no dramatic change in the bush densities from 1957 to 1960. There also was no re-establishment of *Acacia mellifera* in the four plots where the bush had been eradicated manually during 1957.

2 Biological Control with Goats

A trial with goats versus cattle was conducted at the Omatjenne Research Station during the period 1964 to 1977. The stocking rate for both the goats and the cattle treatments was seven large stock units per hectare. The change in bush densities due to browsing of *Acacia mellifera* (Black Thorn), *Dichrostachys cinerea* (Sickle Bush) and the fodder bush is presented in Table 2.

Table 2. Change in bush densities of *Acacia mellifera, Dichrostachys cinerea* and fodder bush in camps utilized by cattle and goats during the period 1964 to 1977.

Species	Bush densities per hectare, treatments and years			
	Cattle (7LSU/ha)		Goats (7 LSU/ha)	
	1964	1977	1964	1977
A. mellifera	277	342	487	555
D. cinerea	359	280	500	56
Fodder bushes	1524	1408	2047	481
Total	2162	2030	3034	1092

1 LSU = 6 SSU

The results presented in Table 2. indicates that neither the goats nor the cattle paid much attention to *Acacia mellifera*. However, in the goat treatment *Dichrostachys cinerea* and the fodder bushes were dramatically reduced in numbers per hectare. In both treatments there was a decline in total bush density of the three above -mentioned species from 1964 to 1977. The decline in total bush density was respectively 6% and 64%. In the cattle treatment the density of *Acacia mellifera* increased with 65 bush per hectare and in the goat treatment with 68 bush per hectare from 1964 to 1977. *Dichrostachys cinerea* and the fodder bush both showed a decline in density per hectare during this period. In the cattle treatment the bush density per hectare of *Dichrostachys cinerea* declined with 22% and the fodder bush with 8%. In the goat treatment the decrease in the number of bush per hectare for the latter two species was more drastic. The number of bush per hectare of *Dichrostachys cinerea* decreased with 89% and for the fodder bush the decrease in numbers was in the order of 77%.

In a case study in the Karstveld Savanna the influence of goats versus cattle on the woody layer is indicated. On the one farm goats were run while on an adjacent farm only cattle utilized the range for over forty years. The bush densities per hectare of *Acacia mellifera, Dichrostachys cinerea, Terminalia pruniodes* and the fodder -shrubs are presented in table 3.

Table 3. Bush densities per hectare in two height classes in a camp stocked with goats and camps stocked only with cattle.

Species	Bush densities, height classes and treatments			
	Goats		Cattle	
	< 1m	> 1m	< 1m	> 1m
A. mellifera	1700	700	500	-
D. cinerea	200	100	-	100
T. pruniodes	100	300	100	300
Fodder bush	900	-	4900	-
Total	3200	1400	5900	800
Total	4600		6700	

The first impression the results presented in Table 3 give is that goats can control bush species. The total population of above-mentioned species in the goat treatment is 4600 bush per hectare, while in the cattle treatment the density is 6700 bush per hectare. In the goat treatment *Acacia mellifera* contributed 2400 bush per hectare to the total population while *Dichrostachys cinerea* contributed 300 per hectare. The contribution of the fodder shrubs for the two treatments was in the order of 900 per hectare and 4900 per hectare. The contribution of *Acacia mellifera, Dichrostachys cinerea* and *Terminalia pruniodes* in the height class smaller than one meter was 2000 per hectare in the goat treatments and only 600 in the cattle treatment. The number of problem bush larger than one meter was respectively 1100 per hectare and 400 per hectare. The results presented in Table 3 indicate clearly that the goats aggravated, rather than, controlled the problem. In the process the fodder shrubs were basically utilized out of the system.

3 Aerial Application of Herbicides to Control Bush

In the early 1970's very little was known regarding aerial application of herbicides to control bushes. A pilot project was launched at Omatjenne Research Station in the Thorn Tree Savanna and TCL mine in the Karstveld Savanna. The aim of the project was to establish the effect of Tordon 225 on the different woody species, the correct application rate per hectare to obtain effective control of the undesirable woody component and at what physiological growth stage the herbicide would be most effective. During 1977 a project was launched on the farm Eastbourne in the Thorn Tree Savanna. The objectives of the project were to test ultra low volumes of the herbicide Tordon 225 to control bush and to establish the relationship between increased grass production to animal production as well as the financial implications (Bester & Van Eck, 1998). The percentage control of the woody component obtained by the three herbicide treatments, namely, 3 litres Tordon 225 per hectare, 2 litres per hectare and 1 litre per hectare was respectively 67%, 55% and 45% control. Mortality rate of the bush obtained with the conventional application of Tordon 225, water and G49 varied between 70% and 90%. The poor results obtained with the ultra-low volume can be ascribed to the small droplets that did not wet the leaves sufficiently and the insufficient amount of herbicide absorbed by the plant.

Despite the low mortality rate of 67% for the highest application rate of Tordon 225 per hectare, the results presented in table 4 do indicate an increase in grass production. This, in turn resulted in an increase in grazing capacity and income per hectare (Van Niekerk & Bester, 1979). The grass production results presented in table 4 for the three application rates of Tordon 225 and control was respectively 944 kg/ha, 731kg/ha, 755 kg/ha and 659kg/ha. The difference in the grass production (kg/ha) between the control treatment and the highest application rate in 1977 was only thirty percent.

Rainfall has an overriding influence on dry-material grass production. There was a gradual decline in the precipitation and number of rainy days from 1977 to 1981. The decline in rainfall from 1977 (536mm) to 1981 (182mm), resulted in a drastic decline in the grass production of all treatments. The number of rainy days for the 1977 and 1981 rainy season was 39 days and 6 days respectively. The grass production for the three application rate treatments and control during 1981 was 192kg/ha, 184kg/ha, 172kg/ha and 160kg/ha. The difference in grass production between the highest application and the control was seventeen percent. During 1982 when the precipitation increased and conditions were more favourable for grass growth, the dry-material grass production once again increased. The precipitation for the 1981 and 1982 rainy seasons was 182mm and 285mm. The grass production for the three application rate treatments and control was 426kg/ha, 518kg/ha, 396kg/ha and 292kg/ha respectively. The difference in grass production between the highest application and the control was thirty-one percent. The percentage increase in grass production from 1981 to 1982 for the three application rate treatments and the control was 55%, 64%, 57% and 45% respectively.

Not only the total rainfall but also the number of rainy days has a dramatic influence on the dry-material grass production. Despite the similarity in the total precipitation for the 1981 and 1998 rainy seasons, there was a vast difference in the grass production between the controlled areas and the area where bush had not been controlled. The precipitation and number of rainy days for the 1981 rainy season was 182mm and 6 rainy days, and for the 1998 rainy season 180mm and 34 rainy days. The grass production surveys conducted (Bester & Van Eck, 1998) for the three application rate treatments and control was in the order of 504kg/ha, 534kg/ha, 431kg/ha and 164kg/ha and are presented in table 4. The difference in the grass production for the years 1981 and 1998 for the three application rate treatments and control, expressed as percentage, is 62%, 66%, 60% and 2%.

Table 4. Grass production in kilograms per hectare, precipitation and rainy days for the years 1977 to 1982 and 1998.

	Percentage bush control and dry-material grass production in kilograms per hectare					
Years	67%	55%	45%	Control	Mm	Days
1977	944	731	755	659	536	39
1978	942	422	467	409	374	26
1979	658	395	384	340	354	26
1980	568	452	392	374	200	16
1981	192	184	172	160	182	6
1982	426	518	396	292	285	-
1998	504	534	431	164	180	34

4 Utilization of Problem Bush

4.1 Bush densities and percentage contribution of the woody layer in height classes before harvesting

During the 1980's, utilization of problem bush in the Karstveld Savanna, as a fuel at the TCL mine was tested. Bush densities per hectare, species composition in three different height classes were determined on five different sites. The results of these surveys are presented in Tables 5 and 6.

The main features of these surveys are the high percentage contribution of the problem bush species to the total bush population and the high proportion of small bushes (< 1m) in the total population. Total bush densities varied from 3198 bush per hectare to 9786 bush per hectare, while the percentage contribution of the problem bush species to the total bush population varied between 49% and 73%. The average contribution of the problem bush species is in the order of 69%. Those species in the Karstveld Savanna that are regarded as problem species are *Acacia mellifera, Dichrostachys cinerea* and *Terminalia pruniodes*. The percentage contribution of the problem bush species to the total bush population in three height-classes is 45%, 22% and 33%. The three height classes are bushes smaller than 1 meter in height, bushes between 1 meter and 2 meters high and bushes larger than 2 meters in height.

Another survey conducted in the vicinity of Otavi also emphasises that the major problem in the field remains those bushes smaller than one meter in height. The two problem bush species on the site are *Dichrostachys cinerea* and *Terminalia pruniodes*. *Dichrostachys cinerea* (Sickel Bush) contributed 21% and *Terminalia pruniodes* (Purple-pod terminalia) contributed 53% to the total bush population. The percentage contribution of these two species in five height classes (< 50cm, < 1m, 1m – 2m, 2m – 4m and 4m) is 21%, 26%, 17%, 8% and 2%. Forty-seven percent of these two species is smaller than 1 meter in height. The average diameter of the bush suitable for charcoal production is 33mm (8%), while the average diameter of the rest is 105mm (2%). Bush diameters suitable for charcoal production is between 20mm and 100mm (Tschudene, 1982). Accepting this standard, only eight percent of the total bush population is suitable for charcoal production.

Table 5. Bush densities per hectare of the total bush population and of the problem bushes and the percentage contribution of the problem bush to the total bush population in five sites in the Karstveld Savanna.

