

Alternative management systems to increase beef production under extensive conditions

by

Susanna Maria Grobler

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External Supervisor: Prof. M.M. Scholtz
Internal Supervisor: Prof. J.P.C. Greyling
Co-Supervisor: Prof. F.W.C. Naser

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DECLARATION

I declare that the thesis hereby submitted by Susanna Maria Grobler for the degree *Philosophiae Doctor* at the University of the Free State is my own independent work and has not previously been submitted by me at any other University/Faculty. I further more cede copyright of the thesis in favor of the University of the Free State



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ABSTRACT

South Africa is still a net importer of beef. Therefore, by increasing off take in the beef sector, South Africa can move towards self-sufficiency. With fertility being regarded as one of the main components influencing total beef herd efficiency, it is essential that the quoted calving percentage of 62% in the commercial beef sector of South Africa must be improved. If the long calving seasons can be shortened and the calving percentage increased, more and heavier calves with a more uniform age can be weaned. Cows that calve early also have a better chance of conceiving in the next breeding season and are generally seen as the more fertile animals

Development, production and quality of replacement heifers is a crucial component in the extensive beef production system. In general, beef heifers are managed to calve for the first time at three years of age, but in some cases mating of heifers at one year of age have been advocated.

All extensive beef production systems in South Africa are dependent on natural veld and it is well documented that veld condition have a huge influence on a number of beef production parameters. Studies conducted on natural veld have concentrated mainly on aspects that affect herd efficiency, including calving percentage, pre-weaning growth and supplementation of cows and calves. However, none of the studies focused on the reproduction performance of beef cattle mated naturally after synchronization, heifer age at breeding and effect of grazing system on veld condition.

The aim of the study was to evaluate: the effect of estrous synchronization followed by natural mating on the calving percentage and calving distribution of multiparous beef cows and heifers; effect of breeding heifers at either 14 months or 26 months of age and the evaluation of a high utilized grazing system and controlled selective grazing on veld condition and animal performance. The effects of climate on cow-calf production characteristics over time was also evaluated.

The study was conducted from 2009 to 2015 at the Roodeplaat experimental farm (REF) of the ARC-Animal Production Institute (25°34'11.27''S; 28°22'05.36''E) on 900 ha of natural rangeland described as Sourish Mixed Bushveld. The experimental herd (n=92) was divided in four sub-herds consisting of 23 cows each at the beginning of the project in 2009. It was

ensured that the four sub-herds were as uniform as possible at the beginning of the project e.g. age, weight, previous number of calves.

Within each sub-herd, 50% of the cows and heifers were synchronized prior to the commencement of the breeding season. Two sub-herds were subjected to high utilized grazing and two sub-herds were subjected to controlled selective grazing. The two grazing systems were related to the use of 30% or 60% of the available grass dry matter. Half the heifers were mated at 14 months and the other half at 26 months.

Results from this study indicated that calving percentage and body condition score did not differ significantly ($P=0.54$) between cows that was either synchronized or not synchronized followed by natural mating. However, estrous synchronization prior to natural mating did influence the average days to conception with synchronized cows calving earlier, except for 2012 in the calving season. Over the six-year project period 15% more cows from the synchronized group conceived within 293 days after the onset of the breeding season. Calves from the synchronized cows weaned on average 5kg heavier than the cows that were not synchronized although this difference was not significant.

Conception rates of heifers mated at 26 months were significantly ($P<0.05$) higher than heifers mated at 14 months of age. It would seem that it may be more viable to breed Bonsmara heifers in an extensive production system in the Sourish Mixed Bushveld region at 26 months of age for the first time. Synchronization of 14 month old heifers did not improve conception rate over 14 month old heifers bred naturally. However, the calving percentage of synchronized heifers bred at 26 months was 6% higher than the non-synchronized heifers.

Almost no veld condition change was recorded except for veld condition scores for both controlled selective grazing and high utilization grazing. In addition, the results indicate a tendency that high utilization grazing improved veld condition score and grass species composition over that of controlled selective grazing, but the duration of the study is too short to make a definite conclusion on the effect of grazing strategy on veld condition.

It was also shown that grazing strategy did not have a significant influence on cow weight and calf growth over the six-year period, indicating that both grazing strategies are sustainable in the Sourish Mixed Bushveld if carrying capacity is adhered to.

With the significant differences between years ($P \leq 0.05$) for calving percentage, cow weight at calving, cow weight at weaning, calf birth weight, calf weaning weight and body condition score over the six-year observation period, the effect of seasonal temperature, relative humidity and rainfall is elucidated. Forward stepwise regression procedures were performed to determine what climatic data were involved in cow and calf weight at birth and weaning as well as calving percentage. In spite of the high standard errors (which were probably due to the small sample size), maximum relative humidity one month prior to the start of the breeding season, made a major contribution to explain calving percentage and minimum temperature within the last month of the 3 month breeding season, had a low negative correlation with calving percentage. It can be speculated that high humidity in the study region (Sourish Mixed Bushveld) is an indication of warm and wet conditions, negatively impacting cow and bull comfort, leading to lower conception rates. The negative correlation between minimum temperature within the last month of the breeding season and calving percentage may indicate that the cows were unable to cool down at night during the warmer summer months of the year, leading to lower conception rates and resorptions.

The researcher acknowledge that the available herd size may be a limitation and that a bigger herd or sub-herds' size combined with bigger land size could benefit the project outcome, possibly resulting in more significant differences and/or enhanced interpretation of results.

CHAPTER 1

General introduction

1.1 The South African beef production industry

Given the natural resource base of South Africa, livestock production is one of the most important farming practices in the country. South Africa covers a total surface area of 122.5 million hectares, of which 103 million hectares are available for farming, with only 11% suitable for crop production from cultivated land (RMRD, 2012). According to data from the Department of Agriculture in South Africa, livestock production is the only viable agricultural activity in a large part of the country while approximately 80% of the South African agricultural land is suitable for extensive grazing (DAFF, 2012).

In the past, beef cattle production in South Africa was used to fulfil multiple functions and the provision of beef being only a secondary or even tertiary function (Van Marle, 1974). However, the application of cattle for production has changed to such an extent over time that the primary role of beef cattle currently in South Africa is to produce beef.

Since the liberalization and deregulation of the South African agricultural markets during the early 90's, the South African red meat industry has been competing in a global market with countries that have ever-changing and innovative consumer driven red meat industries (Hlatshwayo, [no date]). These industries are constantly increasing their productivity in every level of the production cycle and the value chain. Better genetics has improved herd performance and productivity, while better pre- and post-slaughter activities have improved the quality of the end product (Spies, 2011). Internationally escalating production costs, volatile feed grain prices, intermittent drought, livestock disease and increasingly stringent food safety legislation are pressuring global beef farming supply and profitability (BFAP, 2015). This may cause international beef prices to remain buoyant. In addition, South Africa's beef industry is constantly affected by external factors such as the fluid and unpredictable national political milieu; the recent labour unrest in agriculture, mining and transport sectors;

decreases in local and foreign investment; stock theft; uncertainty of the country's land reform program and pressure of significantly higher minimum wages. Nonetheless, the South African beef industry is ideally positioned to take advantage of Africa's increasing middle class expenditure and projected population growth from one billion to two billion people by 2050, including their associated demand for red meat (de Jong *et al.*, 2013). Livestock are produced throughout South Africa, with species, breeds and numbers varying according to the environment, type of grazing and production system (Meissner *et al.*, 2013). Competition for the beef industry will come mainly from the predicted 47% growth in average annual chicken consumption by 2022 (BFAP, 2013). However, the Bureau for Food and Agricultural Policy estimates that South Africa's current annual average beef consumption of about 700 000 tons is likely to increase by 25% by 2020. Due to several factors, including environmental concerns, the national beef herd cannot realistically be increased and therefore it is of utmost importance to improve existing production efficiency in South Africa (de Jong & Phillips., 2013). This is one of the reasons why this project was aimed at the development of beef cattle herd management models to ensure sustainability and to improve the efficiency of beef cattle production in South Africa.

The total number of cattle, including dairy cattle and beef cattle in South Africa, has increased from 13 million cattle in 1995 to 13.7 million in 2015 (DAFF, 2016). The South African beef cattle producers are unique due to the dualistic nature of the country's agricultural situation. There is a clear distinction between the highly sophisticated commercial (formal) sector of the industry who rely on new technology and the smallholder (largely informal) sector who rely mostly on indigenous knowledge. The informal sector can also further be divided into two sub-sectors namely: the small-scale subsistence producers and the communal producers (Spies, 2011).

These three major groups of beef cattle farmers that co-exist in South Africa can further be defined as:

- The commercial beef producer where production is relatively high and comparable to developed countries. Their production is generally based on synthetic breeds and/or crossbreeding, using Indicus / Sanga types and their crosses as dams.

- The emerging beef cattle farmer who own or lease land. Their cattle generally consist of indigenous crossbred or exotic type of animals.
- The communal beef cattle farmer who farm on communal grazing land. Their cattle are mostly of indigenous types (DAFF, 2012).

Approximately 60% of cattle in South Africa are owned by commercial farmers and 40% by emerging and communal farmers (Meissner *et al.*, 2013).

1.2 Beef production systems

In South Africa the commercial livestock sector comprises of approximately 35,000 farmers of which 2,500 are seedstock producers (RPO, 2011). The informal sector includes 240,000 emerging farmers, of which 87,000 have the ability or potential to join the commercial sector. In addition to this, there are approximately 3 million subsistence farmers (DAFF, 2010).

The most common beef production systems in South Africa include weaner production, steer production (tolly/ and ox) and buying-in/speculative systems (Hlatshwayo, [undated]). As a general rule of thumb, in weaner systems, the cowherd consists of approximately 60% of the total animal units and in a steer system, including tolly (yearling ox) and ox (older than tolly) systems, the cowherd comprises of approximately 40% to 50% of the animal units respectively (Beef production systems: kzndard, [undated]).

1.3 Economic overview

1.3.1 Number of cattle per province

Distribution of beef cattle per province in South Africa during the 2010 production year is set out in Figure 1.1. The Eastern Cape commands the greatest share of beef production in South Africa, accounting for 21% of beef cattle numbers in 2010 followed by KwaZulu-Natal, Free State, North West and Mpumalanga (accounting for 18%, 16%, 13% and 11% respectively).

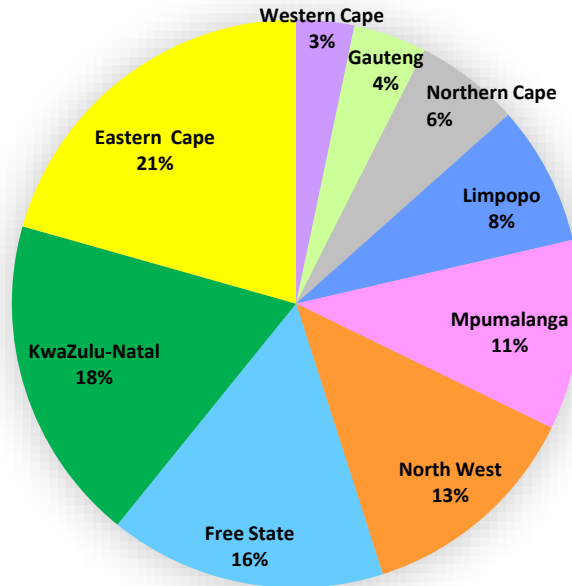


Figure 1.1 Distribution of beef cattle per Province in South Africa (Source: Meissner *et al.*, 2013)

In the recent past (early 1970's) the introduction of feedlots and export markets has changed the beef production scene in South Africa dramatically (Du Plessis *et al.*, 2006). In the past farmers could sell their cattle as oxen or old cows for a reasonable price. Due to the advent of a large feedlot sector in South Africa (70 – 75% of cattle are finished through feedlots), the commercial market now requires large numbers of uniform calves that are earlier maturing, efficient converters of high quality feed and possess superior carcass attributes (Scholtz *et al.*, 2008).