Site number	Bush densities per hectare and percentage contribution of problem bush to the total bush population		
	Total population (/ha)	Problem bushes (/ha)	Percentage
1	9786	7164	73
2	5131	3299	64
3	5386	3812	71
4	3198	1578	49
5	9080	6520	72
Average			69%

Table 6. Percentage contribution of problem bushes in three height classes for the five sites in the Karstveld Savanna.

Site number	Percentage contribution and height classes		
	< 1m	1m – 2m	> 2m
1	52	29	19
2	47	27	26
3	65	11	24
4	20	12	68
5	40	29	31
Average	45	22	33

4.2 Bush densities and percentage contribution of the woody layer in height classes after harvesting

The total bush population and the percentage bush harvested for charcoal production on three sites in the Karstveld Savanna is presented in Table 7. The average percentage contribution of the problem bush species in four height classes, the total bush population, after harvesting, for the above mentioned three sites is presented in Table 8. The average diameter of the problem bush species in four height classes is also presented in the latter table.

The rational of the surveys presented in Tables 7 and 8 is the high proportion of the woody layer remaining after harvesting has taken place. The average density of all the bushes for the three sites is 10008 per hectare. Counting the number of stumps that remained it was calculated that only 8% of the 10008 bushes were harvested. Sixty-two percent of the remaining bush was smaller than 1 meter in height, twenty-four percent between 1meter and 2 meters and fifteen percent larger than 2 meters in height. The diameters of eighty-six percent of the remaining bush was less than 20mm in diameter and therefore not suitable for charcoal production.

Table 7. Total bush population and percentage bush harvested for charcoal production in the Karstveld Savanna

Site number	Bush densities per hectare and percentage bush harvested	
	Total bush/ha	Percentage harvested
1	10600	7
2	9100	8
3	10323	7
Average	10008	8

Table 8. Percentage contribution of problem bush species to the bush population after harvested for charcoal production and average diameters in millimetres for four height classes.

Species	Height classes and percentage contribution to total bush population			
	< 1m	1m – 2m	2m – 4m	> 4m
A. mellifera	85	8	6	1
D. cinerea	52	31	13	4
T. pruniodes	48	32	10	10
Average diameters	9mm	13mm	43mm	90mm

4.3 Re-growth of the woody component after harvesting

It is suggested that the wood bio-mass should be harvested sustainably. This implies that the re-growth after the bush has been harvested be harvested again over time. In the Karstveld Savanna surveys were conducted on two sites, to determine the average diameter and the wood bio-mass of the re-growth of the problem bush species. The surveys were done thirteen years after the bush had been harvested. The average diameters of the problem bush and bio-mass per hectare for the two sites is presented in Table 9. The average diameter of the re-growth thirteen years after harvesting was 67mm and 64mm, while the wood bio-mass was respectively, 752 kg/ha and 1984 kg/ha.

Table 9. Average diameters of the problem bush species and bio-mass per hectare for two of the sites.

Site number	Average diameter and wood production in kilograms per hectare	
	Mm	Kg/ha
1	67	752
2	64	1984

4.4 Wood bio-mass

In the past institutions have requested assistance in determining the wood bio-mass of problem bush in the Karstveld Savanna. Van Eck (1977) determined the mass of individual trees (Acacia species) and calculated total mass per hectare from stands of bushes per hectare. Bester and Calitz (1994) determined the total mass per unit area. Bester and Reed (1996) determined the mass by means of regression equations constructed before hand and diameter measurements of bushes. The results are as follow; 10 – 40 tons/ha (Van Eck, 1977); 20-50 tons/ha (Bester and Calitz, 1994); 20-40 tons/ha (Bester & Reed, (1996). Working in the field for an institution producing charcoal, Tschudene (1984) found that the average mass of the woody layer harvested for charcoal was in the order of 20 tons/ha. These results indicate the large variation that occurs in the woody bio-mass

BUSH ENCROACHMENT: WITH REFERENCE TO THE OCCURRENCE, DIE-BACK AND REGENERATION OF ACACIA MELLIFERA

The following results presented are highlights from the bush encroachment programme that was launched during 1998, and are only tendencies that are presented from the surveys conducted from 1998 to 2002. Should all surveys be analysed and interpreted, conclusions might not differ, however, the over all results may not be as drastic as those presented in this paper. It may therefore be easy to do surveys and obtain contradicting results to those presented in this paper. This paper aims to indicate the vast differences even within the same vegetation type and the caution that should be taken when interpreting results based on a limited number of surveys.

1 Methodology

1.1 Site selection

One hundred and seventy-eight sites were randomly selected every 30 kilometres on predetermined roads in the study area. Vegetation types or habitats were not taken into account when selecting the different sites. The sites are fixed points and will be referred to in the text as quantitative survey sites. All of the sites were marked and GPS co-ordinates taken in order to trace each location in future. At each quantitative survey site the woody layer was monitored in a $500m^2$ transect. In order to characterize the woody layer on each quantitative survey site the total number of live standing tree and bush species were recorded in five height classes as well as the dead and the re-growth of the woody layer.

Between each of the quantitative survey sites certain quantitative estimates were done on *A. mellifera* along a section of approximately one kilometre from a vehicle driving at ninety kilometres per hour. GPS co-ordinates were taken to demarcate each section between the quantitative survey sites. These sections of 1 kilometre will be referred to in the text as observation sites. A total of 6000 observation sites were monitored. In order to determine the structure of *A. mellifera* in the study area estimates of the average height were made along each observation site.

In order to determine the magnitude of natural die-back of *A. mellifera* estimates of the percentage dead bush on a scale of 1 to 10 (1 = less than 10% dead and 10 = 100% dead) were made on all observation sites. Estimates of twig or branch dieback and leaf cover of fifty randomly selected *A. mellifera* trees were made on all 178 quantitative survey sites to determine the disease severity on each site.

Four experimental plots were selected during the 1980's to monitor the rate of decline and disease severity of *A. mellifera* and to determine the most reliable criteria for estimating the health status of bushes and die-back severity. The four experimental plots are situated, in the Karstveld Savanna at Uitkomst Research Station; the Thorn Tree Savanna on the farm Thorn Trees; the Hochland Savanna at Neudamm Research Station and an isolated stand of *A. mellifera* in the Camel Thorn Savanna on the farm Jagboom. Disease severity, re-growth and foliage were rated on a scale from 0 – 10. Where respectively, 0 = no twig or branch dieback and defoliation evident; no new growth present; no leaves formed while 10 = 91 – 100%, of the branches dead and defoliated; of the bush covered with new growth; and the bush covered with leaves (Holz & Schreuder, 1989).

To study seed production of black thorn under natural field conditions, pod production estimates on a scale from 1 – 10 were done annually from 1998 to 2002 on thirty-seven sites. Surveys were done on fifty randomly selected *Acacia mellifera* trees along the quantitative survey site.

To determine seedling establishment and seedling survival four sites were selected. Two transects in the Thorn Tree Savanna and two in the Hochland Savanna. Fifty permanent square meter transects over a distance of 200 metres were selected and marked on each of the four sites. Total seedling population in each square metre transect were recorded during the month of May each year.

In order to study re-infestation by woody species and determine the regeneration of *A. mellifera* further surveys were done on sites where bush had previously been controlled manually or chemically. Surveys were done on eight sites in the Thorn Tree Savanna.

THE CURRENT STATUS OF BUSH ENCROACHMENT IN NAMIBIA

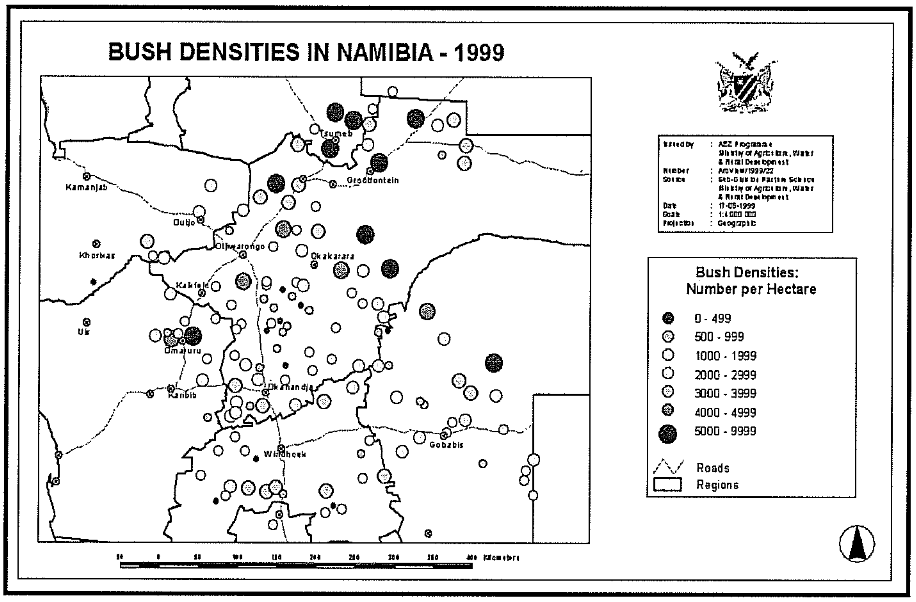
The aims of this study are to:

- Determine bush densities and species composition of the woody layer in stands in Namibia in order to describe the current status of bush encroachment.
- Determine the structure of bushes in stands by grouping them in different height classes.

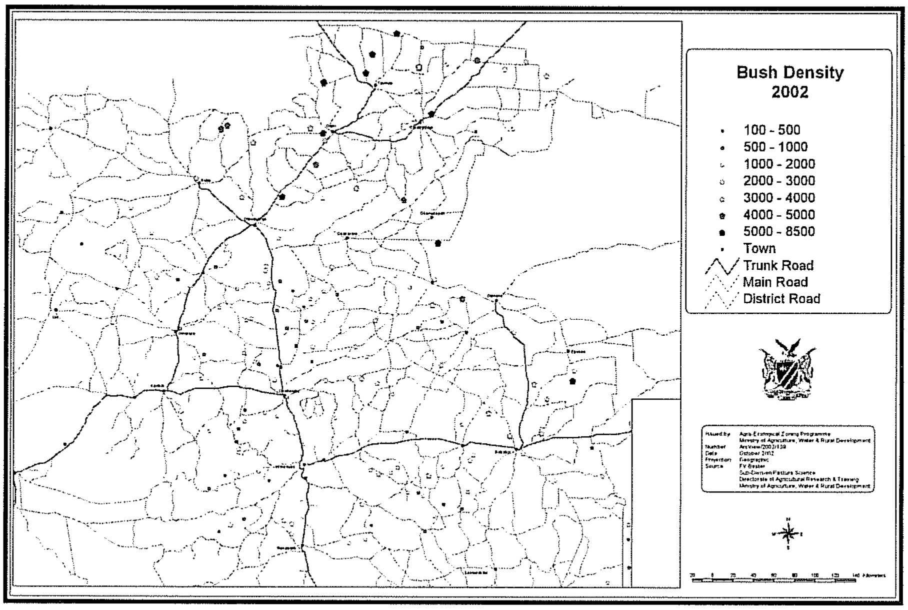
RESULTS

1 Bush Density

From the surveys done on the 178 quantitative survey sites a bush density map was compiled and is presented in Maps 1 and 2.



Map 1: Bush densities for the year 1999



Map 2: Bush densities for the year 2002

2 Structure

Kershaw (1964) distinguishes three components of vegetation structure; (a) vertical structure (i.e., stratification into layers); (b) horizontal structure (spatial distribution of species population and individuals), and (c) quantitative structure (i.e., abundance of each species in the community) (Dombois & Ellenberg, 1974). Dombois and Ellenberg (1974) refer to the trend, of numbers of individuals in size classes of the tree species in the stand, as the stand structure. In this paper quantitative structure will be referred to as species composition and the grouping into height classes as stand structure.

3 Structure of Bush Mapped

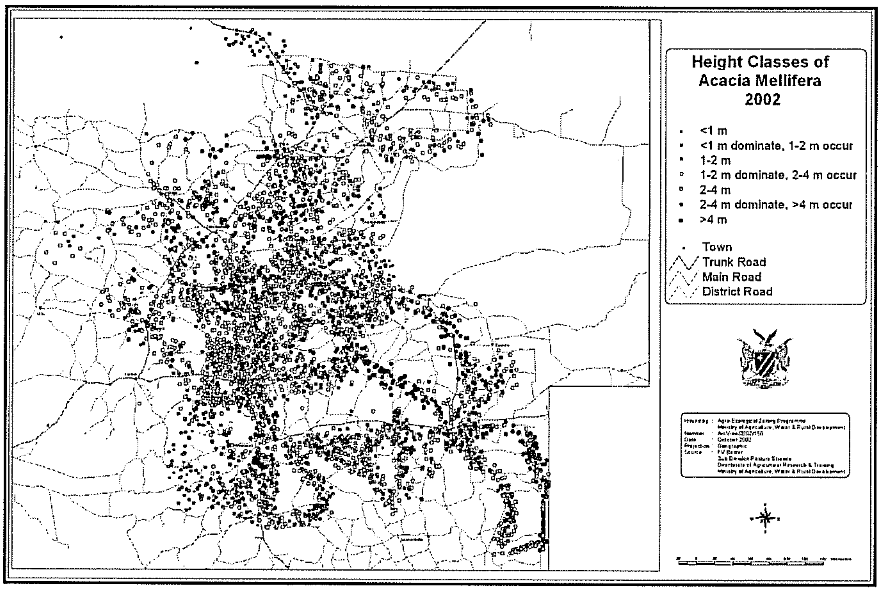
Map 3 is the estimated height classes of *Acacia mellifera* between the quantitative survey sites and Map 4 a simplified version. Height classes presented in Map 1 are;

- bushes smaller than one meter in height are dominant,
- bushes one meter in height are dominant while bushes between one meter and two meters in height also do occur,
- bushes between one meter and two meters in height are dominant while bushes between two meters and four meters in height also do occur,
- bushes between two meter and four meters in height are dominant,
- bushes between two meters and four meters in height are dominant while bushes larger than four meters high also do occur,
- bushes larger than four meters in height.

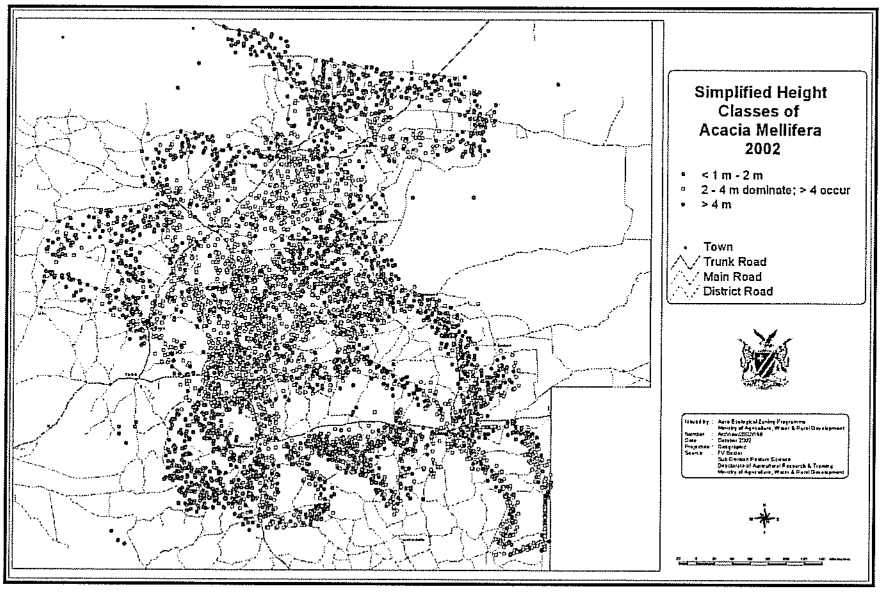
This map was simplified by grouping the above mentioned height classes. The simplified height classes are:

- bushes smaller than one meter in height and bushes between one meters and two meters in height,
- bushes between two meters to four meters in height are dominant while bushes larger than four meters in height also do occur,
- bushes larger than four meters in height.

From the results presented in Map 4, the height class bushes between 2 meters and 4 meters are dominant while bushes larger than 4 meters occur coincides with the area (Thorn Tree Savanna) where bush densities from 500 bush per hectare to 2000 bush per hectare occur (Maps 1 and 2). This is the area where the intensity of the natural die-back of *Acacia mellifera* is the highest. This area is from Okahandja to Otjiwarongo, Okakarara, okandjatu, downwards to Hochveld and Okahandja. The group larger than four meters is dispersed through out the bush infested area, occurring as single standing trees in the east, that is, from Hochfeld towards Gobabis.



Map 3: Estimated height classes (Structure) of *Acacia mellifera* between the quantitative survey sites



Map 4: Estimated height classes of *Acacia mellifera* between the quantitative survey sites (Simplified map)

4 Variation in Species Composition

In the Mopane Savanna surveys were conducted on four sites within a radius of 500 metres. The results of the four problem bush species are presented in Tables 10 to 14. Bush densities for the sites 57, 57a, 58 and 58a is respectively 2960, 3180, 4220 and 3360 bush per hectare. The percentage contribution of *Acacia mellifera, Colophospermum mopane, Dichrostachys cinerea* and *Terminalia pruniodes* to the total bush population of each of the four sites is presented in Tables 10 to 13. The average of all four sites is presented in Table 14. Despite the close vicinity of the four sites a large variation occurs in the contribution of the four problem bush species to the total bush population in the four sites. *Acacia mellifera* (36.49%) is abundant in site 57 and sparse in the other three sites. *Colophospermum mopane* varies between 7.43%, 42.12%, 23.92% and 75.90%. *Terminalia pruniodes* is abundant in all the sites and comprises 28.26%, 22.01%, 34.93% and 12.65% of the total bush population. This implies, one site consisting of a large number of small plants and another site with less smaller plants and more big trees. Bush density, species composition and the structure are of utmost importance when bush control is considered. Removal of the larger trees leaving those smaller than one metre high untouched can only aggravate the problem, emphasizing the need for after-care.

Table 10. Percentage contribution of *Acacia mellifera* to the total bush population in five height-classes on the four sites.

Site no.	Height classes and percentage contribution					
	< 50 cm	< 1m	1m – 2m	2m – 4m	> 4m	Total
57	8.78	10.81	12.16	4.73	-	36.49
57a	0.63	4.40	-	0.63	-	5.66
58	-	-	0.48	-	-	0.48
58a	-	-	-	-	-	-

Table 11. Percentage contribution of *Colophospermum mopane* to the total bush population in five height classes on the four sites.

Site no.	Height classes and percentage contribution					
	< 50 cm	< 1m	1m – 2m	2m – 4m	> 4m	Total
57	-	-	2.03	2.03	3.38	7.43
57a	15.72	8.18	5.66	10.69	1.89	42.12
58	5.74	7.18	8.13	2.87	-	23.92

58a	34.34	18.67	20.48	2.41	-	75.90

Table 12. Percentage contribution of *Dichrostachys cinerea* to the total bush population in five height classes on the four sites.

Site no.	Height classes and percentage contribution					
	< 50 cm	< 1m	1m – 2m	2m – 4m	> 4m	Total
57	0.68	-	3.38	-	-	4.05
57a	5.03	1.26	0.63	1.26	-	8.18
58	0.96	3.35	6.22	2.39	-	12.92
58a	0.60	0.60	3.01	0.60	-	4.82

Table 13. Percentage contribution of *Terminalia pruniodes* to the total bush population in five height classes on the four sites.