1.3.2 Gross value of the beef herds

The South African red meat sector contributed 14.8 % to the total gross value of agricultural production during the 2008/2009 season, with cattle being the main contributor at 10.1% - while sheep contributed 2.5% during the same period (DAFF, 2010). During a 12-year period (1998-2010) the contribution of livestock to the total gross value of agricultural production has increased from approximately 40% to nearly 50% (RMRD, 2012). In South Africa, the gross value of beef production is dependent mainly on the total number of cattle slaughtered at abattoirs and the prices received by producers from abattoirs. The average gross value of beef produced during the period 2005/06 until 2014/15 amounted to R 16, 668,752,000 (DAFF, 2016).

Figure 1.2 illustrates the gross value of cattle and calves slaughtered during the period 2005/06 until 2014/15 as well as the amount of cattle and calves slaughtered during this period. From Table 1.1 it is clear that beef consumption and demand is higher than production indicating that South Africa does not produce enough beef for the domestic market. Although the number of cattle slaughtered has increased from 2005/2006 to 2014/2015, large numbers of weaner calves are imported annually from neighbouring countries showing that South Africa is still a net importer of beef.

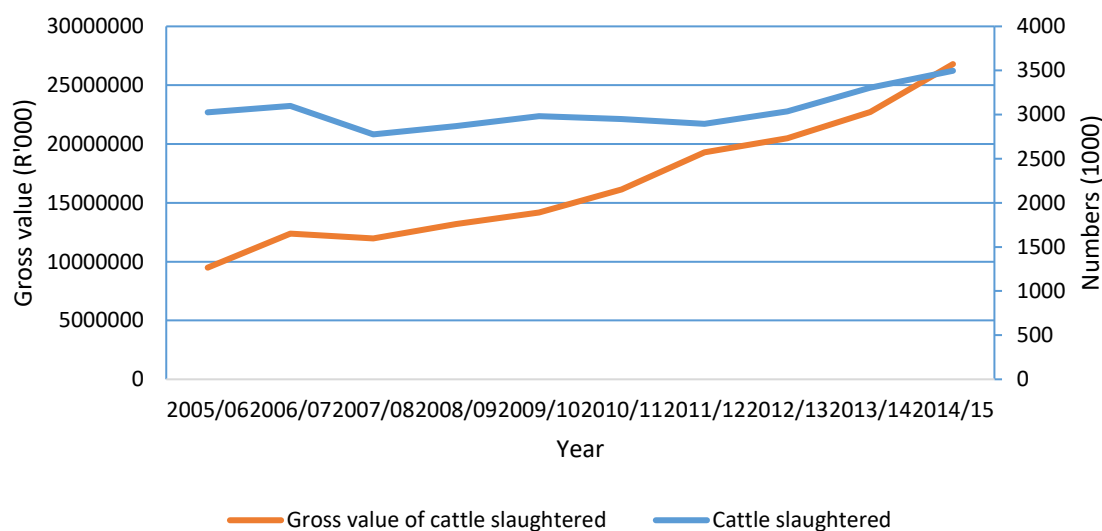


Figure 1.2 Gross value of cattle and calves slaughtered and number of cattle slaughtered for the period 2005/06 to 2014/15 (Source: DAFF – Abstract of agricultural statistics, 2016)

Table 1.1 Total cattle slaughtering, production and consumption of beef (Source: DAFF- Abstract of agricultural statistics, 2016)

Year	Cattle slaughtered	Production (1000t)	Consumption (1000t)
2005/06	3,026,000	808.1	825
2006/07	3,098,000	861.4	865
2007/08	2,776,000	770.2	767
2008/09	2,869,000	796.7	784
2009/10	2,982,000	885.8	880
2010/11	2,948,000	869.5	879
2011/12	2,895,000	852.1	865
2012/13	3,035,000	904.5	910
2013/14	3,307,000	982.6	981
2014/15	3,497,000	1037.9	1023

By increasing the currently low off take in the beef sector, South Africa can move towards self-sufficiency. The major reasons for the low off take in the beef cattle sector are low reproductive and weaning percentage, insufficient fodder flow, environmental risks such as drought and weaning weights of calves that do not meet perceived feedlot specifications (Scholtz *et al.*, 2008).

1.4 Motivation for the study

Globally, the consumption of animal products also continues to grow and this pattern is expected to continue for the immediate future (Arelovich *et al.*, 2011). The increasing demand, for organically produced animal protein from free ranging animals is also adding yet another dimension to beef production, which filters through to the whole production chain, to include also the primary production industry (Du Plessis *et al.*, 2006). This does not only have an impact on the finishing-off of cattle, but will in future inevitably filter through to the whole production chain to include also the primary production unit, the cow and calf herd (Du Plessis *et al.*, 2006).

Natural veld has long been acknowledged to play an important role in extensive beef cattle production and the South African beef industry is very dependent on natural veld. However, of the so-called beef-producing areas, the greater part has a limited agricultural potential, owing to high ambient temperatures, low and unpredictable rainfall, and low soil fertility (Meaker, 1984). The extensive grazing of beef cattle in these areas is the most practical method of production even though very little information is available on production efficiency norms for cowherds under these conditions (Du Plessis *et al.*, 2006). Studies conducted on natural veld have concentrated mainly on aspects that affect herd efficiency, including calving percentage (Lademann & Schoeman, 1994), pre-weaning growth (Venter, 1977), supplementation of cows and calves (Lishman *et al.*, 1984; Lademann & Schoeman, 1994 and De Waal *et al.*, 1996), as well as crossbreeding (Mentz, 1977 and Meaker, 1984). Important production traits and aspects of production were addressed in these studies and the effect of the various traits and aspects on cow production and efficiency were illustrated (Du Plessis *et al.*, 2006). However, none of the studies focused on the reproduction performance of extensive beef cattle mated naturally after synchronization in the Central

Bushveld Bioregion of South Africa and very little information is available on especially reproduction efficiency norms for cowherds under these conditions.

Barely a day goes by without reference being made to the disadvantageous financial position of the South African farmer. The difficult economic conditions encourage a greater awareness among farmers to become more efficient and they are continually looking for means to increase production and profitability of their extensive livestock production system (Foster *et al.*, 2014). Focus on production measures and means to increase production is important as production is the profit equation component directly affecting income from the enterprise. Ultimately, the foremost focus is with profitability of the cow-calf operation (Ramsey *et al.*, 2005) and it is indicated by large that reproduction in sheep and cattle reflect the level of management to which animals are exposed to (Lishman *et al.*, 1984). The need to optimize rather than to maximize and the impact of efficiency and sustainability have been demonstrated for various production and economic measurements (Meaker, 1986). This implies a growing need for livestock research and development to think in terms of a livestock enterprise approach, sometimes referred to as “the systems approach” or “general systems theory”. In fact, a systems approach is the framework of holistic thinking.

Such a systems approach can be defined as the utilization of the principles of genetics, nutrition, physiology, genetic resources, range and forage management, product technology and economics to support practical and profitable animal production by integrating research into the farming practice. This entails a combination of genetic improvement with sound natural resource utilization (both animals and plants), nutrition, forage management, physiology, product technology and economics of production to ensure a sustainable production system over time through the allocation of limited resources.

This research is thus aimed at the improvement of the efficiency of beef cattle production by encompassing a vast number of factors including biological, environmental and market elements. The outcome should be more and uniform calves that meet the market specifications of the vibrant feedlot industry. This can contribute to the decreased reliance on imports of weaner calves and beef to South Africa.

1.5 Objectives of the study

The project aimed to increase the take-off in the beef sector in a competitive market to move towards self-sufficiency and less imports by producing weaner calves economically, in a sustainable production enterprise through the best allocation of limited resources.

The objectives of the study were as follows:

- To establish if synchronization can lead to an increase in the total weight of calves weaned from a limited calving season, most likely by decreasing the days to calving, but also by increasing the number of calves born
- To establish if breeding replacement heifers at 14 months have an economic advantage over breeding heifers at 26 months in terms of reproductive performance
- To establish the impact of two different grazing strategies (high utilization grazing vs. controlled selective grazing) on animal performance over a six-year period, as well as the growth of calves and puberty of replacement heifers
- To evaluate the effect of two different grazing strategies (high utilization grazing vs. controlled selective grazing) on veld conditions.

CHAPTER 2

Source of data and experimental design

2.1 Description of the study area

The study was conducted from 2009 to 2015 at the Roodeplaat experimental farm (REF) of the ARC-Animal Production Institute (25°34'11.27''S; 28°22'05.36''E) on 900 ha of natural rangeland (Fig. 2.1). The study area is situated on the Roodeplaat Igneous Complex which belongs to the Post-Waterberg Formation. The Roodeplaat Igneous Complex is a unique ring-shaped formation with a diameter of approximately 16 km and is also referred to as the "Roodeplaat volcano" (Verwoerd, 1966, 1967 cited by Jansen, 1977). No detailed soil survey exists for this study area. The vegetation in the study area has been described as Savanna (Rutherford & Westfall, 1994), Sourish Mixed Bushveld (Veld Type 19) (Acocks, 1988), Clay Thorn Bushveld (Low & Rebelo, 1996) and Marikana Thornveld (Mucina & Rutherford, 2006) in the Savanna Biome, Central Bushveld Bioregion. The stocking rate, as determined by a 2009 veld analysis of 7ha/LSU, was strictly adhered to with no changes in stocking rate over the study period.

Schulze (1965) categorizes the area in which the study is situated as the Northern Transvaal climatic region which receives an annual rainfall of between 380 and 700 mm, where the average annual rainfall for Roodeplaat is 646 mm (AgroClimatology Staff., 2015). The mean daily minimum/maximum temperatures ranged from 16°C (minimum) to 32°C (maximum) in February (summer) and 1°C (minimum) to 23°C (maximum) in July (winter) as shown in Table 2.1.

Table 2.1 Monthly minimum and maximum temperatures (°C) over a six-year project period at Roodeplaat experimental farm, Pretoria (AgroClimatology Staff., 2015)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2009	18/30	16/29	14/28	9/28	6/22	4/22	1/20	4/23	9/29	14/29	14/28	16/29
2010	18/29	16/31	15/30	13/24	8/24	2/21	4/21	4/25	9/30	14/32	16/30	16/29
2011	17/28	16/29	15/30	12/25	6/24	1/21	1/20	4/24	8/29	12/29	14/30	17/29
2012	17/31	17/31	14/30	9/26	6/26	2/22	3/23	5/25	9/26	12/28	14/29	16/29
2013	17/31	16/32	14/30	9/26	5/25	2/23	3/22	4/24	11/29	12/29	15/30	16/28
2014	17/31	17/30	17/24	10/25	6/25	2/22	2/21	5/23	10/29	12/29	15/27	17/28

The mean rainfall for the past 10 years was 768mm, of which 83% occurred from October to March (spring to autumn). During the study period, the mean annual rainfall averaged 858mm, ranging from 664mm to 1325mm as set out in Table 2.2.

Grazing camps allocated to the different sub-herds are set out in figure 2.1:

Sub-herd A1: A1, A2, A3, A4, A5, A6, A7

Sub-herd A2: D1, D2, D3, D4, 13

Sub-herd B1: B7, B8, B10, B11, 18

Sub-herd B2: B1, B2, B3, B4, B5, B6

Camps that were not used in the study: A8, B12, C1, C2, C3, C4, C5, C10, C18, 13, 19, S1, S4, NN, L, Moedersbond, Rosekamp

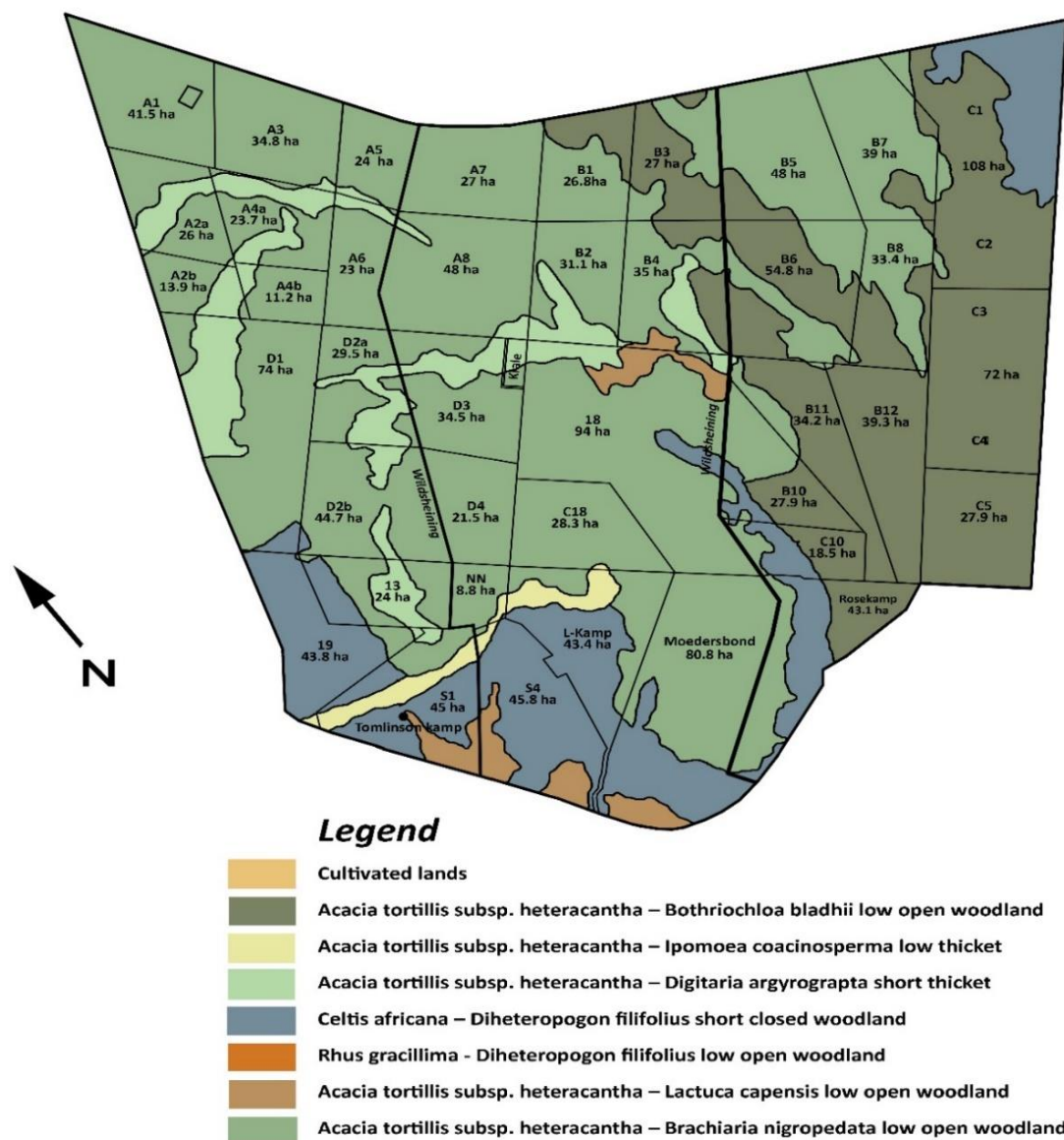


Figure 2.1 Map illustrating name, size and vegetation classification of project camps on the Roodeplaat experimental farm.

Table 2.2 Monthly rainfall (mm) over the six-year project period at Roodeplaat experimental farm, Pretoria (AgroClimatology Staff., 2015)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2009	212	128	74	3	30	31	2	125	386	93	94	147	1325
2010	126	33	48	178	53	0	0	0	0	50	68	216	772
2011	431	40	128	112	5	12	0	5	1	64	68	164	1025
2012	65	104	81	7	1	0	0	0	74	109	81	154	676
2013	90	32	79	98	1	0	0	0	7	104	87	187	685
2014	68	181	86	26	1	0	0	1	1	30	95	175	664

The monthly minimum- and maximum relative humidity over the six-year project period is set out in Table 2.3. Relative humidity was used to calculate the discomfort index (South African Weather Service, 2015).

Table 2.3 Monthly minimum- and maximum relative humidity (%) over the project period at Roodeplaat experimental farm, Pretoria (AgroClimatology Staff., 2015)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2009	42/89	41/90	34/91	26/90	29/91	28/87	20/85	21/84	19/76	29/86	36/89	40/90
2010	43/90	31/89	31/89	49/93	34/92	24/89	25/85	17/83	17/77	19/78	32/87	36/89
2011	44/91	36/90	34/91	45/93	33/94	23/89	20/84	21/82	15/77	21/82	26/83	39/89
2012	33/88	32/89	28/88	27/90	20/94	22/89	18/81	16/74	26/77	34/87	31/87	38/89
2013	35/87	28/89	31/90	32/92	23/90	21/89	22/85	19/80	16/77	26/84	27/85	41/90
2014	32/88	34/89	67/92	36/92	27/91	21/86	21/82	19/74	15/71	21/78	37/85	43/89

The discomfort index was calculated for each month during the study period by using the formula obtained from the local South African Weather Service (South African Weather Service, 2015), which is also used in livestock, as shown below:

$$DI = (2 \times T) + (RH/100 \times T) + 24$$

Where: DI = Discomfort index; T = temperature (°C) and RH = percentage relative humidity.

The index gives the following degrees of discomfort:

- 90 – 100: very uncomfortable
- 100 – 110: extremely uncomfortable
- 110+: hazardous to health

2.2 Experimental design

The animals used in the study were Bonsmara cattle. The Bonsmara breed consist of 5/8 Afrikaner and 3/8 Shorthorn and Hereford (Scholtz, 2010). Under the guidance of Prof Jan Bonsma, the Bonsmara was developed originally to be adapted to South Africa's subtropical climate (Bonsmara SA, [undated]). The first Bonsmara calves were born in 1943 after a well-documented crossbreeding program with the aid of objectively recorded performance data combined with visual evaluation according to norms of functional efficiency (Scholtz, 2010). A survey conducted by the Agricultural Research Council (ARC) indicated that the Bonsmara breed had the highest percentage intake in feedlots of all breeds in South Africa and they are well known for their excellent carcass traits including tenderness, taste and juiciness of meat. The cows are excellent mothers and produce weaners for feedlot or finishing under natural grazing conditions. The Bonsmara breed is expanding at a fast rate internationally, and is accepted by beef cattle industries all over the world (Scholtz, 2010).

As shown in Table 2.4, the experimental herd (n=92) was divided in four sub-herds consisting of 23 cows each at the beginning of the project in 2009. It was ensured that the four sub-herds were as uniform as possible at the beginning of the project with regards to age, weight and previous number of calves.

- The four sub-herds were subjected to one of two grazing strategies, namely high utilized grazing (HUG) or controlled selective grazing (CSG), related to the use of 30% or 60% of the available grass dry matter. Two sub-herds comprising of 23 animals each were subjected to HUG and two sub-herds were subjected to CSG.
- It was ensured that the camps selected for both grazing strategies were as uniform as possible and that the different plant communities present on the Roodeplaat farm were represented the same within camps allocated to the four sub-herds
- Five different plant communities were present on the Roodeplaat research farm. These plant communities present on the farm were evaluated during the growing season (October/November) to determine the veld condition. Veld evaluation was done to determine if there was a significant difference in basal cover,

botanical composition and condition of the veld between the two grazing strategies over time. The animals were moved from one camp to another according to the established stocking rate, camp size and group size.

- Within each sub-herd 50% of the heifers were mated at 14 months of age, while the other 50% heifers were mated at 26 months.
- Within each sub-herd, 50% of the cows and heifers were synchronized prior to the commencement of the mating season. The theory is that this can often induce oestrous cycles in anoestrous cows and shorten the interval from calving to conception. It also gave cows and heifers more opportunities to conceive during a defined breeding season, resulting in increased pregnancy rates and earlier calving dates the following year - ultimately translating into older and heavier calves at weaning.
- Synchronization were done at the onset of the breeding season within the first week of January of each consecutive year 2009-2014.
- One fertile breeding bull was included in each sub-herd (2009-2011) for 90 days after the onset of the breeding season and two fertile breeding bulls were included in each sub-herd from 2012 to 2014 due to sub-herds getting bigger over time as no cows were culled.
- All calves were weaned at an average age of 7 months each year.
- All performance traits (weights, growth rates, fertility) were recorded and used to standardize the different sub-herds to the same large stock unit (LSU).
- The animals were weighed every time they move to the next camp.
- Body condition score (BCS) was performed when animals were weighed from 2012 onwards.

Table 2.4 Illustration of experimental layout

Grazing strategy	Herd A				Herd B			
	High utilization grazing (60% utilization)				Controlled selective grazing (30% utilization)			
Sub-herds	A1		A2		B1		B2	
Heifer age at first mating	± 26 months		± 14 months		± 26 months		± 14 months	
Synchronization	Yes	No	Yes	No	Yes	No	Yes	No

The researcher acknowledged that the available herd size was limiting results and that a bigger herd or sub-herds size combined with bigger land size could benefit the project outcome, possibly resulting in more significant differences and/or enhance interpretation of the results. However, all animals and available camps for the project at the research station were included in the study.

2.3 Oestrous synchronization

2.3.1 Oestrous synchronization 2009-2012

2.3.1.1 Synchronization method and product

The animals selected for oestrous synchronization were subjected to Crestar® (Crestar®; Intervet SA Ltd, Isando, RSA) implants at the beginning of the summer breeding season. The silicone ear implant containing 3mg progestagen norgestomet (17 α -acetoxy-11 β -methyl-19-nor-pregn-4-ene-3, 20-dione) (Crestar®; Intervet SA Ltd, Isando, RSA) was inserted subcutaneous beneath the skin at the outer edge of the ear. Each application was followed immediately by intramuscular administration of 2ml Crestar® injection (Crestar®; Intervet SA Ltd, Isando, RSA) containing 3mg norgestomet and 5mg oestradiol valerate. The day of implant insertion was considered as day 0 of treatment. The implants were removed on day 10 when the cows were injected intramuscular with 300-400 I.U. Folligon (PMSG) before mating commenced approximately 56h later (Crestar®; Intervet SA Ltd, Isando, RSA).