Site no.	Height classes and percentage contribution					
	< 50 cm	< 1m	1m – 2m	2m – 4m	> 4m	Total
57	4.35	8.70	10.14	5.07	-	28.26
57a	5.66	5.03	6.92	4.40	-	22.01
58	1.91	10.53	2.10	1.91	0.48	34.93
58a	0.60	0.60	11.45	-	-	12.65

Table 14. Average percentage contribution of the four problem bush species to the total bush population in five height classes for all four sites.

Species	Height classes and percentage contribution					
	< 50 cm	< 1m	1m – 2m	2m – 4m	> 4m	Total
A. mellifera	2.35	3.80	3.16	1.34	-	10.66
D. cinerea	1.82	1.30	3.31	1.06	-	7.49
C. mopane	13.95	8.51	9.08	4.57	1.32	37.35
T. pruniodes	3.06	6.07	11.98	2.76	0.12	23.98
Total	21.18	19.68	27.53	9.73	1.44	79.48

A further example of the large variations in the contribution of bush species to the total bush population are the results of surveys done in the Karstveld Savanna and are presented in Tables 15, 16 and 17. Bush densities for the three sites are respectively 7800, 8100 and 6900 bush per hectare. The two major problem bush species in the Karstveld Savanna are *Dichrostachys cinerea* and *Terminalia pruniodes. Dichrostachys cinerea* comprised 60.75%, 5.89% and 4.58% of the total bush population in the three sites while *Terminalia pruniodes* contributed 53.78% and 12.32% in two of the sites, not occurring in the second site. *Acacia mellifera* contributed only 3.74%, 5.88% and 10.32% to the total bush population in the three sites. The three problem bush species contributed only 27.22% (Table. 17) to the total bush population of the third site. However, the under shrub consisting of less palatable bush species is in the order of 55.87%. These species also compete for soil moisture resulting in low grass production and a decline in grazing capacity. The results presented in Tables 10 to 17 emphasizes the need for surveys before hand to get an idea of what is going on in the field and to decide upon methods of control as well as after-care.

Table 15. Bush densities per hectare of the problem bush species and percentage contribution to the total bush population in the Karstveld Savanna.

Species	Height classes and percentage contribution					
	< 50 cm	< 1m	1m – 2m	2m – 4m	> 4m	Percentage
A. mellifera	-	400	-	-	-	3.74
D. cinerea	-	3500	1700	300	1000	60.75
T. pruniodes	-	-	-	-	-	-
Problem bush	-	3900	1700	300	1000	64.49

Table 16. Bush densities per hectare of the problem bush species and percentage contribution to the total bush population in the Karstveld Savanna.

Species.	Height classes and percentage contribution					
	< 50 cm	< 1m	1m – 2m	2m – 4m	> 4m	Percentage
A. mellifera	-	500	100	100	-	5.88
D. cinerea	-	-	300	400	-	5.89
T. pruniodes	-	2200	3100	1000	100	53.78
Problem bush	-	2700	3500	1500	100	65.55

Table 17. Percentage contribution of the problem bush species and less palatable bush species to the total bush population.

Species	Percentage contribution
Acacia mellifera	10.32
Dichrostachys cinerea	4.58
Terminalia pruniodes	12.32
Total problem bush species	27.22
Less palatable bush species	55.87

5 Variation in Stand Structure and Factors Influencing Stand Structure

Bush density is mainly dependent of rainfall and soil type. The stand structure of the bush is also dependent on these two factors, however, other factors that may influence the stand structure of bushes are; the occurrence of frost, veld fires, mortality in combination with the re-growth of the bush as well as seedling establishment and seedling survival.

5.1 Rainfall and soil type

The surveys conducted on the following two sites indicates the variation in stand structure (height classes). The first site is situated between the 300mm and 350mm rainfall isohyets and on the Central Plateau with flat plains on metamorphic rocks (Agro-Ecological Zone). The total bush density of this site is 3180 bush per hectare of which *Acacia mellifera* contributes 84,91 percent to the total population. The second site is situated between the 400mm and 450mm rainfall isohyets also on the central Plateau with strongly dissected inselberg plains. The total bush density of this site is 380 bush per hectare of which *Acacia mellifera* contributes 26,32 percent to the total population. The percentage contribution of *Acacia mellifera* in five height classes (stand structure) for these two sites is presented in Table 18.

Table 18. Bush densities per hectare of *Acacia mellifera* and percentage contribution to the total bush population.

Bush density	Height classes and percentage contribution					
	< 50 cm	< 1m	1m – 2m	2m – 4m	> 4m	Percentage
3180	17.61	57.23	10.06	-	-	84.91
380	5.26	-	-	10.53	1.53	26.32

The factors that contribute to the difference in stand structure of these two sites is rainfall and soil type. The variation in the bush density is mainly ascribed to the natural die-back of *Acacia mellifera.* The second site is situated in the area where the natural die-back of *Acacia mellifera* is predominant. The smaller (stunted) growth form of the bushes in the first site is because of a relatively shallow soil.

5.2 Establishment of seedlings

To illustrate the influence of establishment of young plants on the stand structure the results of an individual site is presented in Tables 19, 20 and 21. The total bush density and percentage contribution in five height classes for the years 1998 and 2002 is presented in Table 19. The total bush population and percentage contribution of individual species in five height classes for the year 2002 is presented in Table 20.

Table 19. Total bush density and percentage contribution in the five different height classes.

Years	Total bush density in height classes and percentage contribution					
	< 50 cm	< 1m	1m – 2m	2m – 4m	> 4m	Total
1998	4050	300	1500	50	-	5900 /ha
Percentage	68.64	5.08	25.42	0.85	-	100%
2002	12320	4380	660	460	200	18020 /ha
Percentage	68.37	24.31	366	2.55	1.11	100%

Table 20. Bush density per hectare and percentage contribution of individual bush species to the total bush population for the year 2002.

Species.	Height classes and percentage contribution					
	< 50 cm	< 1m	1m – 2m	2m – 4m	> 4m	Percentage
A. mellifera	540	120	160	40	20	4.88
D. cinerea	-	-	60	20	-	0.44
T.sericea	480	40	-	-	60	3.22
Problem bush	1020	160	220	60	80	8.55
L. nelsii	7160	100	20	-	-	40.40
Grewia spp.	3980	3980	60	300	100	46.73
Total	12320	4380	660	460	200	18020

The results presented in Tables 19 and 20 show a drastic increase in bush density especially in the height class smaller than 50cm. The bush density in this height class increased from 4050 in 1999 to 12320 in the year 2002.

5.3 Die-back in combination with re-growth

The results presented in Tables 21 and 22 illustrate the change in stand structure of *Dichrostachys cinerea* due to die-back in combination with re-growth from below. The percentage top-kill and percentage re-growth is presented in Table 21, while bush densities of the old population and new population in five height classes is presented in Table 22. The old population is live standing plus the dead bush and the new population is the live standing plus the re-growth.

From the results presented in Tables 21 and 22 it is clear that there was a drastic die-back of *Dichrostachys cinerea* in the height class 1m – 2m. Re-growth occurred in the height classes smaller than fifty centimetres and smaller than one meter. Veld fire did not occur on this site so the die-back could possibly be due to low temperature or low rainfall.

Table 21. Percentage top-kill of *Dichrostachys cinerea (*natural die-back*)* and re-growth in five height classes.

	Percentage top-kill and re-growth					
	< 50 cm	< 1m	1m – 2m	2m – 4m	> 4m	Total
Top-kill	2.38	7.14	90.48	-	-	100
Re-growth	14.71	35.29	50.00	-	-	100

Table 22. Bush density per hectare of *Dichrostachys cinerea* in five height classes of the old bush population and the new bush population.

	Height classes and percentage contribution					
	< 50 cm	< 1m	1m – 2m	2m – 4m	> 4m	Total density/ha
Old population	40	80	1080	-	-	1200
New population	120	260	660	-	-	1040

5.4 Die-back and re-growth due to veld fire

The die-back and re-growth of *Dichrostachys cinerea* and *Acacia mellifera* on the same site in the Okahandja district is presented in Tables 23 and 24. The fire occurred during 2001. Bush densities of the old and the new population of these two species in five height classes are presented in Tables 23 and 24. These surveys were done during 2002.

Dichrostachys cinerea shows an increase in density in the lower height classes and a decline in density in the higher height classes, while *Acacia mellifera* shows a drastic die-back in the higher height classes. Acacia mellifera on this site was infested with the fungus *Phoma glomerata*

Table 23. Bush density per hectare of *Dichrostachys cinerea* in five height classes of the old bush population and the new bush population.

	Height classes and percentage contribution					
	< 50 cm	< 1m	1m – 2m	2m – 4m	> 4m	Total density/ha
Old population	40	160	300	600	-	1100
New population	260	400	40	360	-	1060

Table 24. Bush density per hectare of *Acacia mellifera* in five height classes of the old bush population and the new bush population.