2.3.2 Oestrous synchronization 2013-2014

2.3.2.1 Synchronization method and product

The animals selected for oestrous synchronization were subjected to CIDR® B (CIDR®; Pfizer Laboratory (Pty) Ltd, Sandton, RSA) intravaginal device treatment at the beginning of the summer (January) breeding season. The intravaginal device or CIDR® was a silicone-coated nylon insert, infused with 1.9g progesterone was inserted by applicator into the anterior vagina. Each device insertion was followed immediately by an intramuscular administration of a 1mg Ciderol injection (Ciderol®; Pfizer Laboratory (Pty) Ltd, Sandton, RSA) containing 1mg oestradiol benzoate. The day of device insertion was considered as day 0 of treatment. The implants were removed on day 12 before mating commenced 48h later.

2.4 Body Condition Scores (BCS)

Body condition was scored by means of the five-point Scottish scoring system (Edmonson *et al.*, 1989). This system is more commonly used in South Africa than the American nine point scoring system (Escrivão, 2012) as set out in Table 2.5.

Table 2.5 Overview of body condition scores (BCS) of beef cows

BCS	Entire animal	Back bone	Short ribs
1	<ul style="list-style-type: none"> Extremely thin No fat in brisket or tail docks All skeletal structures are visible No muscle tissue evident No external fat present Dull hair Survival during stress doubtful 	<ul style="list-style-type: none"> Individual vertebrae well defined, sharp Can place fingers between each vertebrae 	<ul style="list-style-type: none"> Visually prominent No fat present Very sharp to the touch
2	<ul style="list-style-type: none"> Thin Upper skeleton prominent (vertebra, hips, pin bones) Muscle tissue evident, but not abundant Some tissue cover around the tail dock, over the hip bones and the flank 	<ul style="list-style-type: none"> Individual vertebrae can be felt, but not as sharp Can't place fingers between vertebrae 	<ul style="list-style-type: none"> Feel individual ribs, sharp rather than very sharp Identify individual ribs visually
3	<ul style="list-style-type: none"> Ideal flesh for calving Ribcage only slightly visible Muscle tissue nearing maximum Fat deposit behind shoulder obvious Fat in brisket area Tail docks easily felt 	<ul style="list-style-type: none"> Somewhat defined Difficult to feel top of vertebrae 	<ul style="list-style-type: none"> Completely covered with fat, beginning to spread over rump Individual ribs only felt with firm pressure
4	<ul style="list-style-type: none"> Skeletal structure difficult to identify Obvious fat deposits behind shoulder, and at tail head Fat on brisket and over shoulder 	<ul style="list-style-type: none"> Flat appearance to the top line Can't feel individual vertebrae 	<ul style="list-style-type: none"> Folds of fat beginning to develop over the ribs and thighs Can't feel individual ribs
5	<ul style="list-style-type: none"> Obese Flat appearance dominates Brisket heavy Bone structure not noticeable Tail head and hips bones almost completely buried in fat and folds of fat 	<ul style="list-style-type: none"> Flat back Can't feel backbone 	<ul style="list-style-type: none"> Completely covered by fat Mobility impaired by large amounts of fat

Adapted from: Body Condition: Implications for Managing Beef Cows. Agdex 420/40-1; What's the Score: Beef Cow – Body Condition Scoring (BCS) Guide.

Body condition scoring (BCS) is an effective hands-on management tool that is used to evaluate the nutritional status of beef cattle. In order to manage a beef herd in the most cost-efficient way, producers must, at all times, be aware of the body condition of their herd. It has been indicated through research that the body condition of beef cows is

related to many critical aspects of production - such as days to oestrus, conception rate, milk production and calving interval (CCA & NFACC, 2013).

Body condition scoring is most applicable to mature cattle and may be of very little use for cattle under one year of age. By assessing the degree of muscle and fat cover at specific places on the mature animal's body, specifically over the spinous and transverse processes of the short ribs and in fatter cattle, the tail head and ribs, a BCS between 1 and 5 can be determined (CCA & NFACC, 2013).

2.5 Veld evaluation

2.5.1 Carrying capacity

Carrying capacity was established at the beginning of 2009, before commencement of the project to assure equal vegetation and camp allocation for the different treatment groups. Ten sample sites were surveyed on a 10 x 20m area based method. The PHYTOTAB program was used for data analysis. One of the products was standing biomass, which was used to calculate the carrying capacity using the formula proposed by Moore *et al.* (1985), and again described by Moore and Odendaal (1987) and Smit, (2009):

$$y = d [DM \times f] / r$$

where:

y = carrying capacity (ha/LSU)

d = number of days in a year (365)

DM = total grass dry matter (yield/ha/year)

f = utilization factor (0.3) On average only 30% of all produced material is available for usage

r = daily grass dry matter intake per LSU (13.5kg)

The carrying capacity of all the camps was calculated to be 7ha/LSU.

For the duration of the project (2009-2014), both the area-based method and point based method were used to determine:

- Basal cover %
- Total canopy cover %
- Proportional canopy cover % of grasses
- Standing biomass (kg/ha)
- Decrease grass species contribution (%)
- Veld Condition Score (number out of 1000)

2.5.2 Area-based method

2.5.2.1 Data capture

Three sample sites were located in each of the four areas allocated for each sub-herd as shown in Table 2.6. These sites were used as a basis for vegetation change over time and were geo-referenced (Table 2.7) and plotted on a map as shown in Figure 2.2.

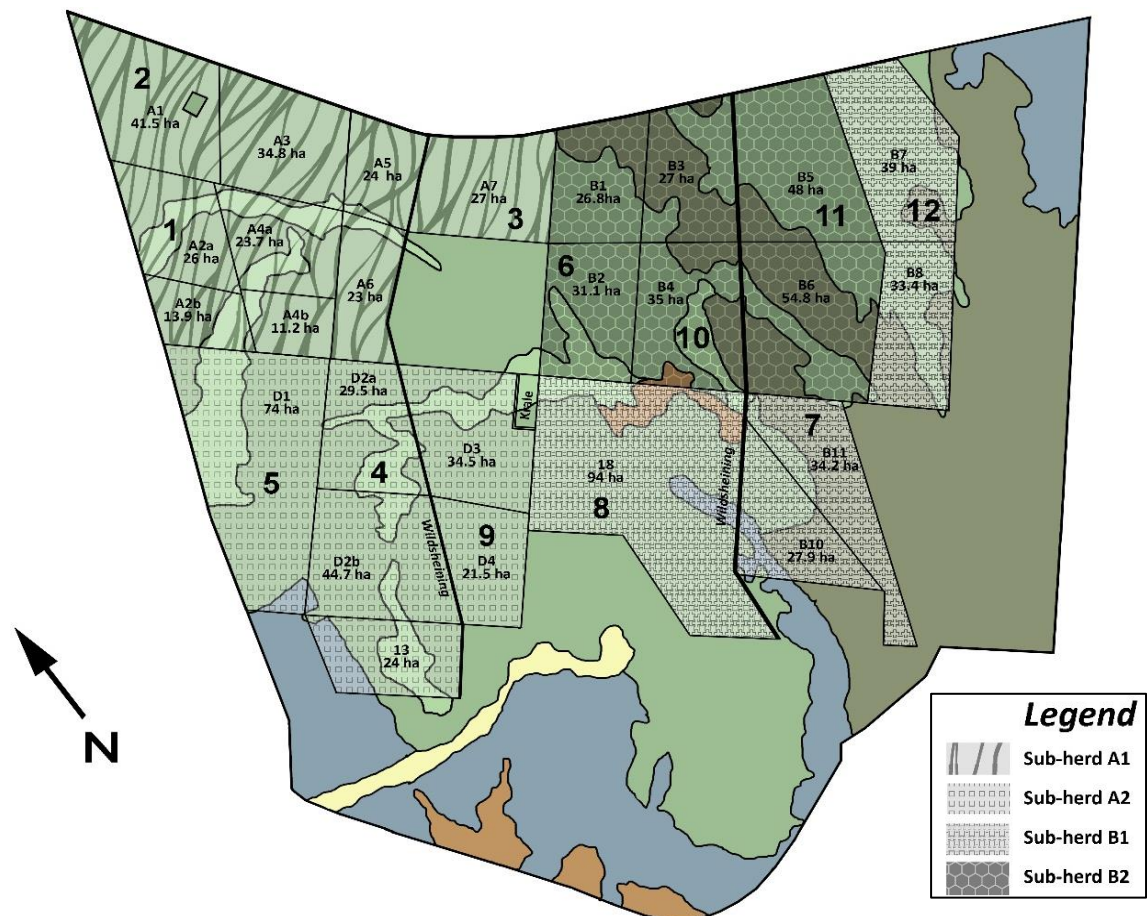


Figure 2.2 Roodeplaat experimental farm, indicating areas allocated to Sub-herds and veld monitoring sites

Table 2.6 Illustration of experimental layout

Grazing strategy	Herd A		Herd B	
	High utilization grazing		Controlled selective grazing	
Sub-herds	A1	A2	B1	B2
Relevé no. of survey sites	1,2,3	4,5,9	7,8,12	6,10,11

Table 2.7 Detail of the twelve survey sites used in the study

Relevé No. (Survey site)	Geo-reference	Slope	Compass bearing	Altitude
1	25°33'21"S 28°21'26"E	0-1°	150°	1191m
2	25°32'52"S 28°21'38"E	0-1°	134°	1191m
3	25°33'43"S 28°22'25"E	0-1°	42°	1207m
4	25°33'56"S 28°21'45"E	0-1°	139°	1191m
5	25°33'41"S 28°21'18"E	0-1°	251°	1219m
6	25°33'48"S 28°22'31"E	0-1°	150°	1192m
7	25°34'28"S 28°22'28"E	0-1°	78°	1196m
8	25°33'21"S 28°21'26"E	0-1°	195°	1190m
9	25°34'26"S 28°21'51"E	0-1°	256°	1189m
10	25°34'25"S 28°22'28"E	0-1°	62°	1200m
11	25°33'56"S 28°23'11"E	0-1°	214°	1200m
12	25°34'17"S 28°23'30"E	0-1°	284°	1203m

The use of an area-based method for vegetation monitoring purposes generally yields a much higher species diversity, as opposed to a point-based method. The recording of floristic data, however, was done by means of an area-based method in conjunction with a 200-point point-based method.

Quadrates of 10m x 20m (200m²) were sampled at each monitoring site. All identifiable plants located in the quadrates were recorded and the mean crown diameter was determined for each species, at each sampling plot. Canopy cover, here-after referred to as cover, was sampled separately, for each species recorded, at each sample plot using the plant number scale as shown in Table 2.8. (Westfall & Panagos, 1988). It must be noted that the plant species that were recorded at each sample plot did not include all the plant species present at the specific area, since by the very nature of sampling, some plants will not be included.

Table 2.8 Plant number scale symbols with corresponding percentage cover values

Symbol	%Cover	Symbol	%Cover
+	0,01	H	29,1
1	0,10	I	32,7
2	0,40	J	36,4
3	0,91	K	40,3
4	1,61	L	44,4
5	2,52	M	48,8
6	3,63	N	53,3
7	4,94	O	58,1
8	6,45	P	63,0
9	8,18	Q	68,1
A	10,1	R	73,5
B	12,2	S	79,1
C	14,5	T	84,8
D	17,0	U	90,7
E	19,8	V	96,9
F	22,7	W	100

A growth form was assigned to each species recorded (Westfall *et al.* 1996) as follows to be included in the data processing by the PHYTOTAB-PC program:

- T: tree (single stem $\geq 2\text{m}$; multi-stem $\geq 5\text{m}$)
- S: shrub (single stem $< 2\text{m}$; multi-stem $< 5\text{m}$)
- D: dwarf shrub (woody, $< 1\text{m}$; perennial)
- G: graminoid (restios, sedges and grasses)
- F: forb (non-graminoid herbs, mainly annual)

2.5.2.2 Data processing

The PHYTOTAB-PC program package developed by Westfall and his team (Westfall 1992, Westfall *et al.* 1996) was used for processing of the data. Classification of the samples (relevés) and species consists of programmatic sequencing of the samples (relevés), community delimitation and species sequencing. The output by means of a phytosociological table was relevé-by-species matrix based on the orderly arrangement of species similarities and differences (Gabriel & Talbot, 1984). Relevant information, which can be derived indirectly from the classification using the PHYTOTAB-PC program package, included a community composition analysis (CCA). The CCA involves grouping of species into competitor classes (weak, normal and strong), within a community and is determined by the ratio of the species cover to frequency (Westfall *et al.*, 1996).

Competitors for each of the growth form types are as follows:

- Strong competitor: high cover/frequency ratio.
- Normal competitor: intermediate cover/frequency ratio.
- Weak competitor: low cover/frequency ratio.

These relations are expressed as:

- relative cover for each growth form class as a percentage of the combined cover;
and
- absolute cover for each growth form class.

Interpretation of these analyses is usually straight forward, but should be done from the perspective of land use practices applied in the specific relevant communities.

Further information, which can be derived from the classification, includes key plant species. Key species being the weak and strong competitors of each community.

2.5.3 Point-based method

2.5.3.1 Data capture

At each sample plot a 200-point nearest plant method was applied. The nearest plant to each of the 200 one metre intervals on the tape was recorded with the direction of the line run in the same direction as the slope, through the quadrat. At each point the nearest plant within a 50cm radius of the point was recorded. If no living plant species occurred in the circle, bare soil was recorded and a strike on any basal part of the plant was also recorded.

2.5.3.2 Data processing

Relative frequencies (as a percentage of the 200 points) and basal cover for species were determined. The data from this survey were also used to determine the veld condition of the two treatments and the four groups. The PHYTOTAB computer program was used with reference to weights allocated to species (Sourish Mixed Bushveld).

2.6 Statistical procedures

The effect of cows being either synchronized or not-synchronized and grazing strategy, high utilization grazing (HUG) and controlled selective grazing (CSG), were studied on cow productivity over a six-year period (2009-2014). Multiparous cows, 14 month old heifers and 26 month old heifers were included in this study. Cows and heifers were analysed separately.

For the cows, the data of the two grazing systems (HUG and CSG) were combined after the variances were tested for comparable magnitude using Levene's test. (John & Quenouille, 1977). A 2 x 2 factorial analysis of variance (ANOVA) was performed with factors two grazing systems (HUG and CSG) and two oestrous synchronization treatments (synchronized or not-synchronized) (Snedecor & Cochran, 1967). The repeated measurements over the six-year period were included as a sub-plot factor (Little & Hills, 1972).

For calving percentage of heifers, a 2³ factorial analysis of variance (ANOVA) was performed using the 6 years as block replications because it was different animals every year. (Snedecor & Cochran, 1967). The factors were two grazing systems (HUG and CSG), two ages (14 and 26 months) and two oestrous synchronization treatments (synchronized or not-synchronized).

For days to calving (DTC) and weight at calving of heifers the two ages (14 and 26 months) were analysed separately as a 6x2x2 factorial with animals as independent replications. The factors were six years, two grazing systems (HUG and CSG) and two oestrous synchronization treatments (synchronized or not-synchronized).

Furthermore, covariance analysis was performed on variables (DaystoCalving, CowWeightatCalving, CalfBirthWeight, CowWeightWeaning, Calf205dayWW and Calf ADG) using CowAge as covariate for each year separately. The adjusted means and standard errors (SEM) are shown in tables (Chapter 6) and pairwise comparisons were done using a t-test. (Snedecor & Cochran, 1967).

The vegetation data of the two grazing systems (HUG and CSG) were combined after the data were tested for homogeneity of variances using Levene's test (John & Quenouille, 1977). An appropriate analysis of variance (Table 7.5) was done with factors two grazing systems (HUG and CSG) and four seasons (2011/2012, 2012/2013, 2013/2014 and 2014/2015).

The Shapiro-Wilk test was performed on the standardized residuals to test for deviations from normality (Shapiro & Wilk, 1965). In cases where significant deviation from normality was due to skewness, outliers were removed, until the standardized residuals were normal or symmetrically distributed (Glass *et.al.*, 1972). The student's t-Least significant difference (LSD) was calculated at a 5% significance level to compare means of significant source effects. All the above data analyses were performed using SAS version 9.3 statistical software (SAS, 1999).

To predict the dependant variable DTC, calving percentage, calf birth weight and cow weight at calving the independent explanatory variables using weather data including average monthly maximum- and minimum temperature (°C), average monthly

maximum- and minimum relative humidity (%), total monthly precipitation (mm) and discomfort index were measured over a six-year period.

Forward stepwise regression procedures were performed for each of the four dependant variables (days to calving, cow weight at calving, calf weight at calving and calving percentage), specifying $P=0.1$ to enter and $P=0.05$ to stay for the independent variables (precipitation, discomfort index, relative humidity and temperature from six months before breeding) (XLSTAT, 2014).

CHAPTER 3

Literature review

3.1 The effect of controlled breeding on the reproductive performance of an extensive beef cattle enterprise

3.1.1 Introduction

All extensive beef cattle producers need to produce the maximum kilograms of beef at the least possible cost, in a sustainable production system. Profitability is therefore primarily dependent on the reproductive performance of the cow herd, which is best measured by percentage calves weaned. In most South African extensive beef production systems, calves are weaned at a specific date. This management system implies that cows that calve late in the calving season wean younger and lighter calves, when compared to cows that calve earlier in the season - weaning a bit older calves with a higher body weight gain from birth to weaning.

Globally, the consumption of animal products continues to grow and this pattern is expected to continue for the immediate future (Arelovich, 2011). If the large numbers of weaner calves that are imported annually from neighbouring countries are taken into consideration, South Africa is still a net importer of beef. By increasing the off-take in the beef sector, South Africa could move towards self-sufficiency (Scholtz *et al.*, 2008). However, environmentally sustainable beef production can only be achieved through the adoption of systems and practices that make the most efficient use of available resources and reduce environmental impact per unit of food (Capper *et al.*, 2011).

Natural veld has long been acknowledged to play an important role in extensive beef cattle production (Meaker, 1984), but very little information is available on production efficiency norms for cowherds under these extensive production conditions (Du Plessis *et al.*, 2006). Studies conducted on natural veld have concentrated mainly on aspects that affect herd efficiency, including crossbreeding (Mentz, 1977; Meaker, 1984), calving percentage (Lademann & Schoeman, 1994), pre-weaning growth (Venter, 1977), as well as supplementation of cows and calves (Lishman *et al.*, 1984; Lademann

& Schoeman, 1994; De Waal *et al.*, 1996). Important production traits were addressed in these studies and the effect of the various traits and aspects on cow production and efficiency were documented (Du Plessis *et al.*, 2006). However, none of the studies focused on the reproduction performance of beef cattle mated naturally after synchronization in the Central Bushveld bio-region of South Africa.

With fertility being regarded as the main component influencing total herd efficiency, it is therefore essential that local quoted calving percentage of 62% (Scholtz *et al.*, 2008) in the commercial beef sector of South Africa needs to be improved. If the generally long calving seasons are shortened and calving percentage increase, more and heavier calves of a uniform age can be weaned (Grobler *et al.*, 2013). Cows calving earlier in the season have an extended “recovery period” and have the opportunity to calve in a better body condition during the next season, compared to cows calving late in the season (Odhiambo *et al.*, 2009). To increase weaning weights by producing more early born calves, cows and heifers have to be bred earlier after calving (Sprott & Troxel, 1988). Cows that calve earlier in the calving season, may also have a better chance of conceiving during the next breeding season and can generally be seen as the more fertile animals (Holm, 2006; Grobler *et al.*, 2014).

3.1.2 Reproduction

3.1.2.1 Postpartum anoestrus

After calving, all cows go through a period of postpartum anoestrus (Bearden & Fuquay., 2000), the time from calving to ovulation or sometimes referred to as the period from calving to conception. Several factors related to pregnancy may influence the postpartum anoestrus period - including uterine involution, short oestrous cycles, effects of suckling calves, and nutritional status. This period of temporary infertility cannot be avoided, but it can be managed effectively to ensure that the cows return to a fertile state in a timely and economically way (Bischoff *et al.*, 2015).

Therefore, to maintain an optimum yearly calving interval, beef cows in extensive systems must be managed in a way to overcome postpartum anoestrus as soon as possible. This is where oestrous synchronization programs can play a major role.

Failure to successfully manage the cow herd through the postpartum anoestrus interval is one of the major causes of low fertility. Infertility occurs mainly when cows:

- 1) become pregnant but fail to calve;
- 2) become pregnant late in the breeding season and fall out of the annual production cycle; or
- 3) fail to become pregnant during the breeding season.

The latter two causes of low fertility are a direct result of the length of the postpartum anoestrus interval (Bischoff *et al.*, 2015).

3.1.2.2 Uterine involution

Uterine involution can be defined as the functional as well as structural reversion of the uterus to a stage that is capable of supporting another pregnancy (Bischoff *et al.*, 2015). After calving and uterine involution, the oestrous cycle of cows can resume as normal. When no complications were present, uterine involution takes place and the uterus returns to a non-pregnant shape, size and position, all fetal membranes are shed, and the uterine tissues are repaired (Kiracofe, 1980). This process is completed in approximately 20–40 days after calving (Bischoff *et al.*, 2015). Although uterine involution is usually seen as an obstacle to conception in the early postpartum cow, it has been found that after uterine involution is completed it has no relationship to a cow's ability to successfully overcome the post-partum interval (Kiracofe, 1980).

3.1.2.3 Short oestrous cycles

According to Bischoff *et al* (2015), abnormal luteal function is normally experienced by the majority of beef cattle following their first ovulation postpartum. This often occurs without any visual signs of expressed oestrus. Usually, the life span of the corpus luteum in the luteal phase, is often 10 days or less in a short oestrous cycle, whereas a typical luteal phase comprises 14–18 days of a normal 21-day oestrous cycle. This phenomenon is referred to as a short oestrous cycle and is common in cows recovering from postpartum anoestrus.

Usually the first ovulation postpartum results in a fully functional corpus luteum (CL) which produce adequate levels of progesterone to support pregnancy. However, the uterus is producing and metabolizing higher than normal quantities of prostaglandin (PGF), which is a result of the involution process of the uterus (Bischoff *et al.*, 2015). The hormone responsible for the regression of the CL is Prostaglandin (Bearden & Fuquay., 2000). High concentrations of PGF result in the premature regression and ultimate death of the CL. If ova fertilization from this ovulation were to occur, CL regression would occur before maternal recognition of the pregnancy, which usually occurs between 16 to 18 days after conception, resulting in loss of the embryo and failure to maintain pregnancy (Smith *et al.*, 1987).