	Height classes and percentage contribution					
	< 50 cm	< 1m	1m – 2m	2m – 4m	> 4m	Total density/ha
Old population	-	60	80	40	20	200
New population	40	100	-	-	-	140

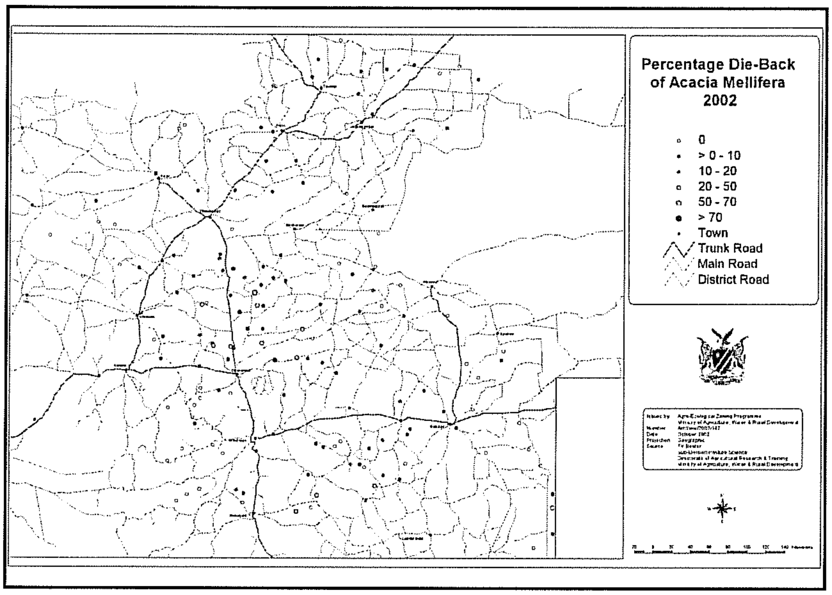
MORTALITY OF BUSHES OF VARIOUS SPECIES IN ENCROACHED STANDS

During the late 1970's it was observed that *A. mellifera* (Black Thorn) was dying back on a large scale. The causes of the die-back of *A. mellifera* will be discussed in more detail below. However, it was also observed that other woody species were also dying back. This study was therefore undertaken to determine the mortality of the different woody species in stands in various localities and locations in the bush infested area of Namibia.

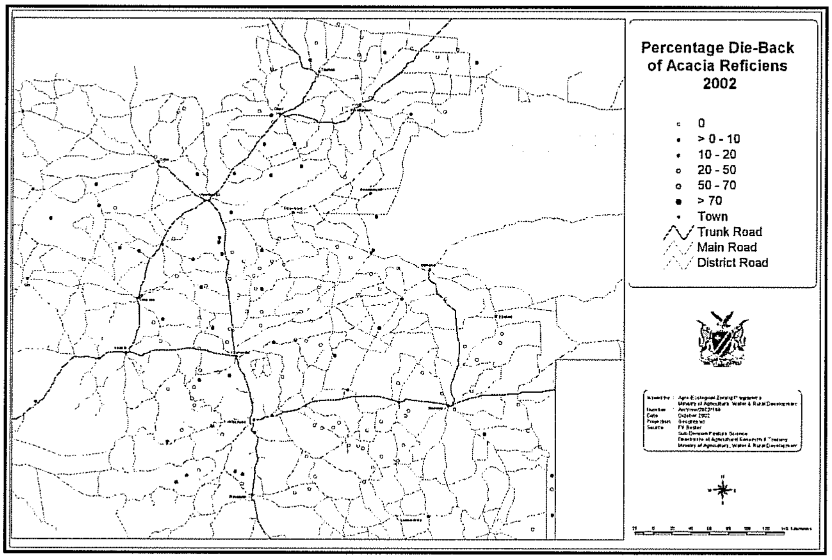
1 Mortality of Individual Bush Species

The percentage die-back of individual species, Acacia mellifera (Black thorn), Acacia reficiens (False-umbrella thorn), Colophospermum mopane (Mopane), Dichrostachys cinerea (Sickle bush), Terminalia pruniodes (Purple-pod Terminalia), Terminalia sericea (Silver Terminalia) are presented in maps 5 to 10. The percentage mortality of the problem bushes and all bushes is presented in Maps 11 and 12.

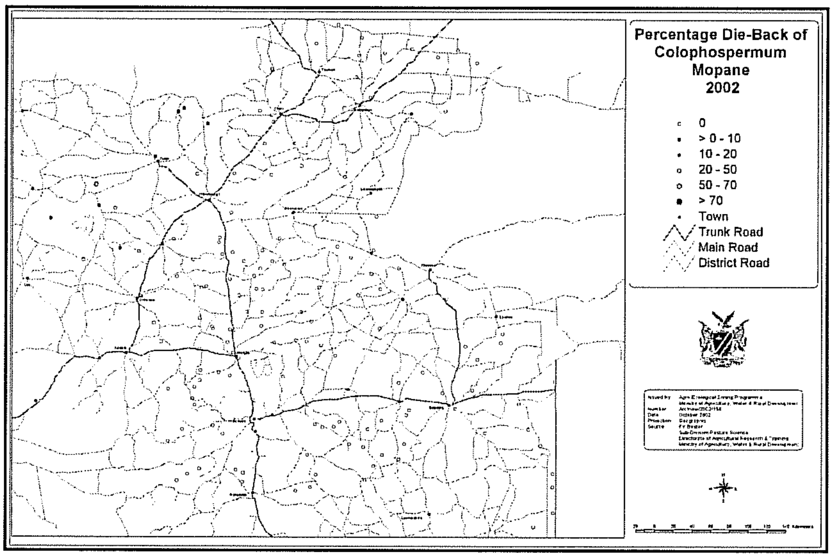
Acacia mellifera has the highest die-back rate also occurring where the lowest bush densities were recorded. The highest rate of die-back of the problem bush species and all bushes (Maps 11 and 12) coincide with the results of Map 1 and 2. This is because of the high mortality rate of Acacia mellifera. For all the other species the average mortality rate is in the order of ten percent. A feature from these maps is the wide distribution of Acacia reficiens and Dichrostachys cinerea in the bush infested area.



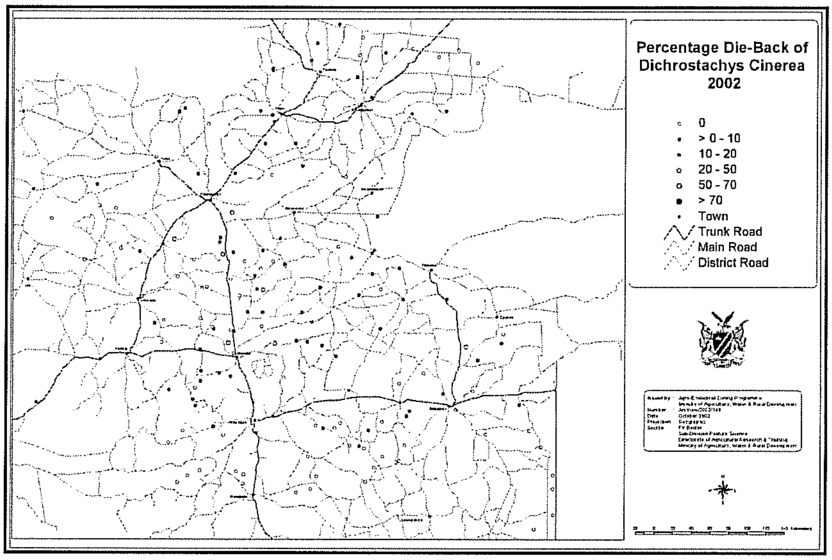
Map 5: Percentage die-back of *Acacia mellifera*



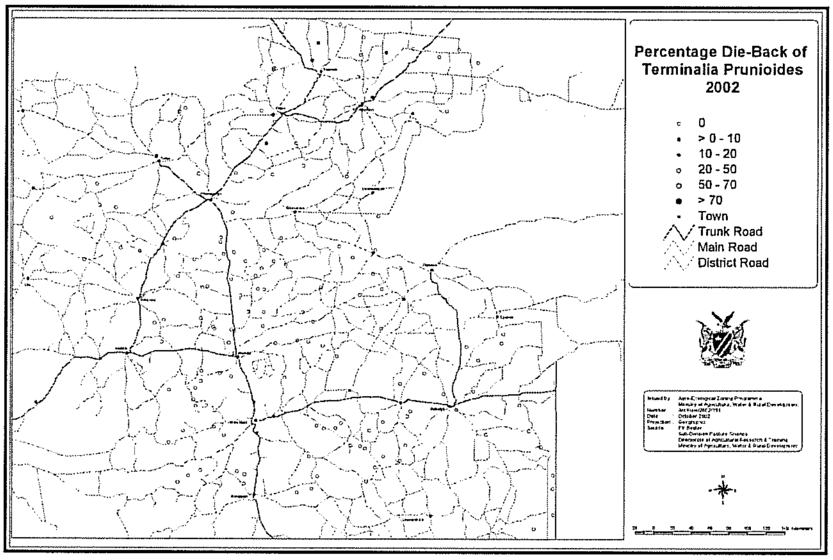
Map 6: Percentage die-back of *Acacia reficiens*



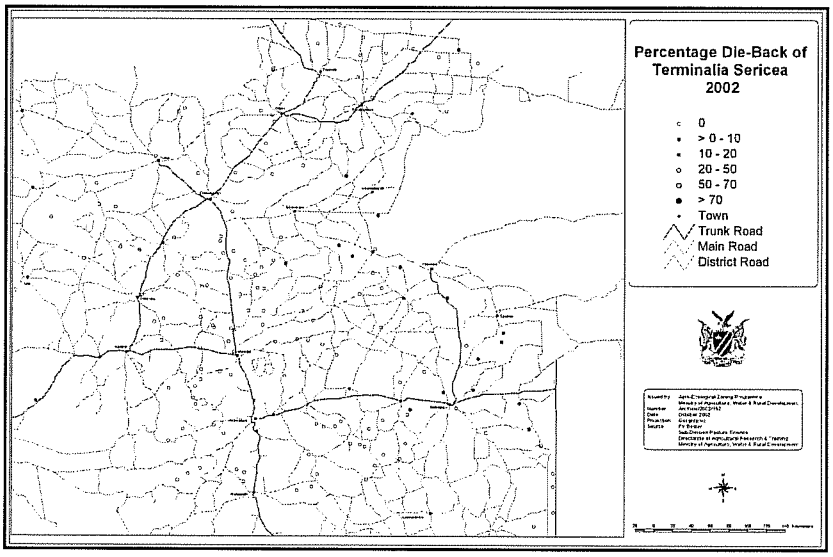
Map 7: Percentage die-back of *Colophospermum mopane*