Progesterone from exogenous sources, such as a controlled intravaginal release device e.g. CIDR®, can be a useful tool in managing short oestrous cycles. A lack of progesterone in the anoestrous cow limits luteinizing hormone (LH), which drives development of the follicle and in the process causes ovulation. Through progesterone exposure, this inhibition is lessened, which lead to increasing LH secretions. Therefore, cows that ovulate after a CIDR® treatment may have a reduced incidence of short oestrous cycles (Bischoff *et al.*, 2015).

3.1.2.4 Effects of suckling

The energy demand of lactation is not the primary factor associated with nursing that limits resumption of the normal oestrous cycle, but the actual suckling and presence of the calf limits resumption of the normal oestrous cycle (Bischoff *et al.*, 2015). When suckling takes place, a complex system of hormonal feedback loops and neural responses results in reduced LH pulse frequency by altering gonadotropin-releasing hormone (GnRH) release. This results in decreased follicular development and a lack of follicles eligible for the next ovulation (Hanlon, 1995). Suckling has the greatest impact on cows with low body condition scores and also first calf heifers. The maternal bond with the calf also plays an important role. It has been demonstrated that twice daily milking does not impact the length of the postpartum period significantly, but daily suckling of calves does lengthen the postpartum interval, indicating that cows may have a lengthened postpartum interval if the cow is being suckled by a calf that shares a maternal bond with the cow (Bischoff *et al.*, 2015). However, overall pregnancy rates can be improved during this period with an oestrous synchronization protocol.

3.1.2.5 Nutrition

Postpartum reproduction is influenced more by body condition and nutritional status before calving than supplementation after calving. In order to take advantage of this, the producer must be aware of the critical periods within the production cycle where cows must have a body condition score (BCS) of 3 (Selk *et al.*, 1986). Typically, these critical periods include early gestation and the period just after weaning when the nutritional maintenance requirements of the beef cow are at their lowest, compared to other phases of the production cycle. With the decline in required protein and energy, this becomes the optimal time to increase BCS and improve energy reserves, both physiologically and economically. Ideally, a BSC of 3 should be obtained before calving, which then allows for weight loss following calving without dramatic effects on the animal's health and consequently fewer negative impacts on the cow's reproductive performance (Kunkle *et al.*, 1997). Sufficient nutrient intake postpartum can lessen the duration of postpartum anoestrus, but it cannot compensate entirely for low BCS and nutrient intake prior to calving. It has been shown that even when thin cows gain body weight during their postpartum period, ovulation is still delayed when compared to cows with a good BCS (3 or greater) at calving. Therefore, to improve reproduction efficiency within a beef herd, managing BCS and nutrient intake before and after calving are very important (Bischoff *et al.*, 2015).

When managing the herd strategically, producers can limit the negative effects of postpartum anoestrus on the productivity of the beef cow herd. With proper attention to BCS prior to calving, acceptance of the suckling interaction, proper uterine involution, and lessening of short oestrous cycles - the period of postpartum anoestrus can be reduced for successful reproductive efficiency.

Tools available to help producers successfully overcome anoestrus and the incidence of short oestrous cycles during the postpartum interval include the implementation of oestrous synchronization protocols along with administration of exogenous progesterone, through treatment with a CIDR® intravaginal device after 21 days of calving. Administration of any progesterone or progestin within 21 days of calving could hinder this process (Bischoff *et al.*, 2015).

3.1.3 Oestrous synchronization

Since it was discovered that daily injections of progesterone suppressed oestrus and prevented ovulation during the treatment period (Christian & Casida, 1948), intensive research into oestrous synchronization in cattle has been conducted (Hanlon, 1995). Even though oestrous synchronization has been cited over the past several decades to have a substantial impact on reproductive performance to increase production and profitability of beef cattle (Lesmeister *et al.*, 1973; Bellows & Short, 1990; Schafer *et al.*, 1990; Wiltbank, 1990 and Kesler 2002) only a limited percentage of extensive beef cattle producers synchronize oestrous.

According to Hanlon (1995) oestrous synchronization regimes are effective in producing a synchronous decline in blood progesterone levels in treated cows. Unfortunately, the time taken for ovulation and follicular maturation tends to be inconsistent between animals (Savio *et al.*, 1988; Sirois & Fortune, 1988; Ginther *et al.*, 1989), causing the variation in fertility observed following fixed time insemination after oestrous synchronization treatments (Macmillan & Peterson, 1993). Low oestrous detection efficiency is also a major cause of poor reproductive performance (Larson & Ball, 1992). In the current study animals were bred by natural mating after synchronization surmounting the problem of variable degree of follicular development and ovulation after synchronization and inefficient oestrous observation.

3.1.3.1 Advantages of an oestrous synchronization program

According to Larson and Ball (1992) the desirable features of an oestrous synchronization program include:

1. High response rates regardless of stage of oestrus cycle at which treatment is administered,
2. Tight synchrony in time of oestrous and time of ovulation,
3. Normal fertility at the synchronized ovulation, and
4. Normal return to oestrus and fertility at subsequent services
5. To achieve sufficient synchrony, while still achieving pregnancy rates at least equal to those with natural mating (Roche, 1976; Macmillan & Asher, 1990).

Benefits of an oestrous synchronization program:

1. Economic benefits from increasing the percentage of cows that conceive during the optimum breeding period (Hanlon, 1995)
2. Schedule livestock handling, observation and breeding to fit into the optimum breeding season (Bearden & Fuquay, 2000)
3. Calf losses in many cases are reduced because of improved management during the calving period (Patterson *et al.*, 2005a).
4. Increasing the number of breeding opportunities for each cow during the breeding period (Odde, 1990; Woolly & Thurston, 1993), therefore reducing cow wastage due to culling.

In a study conducted by Holm (2006) where beef heifers were inseminated after synchronization, it was found that oestrous synchronization can lead to an increase in the total weight of calves weaned from a limited calving season, most likely by increasing the number of calves born as well as decreasing the days to calving. Seasonal patterns in calf growth and mortality rates caused by disease or climate can also influence total weight of calves weaned. If the concentrated calving season is synchronized with the “safe” season (season most conducive to cow and calf comfort and health), it can contribute to an increase in the total weight of calves weaned. Similarly, if the calf growth season is synchronized with the “unsafe” (excessive heat, cold, drought, floods, diseases etc.) season, it can have a negative effect on total weight of calves weaned and represents an increased risk of a high incidence of production loss or mortality. Other possible benefits from a synchronization program that require verification and further study include reduced abortion rate and induction of puberty (Holm, 2006).

Holm (2006) also concluded that a practical way to predict the cost effectiveness of an oestrous synchronization protocol is to determine the ratio between the value of the total cost of the program and the future price of weaner calves per kg live weight. This ratio represents the minimum increase in mean weaning weight that has to be achieved for the program to be cost effective. Further research is required to determine the likely increase in mean weaning weight achievable by making use of different synchronization protocols.

3.1.3.2 Methods of oestrous synchronization

Oestrus synchronization procedures and ovulation in cycling beef cattle are based on synchronizing the end of the progestational phase of the oestrous cycle (Wright & Malmo, 1992; Hanlon, 1995; Abdullah, 2000). A negative feedback effect is exerted by progesterone on the oestrous cycle by decreasing luteinizing hormone (LH) release from the anterior pituitary gland (Rajamahendran *et al.*, 1979; Stumpf *et al.*, 1993). Follicles fail to ovulate and behavioural oestrus is suppressed in the presence of progesterone (Sirois & Fortune, 1990). The inhibitory effects on the pituitary are removed, the pulse frequency and amplitude of LH secretion increases and the sequence of neuro-endocrine events leading to ovulation and oestrus occurs when progesterone concentrations decline (Fogwell *et al.*, 1978; Cruz, *et al.*, 1997).

There are two ways in which to control plasma progesterone levels. Firstly, by administering an exogenous source of progesterone for a time which allows natural luteal regression, and termination of the progestational phase occurring, when progesterone treatment ceases and secondly by prematurely removing the CL and therefore the source of the endogenous progesterone (Hanlon, 1995).

These methods have been used in different synchronization programs available for cattle, alone; in combination with each other and various other hormones like progesterone, prostaglandin, gonadotrophin releasing hormone (GnRH) and prostaglandins; a combination of progestins and prostaglandins; and with various other compounds such as oestrogens and pregnant mare serum gonadotrophin (PMSG) (Hanlon, 1995).

3.1.3.3 Progestagen-Oestrogen combinations

Progestagens have been administered to cattle by means of several routes with the most common being daily subcutaneous or intramuscular injections, subcutaneous implants, oral preparations, and intravaginal devices (Hanlon, 1995).

The desirable features of methods of administering progesterone to cattle to synchronize oestrous was outlined as follows by Roche (1976):

- The method must be easily applied and terminated;
- Must reach satisfactory amount of endogenous levels and patterns of progesterone in blood;
- Allow a swift drop in plasma and tissue levels of progesterone when the treatment is terminated; and
- give predictable and precise onset of oestrus after the end of treatment.

Estrogens are usually included in the beginning of all of the commercially available programs which utilize exogenous progestogens to synchronize oestrus because of the observed evidence that they improve desired outcomes (Hanlon, 1995). According to Gyawu *et al.* (1991) progestagen/prostaglandin combinations are more effective than progestogen/oestrogen combinations in synchronizing oestrous because of the unpredictable luteolytic action of oestrogens. However, the inclusion of oestrogens as either oestradiol benzoate or oestradiol valerate at the start of synchronization treatments using exogenous progestogens has been shown to increase the number of treated animals in oestrous and to shorten the interval from ending of treatment to oestrus (Wiltbank & Kasson, 1968; Cumming *et al.*, 1982; Sprott *et al.*, 1984).

In the current study, oestrous synchronization was done by administration of exogenous progestogens in combination with oestrogen by means of Crestar® (Crestar®; Intervet SA Ltd, Isando, RSA) implants (2009-2012) and CIDR-B® (CIDR®; Pfizer Laboratory (Pty) Ltd, Sandton, RSA) intravaginal devices (2013-2014).

3.1.3.3.1 Crestar®

“Crestar®” is a subcutaneous ear implant containing 3mg norgestomet. An injection containing 3mg norgestomet and 5mg oestradiol valerate is also injected intra-muscular at the time of implant insertion.

Mode of action Crestar® injection:

The luteal phase is shortened by the estrogen and Norgestomet compound in the Crestar® injection, if treatment is given in an early stage of the cycle and induces the so called follicular turnover (ovulation or luteinisation of any LH-sensitive follicle present on the ovary at the time of injection), preventing thus the formation of dominant persistent follicles. At the same time oestrus and ovulation by pituitary inhibition is suppressed by the Norgestomet compound (Chastant-Maillard, [undated]).

Mode of action Crestar® implant:

The continuous release of Norgestomet through the Crestar® implant maintains the suppression of oestrus and ovulation. After removal of the implant the blocking effect on the pituitary ceases and a new follicular phase starts. In non-cyclic animals the priming effect of Norgestomet is enhanced when the implant is removed by combining the removal of the implant with an intramuscular injection of PMSG that stimulates synchronized follicular development (Cavaliere *et al.*, 1997).