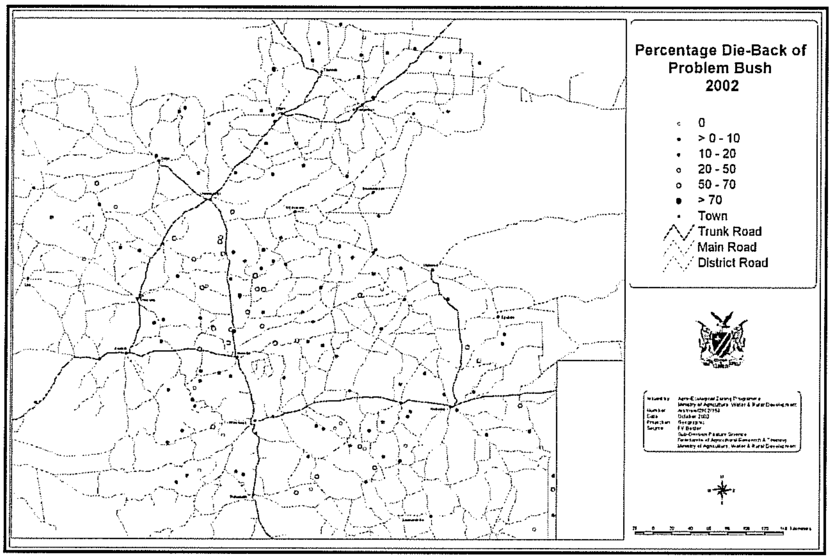
Map 8: Percentage die-back of *Dichrostachys cinerea*



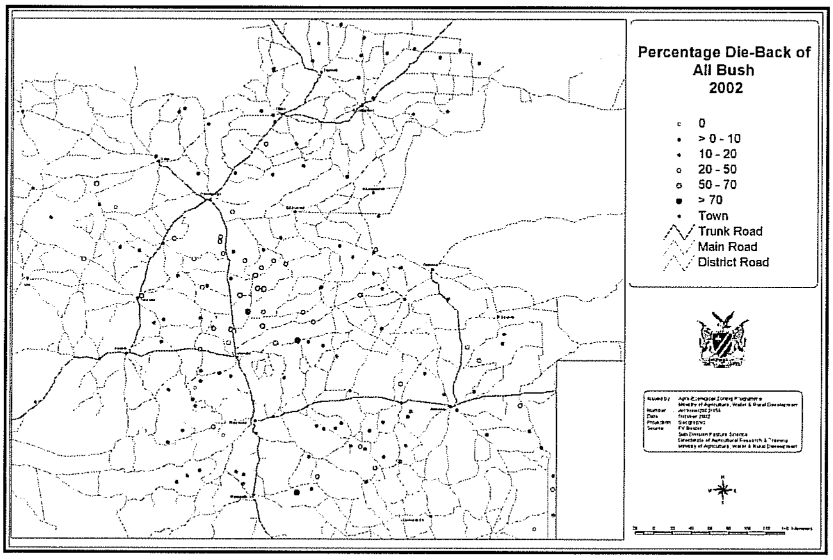
Map 9: Percentage die-back of *Terminalia pruniodes*



Map 10: Percentage die-back of *Terminalia sericea*



Map 11: Percentage die-back of the problem bush species



Map 12: Percentage die-back of all the bushes species

2 Mortality of Bushes on Sites

The results presented in Tables 25 to 31 shows the mortality rate of the total bush population, change in stand structure and change in species composition due to the mortality of certain bush species. Tables 25 to 29 are results on a site in the Khomas Hochland and the results in Tables 30 and 31 a site in the vicinity of Dordabis. The bush densities of the total bush population and the percentage mortality of the bush on the first site are presented in Table 25. The bush density and percentage mortality of *Acacia reficiens* (False umbrella thorn) on the same site is presented in Table 26 and the percentage contribution of *Acacia reficiens* for the years 1998 and 2002 is presented in Table 27. The percentage contribution of *Acacia reficiens* and *Catophractes alexandrii* to the total bush population and the bush densities of these two species for the years 1998 and 2002 is presented in Tables 28 and 29.

The results presented in Tables 25 to 29 shows a die-back of *Acacia reficiens,* an increase in density from the lower height classes to a higher height class (change in structure) and an increase in the population of *Catophractes alexandrii. Acacia reficiens* grew rapidly during the period of the two surveys which could be ascribed to favourable rainfall. *Catophractes alexandrii* increased in density due to the establishment of new plants.

Table 25. Bush density of the total bush population and percentage mortality in the Hochland Savanna for the years 1998 and 2002.

Year	Bush density per hectare	Percentage mortality
1998		
Old population	3280	
New population	2550	22.82
2002		
Old population	2500	
New population	2080	16.80

Percentage mortality of total bush population from 1998 to 2002 = 18.43%

Table 26. Bush density and percentage mortality of *Acacia reficiens* in the Hochland Savanna.

Year	Bush density per hectare and percentage mortality	
	Bush density	Percentage mortality
1998	1950	38.47
2002	1340	23.86

Live standing + dead and live standing no re-growth

Table 27. Percentage contribution of live standing *Acacia reficiens* in five height classes for the years 1998 and 2002.

Years	Height classes and percentage contribution				
	< 50 cm	< 1m	1m - 2m	2m – 4m	> 4m
1998	45.83	37.50	16.67	-	-
2002	16.42	40.30	38.81	4.48	-

Table 28. Percentage contribution of *Acacia reficiens and Catophractes alexandrii* to the total bush population in the Hochland Savanna.

Species	Percentage contribution and years	
	1998	2002
Acacia reficiens	66.67	64.42
Catophractes alexandrii	16.67	25.96

Table 29. Bush density per hectare of *Catophractes alexandrii* in the Hochland Savanna for the years 1998 and 2002.

Year	Bush density per hectare and height classes					
	< 50 cm	< 1m	1m - 2m	2m – 4m	> 4m	Total
1998	-	250	50	-	-	300
2002	100	120	320	-	-	540

The percentage contribution of *Acacia mellifera* and *Catophractes alexandrii* to the total bush population is respectively presented in Tables 30 and 31.

From the results presented in Tables 30 and 31 it is clear that there was a drastic die-back of *Acacia mellifera* and an increase in the density of *Catophractes alexandrii* from the lower height classes to higher height classes. The die-back of *Acacia mellifera* was mainly due to the fungus *Phoma glomerata.*

Table 30. Percentage contribution of Acacia mellifera to the total bush population in five height classes for the years 1998 and 2002.

Year	Bush density per hectare and height classes					
	< 50 cm	< 1m	1m - 2m	2m – 4m	> 4m	Total
1998	13.29	4.05	1.16	0.85	-	19.08
2002	-	1.04	-	-	-	1.04

Table 31. Percentage contribution of *Catophractes alexandrii* to the total bush population in five height classes for the years 1998 and 2002.

Year	Bush density per hectare and height classes					
	< 50 cm	< 1m	1m - 2m	2m – 4m	> 4m	Total
1998	5.20	26.59	30.64	-	-	62.43
2002	1.04	11.46	62.50	1.04	-	76.04

HEALTH STATUS OF BUSHES IN BLACK THORN STANDS

During the late seventies die-back of *Acacia mellifera* was observed by the Extension Officer M.L. Fourie on the farm Otjikuoko in the Okahandja district. A team from the University of the Orange Free State, Professors D.P.J. Opperman and Power, F. and J.P. Van Niekerk from Glen Agricultural College visited the country. They concluded that the die-back of *Acacia mellifera* was due to low rainfall, however, further research should be done regarding the die-back. Later a team from the University of Stellenbosch, Dr. G. Holz, Professor K. Smit and Mr. L. Lambrecht visited the country. They concluded that there was a possibility of a pathogenetic fungus that caused the dieback of *Acacia mellifera.* In collaboration with the University of Stellenbosch a project was then launched during the early 1980's. Publications from the Department plant Pathology, University of Stellenbosch, from greenhouse studies as well as studies in the field that followed are:

Dieback of Blackthorn (*Acacia mellifera* Subsp. *detinens*) in South West Africa.

Pathogenicity of *Phoma glomerata*, *P. cava*, *P. eupyrena* and *Cytospora chrysosperma* on Blackthorn (*Acacia mellifera* Subsp. *detinens*).

Phoma glomerata, *P. eupyrena* and *P. cava* on seeds of Blackthorn (*Acacia mellifera* Subsp. *detinens*) and their pathogenicity on Blackthorn seedlings.

Soil moisture stress and infection of (*Acacia mellifera* Subsp. *detinens*) by fungi associated with Blackthorn die-back.

Blackthorn die-back disease development in the Northern regions of South West Africa. (*Acacia mellifera* Subsp. *detinens*) in South West Africa.

Phoma glomerata endophytic on Blackthorn (*Acacia mellifera* Subsp. *detinens*) in Namibia.

Observations on disease development made during 1985 – 1989 revealed features typical of an infestation biotic disease. The first disease symptoms, which are usually more prevalent at the end of the period of active growth (March-April), are a yellowing of leaves on individual twigs or branches, defoliation, and die-back of defoliated shoots. The most conspicuous symptoms is an internal green-yellow to black-green discolouration and decay of wood at the base of the trunk and the upper taproot. Isolation studies associated the disease with a fungal complex consisting of *Phoma glomerata, P. cava, P. eupyrena and Cytospora chrysosperma (Agricola).* A subsequent study showed that *P. glomerata* caused leaf chlorosis and restricted defoliation on glasshouse-inoculated seedlings, *P. cava* induced wilting and chlorosis on seedlings and toothpick-inoculated potted plants. The fungi caused significant wood discolouration in field inoculated black thorn bushes. Wood discolouration was most extensive on bushes in areas with normal precipitation. Later studies described the disease primarily to *P. glomerata*.

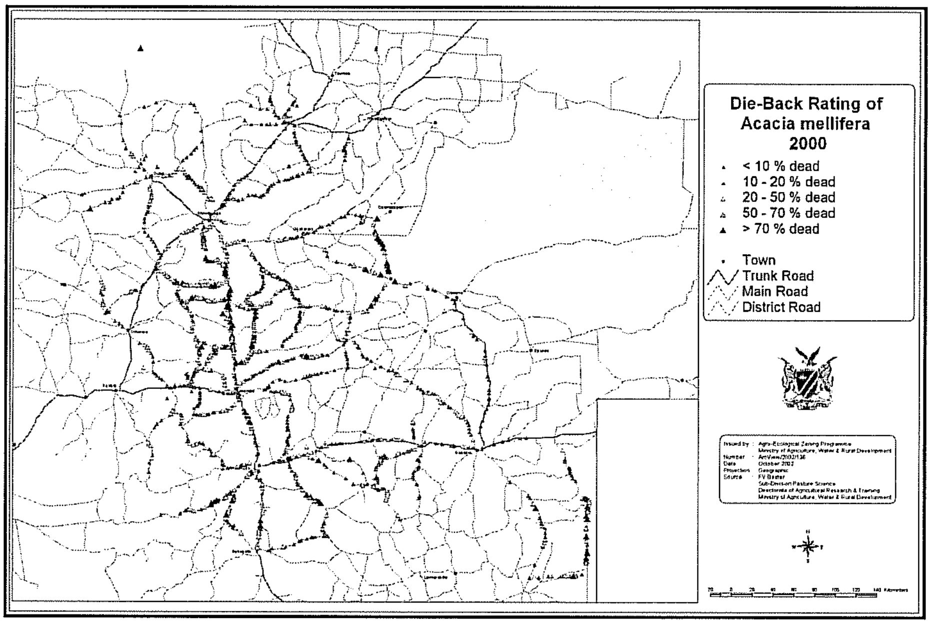
The objective of this study is to:

- To determine the rate of die-back in specific sites.
- To find the most reliable criteria for estimating the health status of bushes die-back severity.
- To describe the health status of different black thorn stands.

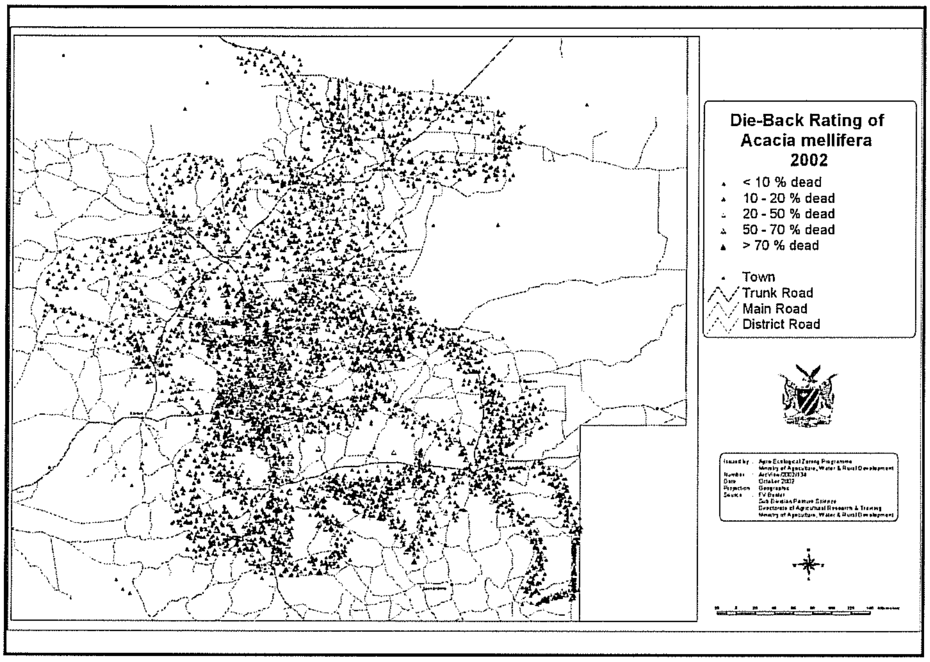
The first two objectives of the project are undertaken in collaboration with the University of Stellenbosch. The project was initiated during the 1980's. The results presented are those results obtained through two M.Sc. studies undertaken at the University of Stellenbosch promoted by Professor Gustave Holz. The project consisted of greenhouse studies and studies in the field. Initially four sites were selected; Uitkomst and Neudamm Research stations and two farms, one site in the Camel Thorn Savanna and the other site in the Thorn Tree Savanna. The site at Uitkomst Research Station burnt down and the farm in the Camel Thorn Savanna changed hand and markers on the trees were removed rendering both sites unavailing.

1 Health status of different black thorn stands.

In order to describe the health status of Blackthorn stands, estimates of the percentage dead *Acacia mellifera* bushes on a scale from 1 to 10 (1 = less than 10% dead and 10 = 100% dead) were made on the 6000 observation sites. These results are presented in Maps 13 and 14 for the years 2000 and 2002.



Map 13: Percentage die-back estimates of *Acacia mellifera* for the year 2000 (observation sites)



Map 14: Percentage die-back estimates of *Acacia mellifera* for the year 2002 (observation sites)

REGENERATION OF BUSHES IN BLACK THORN STANDS CLEARED BY NATURAL DIE-BACK OR OTHER MEANS

It can be expected that stands cleared by different means will be re-infested by either black thorn or other woody species. For this to occur a few factors should synchronize in cleared stands. Firstly, there should be a seed bank available in soils in the cleared area. Secondly, there should be ample seed production by bushes remaining in the stand or from the surrounding area. Thirdly, weather condition conducive to seed production germination and seedling establishment and survival should occur in stands.

During the period 1989-1996, seed production and seed health in natural blackthorn (*Acacia mellifera* ssp. detinens) stands in northern Namibia and the North Western Cape province, affected or unaffected by die-back (*Phoma glomerata),* were investigated. Seeds were rarely produced by blackthorn in Namibia. The fungus occurred on seeds from all the regions and appears to be ubiquitous on blackthorn. However, seed from areas with a high disease severity usually yielded more *P. glomerata* than those seeds from healthy regions. Seeds from diseased stands, futher more invariably yielded higher number of diseased germlings (first stages of seed germination) than those seeds from stands unaffected by die-back. Germlings produced by seed obtained from the North Western Cape province, also remained free of disease in spite of moderate incidences of *P. glomerata* infection. This finding clearly indicates that different forms of the fungus occur on blackthorn, and suggests that lesions on the hypocotyl and radicle of germlings are formed by virulent bio-types. It also suggests that areas in natural stands opened by die-back should not be invaded by new plants in the near future.

The aim of this study was therefore to:

- Study seed production by black thorn under natural field conditions (pod production),
- To determine the health of seed produced in stands with different disease
- To monitor seedling growth and survival in black thorn stands,
- To study re-infestation by woody species in stands cleared by various means.

The percentage normal and abnormal seeds as well as the germination rate of these seeds is presented in Table 32. Twenty-eight percent of seeds collected was normal while seventy-two percent are abnormal. Fifty-one percent of the normal seeds germinated while only twelve percent of the abnormal seeds germinated.

Table 32. Percentage normal and abnormal *A. mellifera* seeds from stands infested with the fungus *Phoma glomerata* and percentage germination.

Percentage germination	
Percentage normal	Percentage abnormal
28%	72%
51%	12%

DISCUSSION

A prolonged spell of low rainfall has an overriding influence on dry-material grass production irrespective of bush density. It can therefore be expected that, should rainfall decrease over a period of time, there will be a decrease in the grass production, even to such an extent that there might not be a large difference in production between controlled areas and uncontrolled areas. As precipitation decreased from 536mm (1977) to 182mm (1981), grass production decreased with 80% in a controlled area (67% bush mortality) and by 76% in an uncontrolled area. The difference in the percentage grass production between the controlled area and uncontrolled area was in the order of 17 percent. However, should rainfall increase, the grass production will also increase. The total precipitation for the 1982 rainy season was 285mm, resulting in an increase in grass production of 55% in the controlled area and 45% in the uncontrolled area. The percentage difference in grass production between the controlled area and uncontrolled area was in the order of 31 percent. Compared to the 30% increase in production after the initial control of the bush, it can be concluded that the grass production was back to normal. The fact that there was a difference of 60% in the increase in grass production between controlled and uncontrolled areas, it can be concluded that the rate of recovery is influenced by bush density. The distribution of the rainfall during a rainy season can influence the grass production dramatically. The total precipitation for the 1981 and 1998 rainy seasons was 182mm and 180mm while the number of rainy days was respectively, 6 days and 34 days.

From the results presented above it can be concluded that bush control is feasible. An increase in grass production of 30% can be achieved even when the rate of success (mortality rate) is as low as 67 percent. However, as the degree of mortality decreases the percentage increase in grass production also will decline. Mortality rates of 55% and 45% resulted in an increase in grass production of only 10% and 13 percent. The reason for this is the competition for soil moisture between the grass layer and the number of bushes present. Other methods of bush control to be considered are to utilize the bush either biologically by using the Boer Goat or harvesting for charcoal production. From the Omatjenne goat trial and the case study in the Karstveld with goats it is clear that the goats did not utilize black thorn and is unlikely that one could control Black thorn with goats. However, the goats did utilize Sickle bush heavily as well as the more palatable fodder bush. The correct stocking rate and sound range management is therefore of utmost importance. If not, the range can be damaged severely when utilizing the range with goats. Surveys in the Karstveld Savanna during the 1980's showed clearly that only eight percent of the total bush population is harvested for charcoal production. After harvesting, sixty-two percent of the bush remaining was smaller than one meter in height. Twenty-four percent between 1m – 2m high and fifteen percent larger than 2m in height. The average diameters of the bush in four height classes, < 1m, 1m – 2m, 2m – 4m and > 4m was respectively, 9mm, 13mm, 43mm and 90mm.