A similar product is marketed under the brand-name “Syncro-Mate-B” (6mg norgestomet ear implant). Fertility using this regime has varied, with reported first-service conception rates ranging from 33-68% (Odde, 1990). When using Syncro-Mate-B for synchronization, variability in conception rates were observed and were reportedly due to a high proportion of anoestrous cows prior to treatment; poor body condition; luteal dysfunction and delayed oestrus and ovulation (Mikeska & Williams, 1988). Fertility following Syncro-Mate-B treatment may be higher when treatment starts after day 11 of the oestrous cycle (Brink & Kiracofe, 1988). Infection at the site of implantation was found to hinder the removal of implants and could result in some implants not being found (Tregaskes *et al.*, 1994). In suckling beef cows, removing calves from their dams is recommended from the time of implant removal until breeding, however the response to calf removal is inconsistent (Odde, 1990; Kiser *et al.*, 1980; Hixon, 1993).

3.1.3.3.2 CIDR®

“CIDR® B” is an intravaginal device, made of a pre-moulded annealed nylon spine, coated with a silicon-based elastomer containing 1.9g of progesterone (Macmillan *et al.*, 1991) with an attached nylon cord to facilitate removal from the vagina. When used for a 12-day treatment period (as in the current study) with intra-muscular injection of 10mg oestradiol benzoate at device insertion, oestrus is successfully synchronized. Onset of oestrus occurs 48 hours after device removal with the majority of responding animals exhibiting oestrus at 48 and 96 hours after device removal (Duijs *et al.*, 1986). Macmillan and Peterson (1993) found that 94% of heifers aged 12-14 months were in oestrus by 96 hours after device removal with an average pregnancy rate of 60%.

Mode of action CIDR® B

CIDR®’s are infused with progesterone which is released via the skin through the walls of the vagina, entering the circulation (Macmillan & Peterson, 1993) causing the animal’s blood progesterone concentration to increase rapidly. Progesterone provides a potent suppression of oestrus (Bearden & Fuquay, 2000). When the CIDR® is removed at the end of the 12-day treatment period, a rapid drop in concentration of systemic progesterone occurs in each animal, thus promoting a synchronized oestrus effect within the animal (Cavalieri *et al.*, 1997).

Mode of action Ciderol

Ciderol contains 1mg/ml oestradiol benzoate and is administered by intra-muscular injection at time of device insertion to synchronize the follicular wave.

3.1.3.4 Conception rates following oestrous synchronization

According to Hanlon (1995), the stage-of-cycle has been demonstrated to influence the conception rate following prostaglandin induced oestrus. Lower conception rates are seen when luteolysis is induced in early dioestrus, compared to late dioestrus (Watts & Fuquay, 1983; Watts & Fuquay, 1985). Failure of prostaglandin synchronization programs in heifers has been attributed to a high proportion of anoestrous animals (pre-pubertal) and abnormalities of the reproductive tract (Macmillan *et al.*, 1978).

3.2 The effect of age at mating on cow productivity

3.2.1 Introduction

Development, production and quality of replacement heifers is a crucial component in the extensive beef cattle production operation. A heifer's lifetime productivity as a productive beef cow is influenced by age at puberty, age at first conception and calving interval. When a heifer calves for the first time, it marks the beginning of her productive life and one of a few ways of improving beef-cow lifetime productivity is to reduce age at first calving (van der Merwe & Schoeman, 1995). At times when beef returns are good, it may be worth bringing heifers into production as early as possible. However, the incentive may be less when heifers are calved as two-year-olds if seasonal conditions are poor, as extra feed costs may not be compensated for by the extra return (Kroker *et al.*, 2000).

Age at first calving can therefore have a significant effect on a beef producer's return on investment and a delay in the age at first calving has many disadvantages other than increasing a heifer's non-productive life. These disadvantages include a larger number of heifers that needs to be maintained in the heifer herd, an increased generation interval and delaying the introduction of genetically superior replacements in the herd (Grobler *et al.*, 2013). In general, beef heifers are managed to calve for the first time at three years of age, but in many studies mating of heifers calving at two years of age have been advocated (Fahmy *et al.*, 1971; Meaker *et al.*, 1980; Nunez-Dominguez *et al.*, 1991). The theoretical advantage of mating heifers one year earlier, lies mainly in the potential increase in lifetime productivity and the expectation of an extra calf (Meaker *et al.*, 1980).

Little information is published locally on the biological or economic value of early mating of extensive beef heifers while international information is mostly restricted to dairy cattle (Morris, 1980; Scholtz *et al.*, 1991; van der Merwe & Schoeman, 1995). According to van Niekerk *et al.*, (1990) replacement heifers are not generally mated before the age of 24 months because of the extensive nature of the majority of beef enterprises in South Africa. Scholtz *et al.*, (1991) concluded that there is no consensus on the advantages of early breeding of beef heifers in South Africa.

Geographical-region differences in the age at which heifers are first exposed for breeding will therefore depend on management systems, forage quality and availability, and adaptation of respective breed types to specific environmental conditions. In some cases, the economic advantage of early calving and breeding may be counterbalanced by biological limitations of the animal and management constraints of the environment (Short *et al.*, 1990; Patterson *et al.*, 2005a; Ahmadzadeh *et al.*, 2011).

3.2.2 Age at first mating

Heritabilities of age at puberty, age at first conception and age at first calving are generally low, indicating that these traits are highly influenced by environmental factors. The age at which beef heifers should therefore be first bred depends upon the economics of management input against returns (Mukasa-Mugerwa, 1989; Kroker *et al.*, 2000). Heifers cannot be bred early unless they reach puberty prior to, or early in their first breeding season. Puberty in heifers can be characterized in several ways including age at first ovulation, age at first oestrus, and/or age at which a heifer can support pregnancy without any difficulty (Ahmadzadeh *et al.*, 2011). Regardless of the criteria used to define puberty, there are several major environmental, physiological and managerial factors that can advance or delay the age at puberty. Well grown heifers can be mated as early as 15 months to calve at 24 months, but require extra managerial effort if acceptable results are to be obtained (Mukasa-Mugerwa, 1989). To calve at 24 months a heifer must reach puberty by 13 to 16 months of age, while taking into account breed, environment, nutrition and other factors (Spratt & Troxel, 1988).

The three main advantages of mating heifers as yearlings instead of two- year-olds are:

- Heifers bred as yearlings can produce an extra calf during their life in the herd
- High producing mothers can be identified earlier, which allows for a shorter generation interval and hence, quicker genetic progress
- Less heifers needs to be maintained in the heifer herd

The decision to breed extensively managed beef heifers as yearlings involves careful consideration of the economics of production and the breed type, reproductive status, or genetic make-up of the heifers involved (Wiltbank & Kasson, 1968; Morris, 1980; De Rouen & Franke, 1989; Kinder *et al.*, 1990; Marshall *et al.*, 1990, Short *et al.*, 1990).

3.2.3 Target weight

In several studies, early mated heifers need preferential nutritional treatment which means that the main cost of breeding heifers as yearlings is the need to feed weaner heifers so that they achieve a minimum required live weight at breeding (Meaker *et al.*, 1980, Lepen *et al.*, 1993). Target weight is considered to be the threshold weight for puberty and thus the onset of oestrus in heifers (Kroker *et al.*, 2000; Hall, 2005a). Below this weight growth rate and nutrition are the limiting factors to puberty onset. Above this weight, maturation rate of the reproductive tract as well as genetics are the limiting factors to puberty.

Heifers raised on low energy diets are delayed in reaching puberty and have lower pregnancy rates in their first breeding season than heifers raised on a high energy diet (Hall, 2005b). The target weight principle calls for feeding heifers to a pre-breeding target weight that represents 65% of the heifer's projected mature weight (Patterson *et al.*, 2005a). When heifers are developed to reach approximately 65% of their mature weight by 12 to 13 months of age, puberty is not restricted by nutrition (Hall, 2005b). In contrast, feeding heifers' excess energy to reach 65% of mature weight prior to 12 months of age does not initiate puberty (Hall, 1997) but increase body fat percentage at puberty in rapidly developed heifers. Puberty can be expected to occur at a genetically predetermined size among individual animals (Lamond, 1970; Patterson *et al.*, 2005a), and only when heifers reach genetically predetermined target weights can high pregnancy rates be obtained. The genotype of the heifer must be considered in the development program (Patterson *et al.*, 2005a).

When heifers are fed to achieve appropriate weights prior to first breeding, a positive effect on re-breeding after the first calf can be seen. When heifers are bred for the first time with inadequate live weights, conception rates and calving percentages are poor, calving problems increase and their chances of being rebred while nursing their first calves are very low (Kroker *et al.*, 2000).

3.2.4 Lifetime performance of heifers calving at two years

According to Kroker *et al.*, (2000) well managed heifers calving first at two years have a higher lifetime productivity than heifers calving first at older ages. However, van der Merwe and Schoeman (1995) found that although early mating of Simmentaler heifers resulted in an increased number of calves born and weaned, lifetime productivity was not significantly influenced.

3.2.5 Fertility of heifers mated as yearlings

In a study by Sprott and Troxel (1988), it was noted that 90% of Hereford heifers weighing more than 272kg at the onset of the breeding season conceived. In the subsequent breeding season, 69% of the heifers calving the first year got pregnant. However, only 56% of Hereford heifers weighing less than 249kg conceived. In the subsequent breeding season, only 18% of those calving from this group were pregnant; with only 8% of the lightweight heifers exposed after the first year were able not to skip a calf. In a study by Scholtz *et al.* (1991) it was found that Nguni heifers needed a target weight of 215 kg at the onset of the breeding period, in order to conceive. The heifer progeny of the heifers that calved early did not reach this target weight at 13-15 months of age. Thus, a system of early breeding could not be maintained in this study.

According to Kroker *et al.*, (2000), heifers, particularly those calving at two years of age took considerably longer after their first calving to return to oestrus. In many cases, heifers may become pregnant late or fail to conceive altogether. This can be overcome by ensuring that only well grown heifers are bred, that the heifers calve down in acceptable body condition, (condition score 3), and are well fed after calving to be bred the subsequent season at condition score 2.5 to 3. The success of implementing breeding heifers at one year of age depends on management and nutritional levels. Under extensive farming conditions early breeding of heifers will require additional supplementary input. In most studies of this nature, there was a positive correlation between early and subsequent reproduction (Morris, 1980), but the sign of this correlation (positive or negative) depended entirely on the nutritional and management levels and on the breed (van der Merwe & Schoeman, 1995).