Bush encroachment occurs in various degrees of densities and species composition north of 22^{o} latitude. These features are mainly influenced by rainfall and soil type. Total bush densities above 6000 to as much as 10000 bush per hectare occur mainly in the Karstveld Savanna (Giess,1970) in the vicinity of Tsumeb in the higher rainfall area. However, bush densities of 3000 bushes per hectare and more also occur as far south as Rehoboth and Dordabis. For the southern region of the bush-infested area such densities can be regarded as very high. The percentage contribution of the problem bush species to the total bush population varies from site to site, however, remains high through out the bush infested area. Surveys done during the early 1980's in the Karstveld Savanna show that the problem bush species contribute as much as 69% to the total bush population. These bush species are *Acacia mellifera, Dichrostachys cinerea* and *Terminalia pruniodes.* Recent surveys show the same tendency. The same three above-mentioned species contributed 64.495 and 65.55% to the total bush population on two different sites. Towards the south in the vicinity of Witvlei, in a stand of 3180 bush per hectare, *Acacia mellifera* contributed 84.91% to the total bush population. To the west in the Hochland Savanna, *Acacia reficiens* contributed 64.42% to a total bush population of 2080 bush per hectare.

The stand structure (height classes) also varies considerably throughout the bush-infested area. Soil type and rainfall are the major factors influencing stand structure. An example is the site in the vicinity of Witvlei on a shallow soil where 74.84% of the 84.91% *Acacia mellifera* population is smaller than one meter in height. A major feature is the natural die-back of *Acacia mellifera* in the Thorn Tree Savanna (Giess, 1970). The stand structure in the Thorn Tree Savanna averages two meters in height, however, on some sites where *Acacia mellifera* dominates the majority of the bushes are smaller than one meter in height. This is attributed to the fact that the larger trees have already died back. On other sites due to virtually no regeneration of *Acacia mellifera* the younger generation only contributed 5.26% to the population. Along with the natural die-back other factors such as fire and low rainfall result in a change in stand structure of *Dichrostachys cinerea*. On a site where no fire had occurred *Dichrostachys cinerea* bushes larger than one meter declined by 55% while the percentage re-growth was in the order of 50%. Where a veld fire occurred the population of *Dichrostachys cinerea* bushes smaller than one meter increased in the form of re-growth by 70.00%. In the Hochland Savanna, *Acacia reficiens* increased from 1998 to 2002 by 2.80% in the height class smaller than one meter, 22.14% between one meter and two meters and by 4.48 percent in the height class two meters to four meters high. During the 1998 survey no bush larger than two meters high were recorded. No bush larger than four meters were recorded in any of the surveys. However in the later two height classes mortality was recorded.

Coinciding with the lowest bush densities recorded the highest percentage mortality of *Acacia mellifera* occurs in the Thorn Tree Savanna, from Otjiwarongo to Osire, Okandjatu downwards towards Hochfeld and Okahandja. The percentage mortality of *Acacia mellifera* varies from as low 10% on some sites to as high as 80% on others. The overall average would be in the order of 30% mortality. Other bush species such as *Acacia reficiens* also has a considerable mortality rate in certain areas. In the Hochland Savanna *Acacia reficiens* densities declined from 1950 bush per hectare to 1340 bush per hectare from 1998 to 2002, a percentage mortality in the order of 31%.

Work done by Vermeulen (1997) indicates that 28% of Acacia mellifera seeds collected were normal seeds while 72% of the seeds were abnormal. Of the 285 fifty-one percent seeds germinated and only 12% of the abnormal seeds germinated. In the process of determining the regeneration of *Acacia mellifera* in areas of die back , no seedling establishment was recorded on two sites in the Thorn Tree Savanna during the period 1999 to 2002. On two sites in the Hochland Savanna seedling establishment was recorded, however, on the two sites a mortality rate of 60% and 83% was recorded during the year 2002.

CONCLUSIONS AND RECOMMENDATIONS

Bush control is feasible, however, the aim, the degree and the method of control remains of cardinal importance. Where high densities of bush occur, the initial method of control would be by applying herbicides, either manually or aerial application. Bush densities above 2000 bush per hectare, aerial application would be preferable.

The harvesting of bush in order to produce charcoal is recommendable. However, a major problem in the field, established by various surveys, is that only eight percent of the bush is harvested in the process. This leaves eighty-six percent of the bushes smaller than one meter and between 1m – 2m after harvest. Considering an average bush density of 10000 bush per hectare, the remaining density is still to high to ensure sufficient soil moisture for grass growth during years of low or even normal rainfall. A minimum of seventy percent control can be recommended if cattle ranching is the aim of controlling bush.

Incorporating the Boer Goat in to a management system would be a method of after care rather than initial controlling of bush. However, incorporating the Boer Goat must be done with caution and a highly sophisticated management must be applied. That implies, a rotational grazing management system should be applied, if not, devastating results can be expected. The correct stocking rate is of cardinal importance.

Due to insufficient fuel load for a hot enough fire most of the time, it would be recommendable rather as a method of after-care. In most cases, only a top-kill is achieved and profoundly re-growth of most bush species.

Within a vegetation type large variations occur in bush density, species composition and the structure of the bushes. One must therefore be cautious to base conclusions on a limited number of surveys. Due to these variations along with the results of the different methods of bush control, a rule of thumb is not possible in the course of bush control. Bush control would rather be a combination of methods, initially to decrease bush numbers and thereafter as an after-care. It must be kept in mind, that where after-care is not applied or it is not possible to apply sound range management, it would be best to leave the bush in the state it is in. Enough examples exist where rangeland has been degraded to such an extent that virtually no vegetative cover occurs. The ultimate measure of after-care is sound range management.

It will be necessary to create awareness regarding the variations in bush density, species composition and structure that occur in the field, and the complications that may arise during the process of bush control because of these variations. Training in the different methods of bush control and after-care will also be necessary in order to be able to decide on the correct methods of control in the course of a bush control programme. In order to control bush over the long term, a bush control programme is of utmost importance.

REFERENCES

Bester, F.V., 1998. Bush encroachment: Goats a solution or a menace. Spotlight on Agriculture. (6).

Bester, F.V. & Reed, E., 1996. Wood bio-mass production and characteristics of the Karstveld vegetation type in the vicinity of Tsumeb. *Procd. Annul. Cong. Agric. Sci. Soc. Of Namibia*

Bester, F.V. & Van Eck, J.A.J., 1998. Status of the grass layer after bush had been controlled. *Proceedings of the Second National Annual Agriculture Research Reporting Conference*. Directorate of Agriculture Research and Training, Ministry of Agriculture, Water and Rural development.

Bester, F.V. & Van Eck, J.A.J., 1998. The influence of bush control with Tordon 225 on the vegetative component. *Agri-Info*,2000.

Giess, W. 1970. *Dinteria*, (5). Contribution to the flora of South West Africa.John Meinart (Pty) Ltd. Windhoek.

Holz, G. & Screuder, W., 1989. Dieback of Blackthorn (*Acacia mellifera* Subsp. *Detinens*) in South West Africa. *Agricola*, 7.

Holz, G., Madelaine Morley & Screuder, W., 1989. Pathogenicity of *Phoma glomerata*, *P. cava*, *P. eupyrena* and *Cytospora chrysosperma* on Blackthorn (*Acacia mellifera* Subsp. *detinens*). *Agricola*, 7.

Holz, G. & Screuder, W., 1989. Phoma glomerata, *P. eupyrena* and *P. cava* on seeds of Blackthorn (*Acacia mellifera* Subsp. *detinens*) and their pathogenicity on Blackthorn seedlings. *Agricola*, 7

Holz, G. & Screuder, W., 1989. Soil moisture stress and infection of (*Acacia mellifera* Subsp. *detinens*) by fungi associated with blackthorn dieback . *Agricola*, 7

Holz, G. & Screuder, W., 1989. Blackthorn dieback disease development in the Northern regions of South West Africa. (*Acacia mellifera* Subsp. *detinens*) in South West africa. *Agricola*, 7.

Joubert, J.G.V., 1966. Die invloed van verskillende behandelings op die verhouding van Swarthaak to gras in die Damaraland Doringboomsavanne in Suidwes Afrika. Annale, Universiteit van stellenbosch. Volume 41, Serie A No. 9.

Tschudene, R., 1982. Personal Communications.

Van Niekerk, J.P. & Bester, F.V., 1979. Bush control by means of aerial spraying with Tordon 225 in South West Africa. Report, Department of Agriculture Technical Services.

Vermeulen, A.K., 1997. *Phoma glomerata* endophytic on Black thorn (Acacia mellifera ssp. *Detinens* in Namibia. M. Sc. Thesis, University of Stellenbosch.

DISCUSSION FOLLOWING THE PRESENTATION [1] [2] [3]

Q (Mr. Jessen): Mr. Bester's bush data should be included in the "Bush Expert" database of Prof. Kellner.

[1] The questions and answers may have been abbreviated during compilation of these proceedings, therefore only key points are recorded here. The authors apologise if due to abbreviation the original argument or thoughts of an individual or individuals are not expressed as they were intended.

[2] Q = Question or Comment / A = Answer

[3] The names of persons asking questions and giving answers are included wherever they were recorded.