3.2.6 Calving difficulty

It was commonly believed that calving difficulty results from breeding heifers at too young an age. However, according to Kroker *et al.*, (2000) calving difficulty is a problem of first-calf heifers, whether they calve for the first time at two years or three years. Well grown two-year-olds should have no more difficulty to calf than three-year-old heifers, despite the more mature frame of three-year-old heifers. This is usually due to the fact that calf size increases with the increased frame size of the dam, and the fact that older heifers tend to be fatter at calving, both of which can lead to calving difficulty. This statement is in contrast with results found by van der Merwe and Schoeman (1995) who concluded that calving difficulties (dystocia and assisted births) in extensively managed Simmentaler heifers differed ($P < 0.01$) between heifers calving at 24 months and heifers calving at 36 months. The factors contributing to calving difficulties in a study by Van der Merwe and Schoeman (1995) were body weight of the heifer at breeding, birth weight and sex of the calf. Pelvic size in the heifers was, however, not important ($P > 0.05$). Heifers that experienced calving difficulty weighed on average 8.7% less and gave birth to calves which weighed on average 8.9% more than the heifers which did not experience calving difficulty. Although early mating of Simmentaler heifers resulted in an increased number of calves born and weaned, lifetime productivity was not significantly influenced. It would seem as if early calving had a serious detrimental effect on calving ease and calf survival rate. It was further concluded that early breeding of extensively managed Simmentaler heifers should not be considered as a standard management practice. It would seem unlikely that such a system can improve in the traditional system on natural pasture. The system was not even self-maintaining (van der Merwe & Schoeman, 1995). In indigenous breeds, however, calving problems in early calving heifers may be of less concern (Penzhorn & Meintjes, 1968; Scholtz *et al.*, 1991; Lepen *et al.*, 1993).

3.2.7 Milk production and calf growth

Heifers calving at two years produce less milk and wean lighter calves than older cows, but can still produce good calves if calving in an acceptable body condition and are well fed after calving (Kroker *et al.*, 2000). Webb *et al.* (1955) found that the average weaning weight of beef calves born from cows that were mated at 15 months of age was less than that of calves from cows that were mated at 27 months of age (173kg and 183kg, respectively). Morris (1980), in his review, also indicated that in nearly all trials studied by him weaning weights of first calves were reduced in early mated heifers. Calf weights from the current study will be further discussed in Chapter five.

Although calves of yearling bred heifers weigh less at weaning, the following calves are as heavy as if the heifers had calved at three years. The first calf of yearling bred heifers, although lighter, therefore represent an extra year of production and therefore genetic gain, as opposed to heifers calving for the first time at three years of age (Kroker *et al.*, 2000). This is in agreement with results found by van der Merwe and Schoeman (1995), where weaning weight differed by 30% between calves of heifers bred at either 24 months or 36 months - probably due to lower milk production. Heifer calves produced by the 36 month old heifers were 15.6% heavier at 24 months, indicating a stunted influence in the offspring of early bred heifers (van der Merwe & Schoeman, 1995).

Early calving may have a negative effect on the lifetime milk production of a cow, and the main reason may be due to poor udder development. On the other hand, a cow that calves early may potentially wean more calves throughout her lifetime (Scholtz *et al.*, 1991). Furthermore, with earlier breeding, the replacement costs per heifer may be less, suggesting that there should be an optimum age for first calving (Leuenberger & Kunzi, 1988). It is important that a thorough investigation is carried out to determine all possible economic implications before deciding to practise early calving. Furthermore, the age and month of first mating as well as the possibility of two breeding seasons a year, should fit into the natural breeding and calving seasons within that specific region and management system (Scholtz *et al.*, 1991).

3.3 The impact of grazing strategies on animal production and the vegetation

3.3.1 Introduction

Natural veld has long been acknowledged to play an important role in extensive beef cattle production (Meaker, 1984), but little information is available on production efficiency norms for cowherds under these conditions (Du Plessis *et al.*, 2006). It is only herbivores which can convert high fibre, for example cellulose, into high-quality protein sources for human consumption (Scholtz *et al.*, 2013). Cellulose still remains one of the most prolific natural organic compounds on earth and because of the evolutionary development of the ruminant enzyme system, is an inexpensive source of energy for ruminants (van Pletzen, 2009). However, South African veld types (Acocks, 1988) are very diverse, resulting in reported differences in botanical composition, dry matter production potential and nutritive value within these different veld types, over different seasons and years. Furthermore, large variations in dry matter yield of veld, mainly due to differences in rainfall distribution and annual rainfall, occur at any specific site between years and are invariably reflected in animal performance (Reid & Jung, 1982, de Waal, 1990).

The grazing ruminant therefore exists in a highly dynamic situation where its production performance, is determined not only by changes in nutrient requirements, quantity and quality of available pasture but also by the physical environment (Reid & Jung, 1982). Although diet or pasture quality is important, production by the grazing ruminant is more dependent on the total intake of digestible nutrients. The amount of herbage ingested by grazing ruminants depends on the availability of acceptable herbage, the physical and chemical composition of the pasture and the nutrient requirements, as well as the capacity of the animals to ingest herbage (de Waal, 1990).

With the market fluctuations in the beef industry, it is vital for extensive beef cattle farmers to produce beef as cost effectively and as efficiently as possible. Although it is common practice to study veld as a separate entity to cattle or beef farming, cattle cannot be separated from the veld on which it is kept - primarily because of a dynamic equilibrium between the animal and the grazing plants the animal utilizes. Although the

cost of providing feed to extensive grazing cattle is more complex to quantify, it remains a major input (Foster *et al.*, 2014) and according to Pogue *et al.*, (1996) grazed forages are approximately one-third the cost of stored forages, based on total digestible nutrients per kilogram product.

Several studies have been conducted to measure the increase in cow-calf productivity by utilizing large-frame cattle breeds in grazing systems (Gregory *et al.*, 1978; Oliver, 1978; Knox *et al.*, 1982), utilizing legumes in grazing systems (Hoveland *et al.*, 1978; Stricker *et al.*, 1979; Morrow *et al.*, 1988) and by utilizing different calving seasons (Bagley *et al.*, 1987; Gaertner *et al.*, 1992; Ivy *et al.*, 1995). Although each of these management tools may have an impact on forage-livestock system productivity, the effects of forage-livestock management systems need to be evaluated in the specific climate, veld type and type of cattle.

South Africa has a total surface area of 122.5 million ha of which almost 84% or 103 million ha is available for agricultural practices. Only 11% is arable land with the remaining area only suitable for extensive livestock production (RMRD SA, 2012). Beef cattle farming in South Africa is mostly extensive and are therefore dependent on natural veld (RMRD SA, 2012). With the development of technology in crop production, particularly since the fifties of the previous century, production from grain increased astronomically worldwide. However, the rapid and drastic changes in world markets and commodity prices increased the risk of intensive production systems that present particular challenges for remaining profitable. Against this background the cost of production from natural veld is still the lowest (van Pletzen, 2009).

Grazing strategies have evolved from a need to sustain efficient use of natural veld by livestock over long periods of time (Manley, 1997) and it is well documented that veld condition has a large influence on a number of beef production parameters (Grobler *et al.*, 2013). It is generally understood that veld management practices may either cause deterioration or improvement of the veld (van Pletzen, 2009) and the application of different grazing systems or strategies may have an effect on financial return in the long term or even result in immediate decreases in financial return (Grobler *et al.*, 2013).

3.3.2 Effect of grazing on the grass plant

As summarized by Torrano and Valderrábano (2004), the main effect of grazing on plant growth is the loss of leaf area associated with the reduction of the plant's photosynthetic capacity. This reduces the supply of assimilated compounds to seeds, roots, growing shoots and developing fruits (Willard & McKell, 1973; Donaghy & Fulkerson, 1997). Consequently, the success of plants faced with herbivory depends mainly on the efficacy of their physiological and morphological adaptations for replacing consumed biomass (Roundy & Ruyle, 1989; Herms & Mattson, 1992; Edenius *et al.*, 1995).

Mechanisms that could potentially compensate for defoliation by herbivores include complex responses and physiological inter-relationships (Paige & Whitham, 1987; Torrano & Valderrábano, 2004). Therefore, Whitham *et al.* (1991) proposed a model to analyse compensation mechanisms by divided the plant into a balanced system of sink regions and source organs. The source organs include those parts of the plant which specialised in the net gain of carbon (photosynthetic and storage organs), whereas the sink regions of the plant are regions specialising in growth and reproduction (growing meristems and flowers). According to this model, it seems that plants can physiologically compensate for the damage caused by herbivory through an adequate response of either the sink or source organs. The source organs, undamaged by the grazing herbivores, could react by increasing the supply of photo-assimilated compounds to the sink organs. This happens through increased photosynthetic efficiency (compensatory photosynthesis) as a result of the elimination of less active, older tissue. The increased photosynthetic efficiency is caused by the increased efficiency of water use associated with the reduction in transpiring surfaces or due to the increasing amount of light reaching lower tissues (McNaughton, 1979; Nowak & Caldwell, 1984; Torrano & Valderrábano, 2004). The sink organs response to defoliation is then usually an increase in active growing point numbers caused by the elimination of the dominant apical meristem and the subsequent stimulation of lateral buds growth (Whitham *et al.*, 1991; Briske, 1996; Torrano & Valderrabano, 2004).

There is an ongoing debate between those who suggest that herbivory effects might be beneficial to the plants by increasing plant productivity and biological success of the plant (Paige & Whitham, 1987) opposed to those who believe that herbivory is

detrimental for plants (Belsky, 1986) due to the different physiological and morphological characteristics of plants. Different ecological groups' resistance to grazing has indeed been ordered according to their morpho-physiological adaptations (Whitham *et al.*, 1991). However, intercalary and apical meristems in herbaceous monocotyledonous plants are less vulnerable to grazing by large herbivores because of their basal location, in contrast with the sprouting shoots of herbaceous dicots' which are found in lateral or terminal positions, increasing the likelihood of damage to the plants by grazing animals (Briske, 1996). In some parts of the world, the lack of grasses has even been linked to the absence of large herbivores, as these plants are well adapted to grazing conditions (Torrano & Valderrábano, 2004).

In a study by Manley *et al.* (1997), continuous or season-long, 4-pasture delayed rotation, and 8-paddock time-controlled rotation grazing on mixed-grass rangeland under light, moderate and heavy stocking rates were compared near Cheyenne, Wyoming from 1982 through 1994. Results from this study indicated that stocking rate and grazing strategy had no effect on above-ground biomass and little effect on below-ground biomass. Under heavy stocking, forbs increased and therefore the forbs contributed to the above-ground biomass, especially under time-controlled rotation grazing increased. The effects of grazing strategy, slope vs. level, and north vs. south slope were however, insignificant on vegetation (Manley *et al.*, 1997).

Studies showed that the vegetative composition of mixed-grass rangelands, as well as the performance of grazing livestock is influenced by grazing pressure and/or stocking rates in Alberta, Canada (Smoliak, 1974; Dormaar *et al.*, 1994), Montana (Reed & Peterson, 1961; Houston & Woodward 1966), and North Dakota (Rauzi 1963; Brand & Goetz 1986). However, almost no change was observed after only 4 years of grazing in Montana (Vogel & Van Dyne, 1966) and North Dakota (Hofmann & Ries, 1989), illustrating the need for long term studies to measure grazing impacts.

Quality and availability of veld are also subject to differences in annual rainfall and distribution with differences in botanical composition and stocking rate (Fourie, 1983; De Waal *et al.*, 1989).

3.3.3 Veld management - definitions and implications

3.3.3.1 Carrying capacity:

Carrying capacity was defined as the area of land required to maintain an animal unit through utilization of the vegetation in order to achieve maximum profit in the short term - while maintaining the condition of the vegetation and soil in such a way as to be able to fulfil the needs and aspirations of future land users (Van Oudtshoorn, 1991).

3.3.3.2 Grazing capacity

The term grazing capacity is often loosely used to describe the productivity of all vegetation on a farming unit. This is incorrect, as the term 'grazing' generally refers specifically to the utilization of grass by animals. The main difference, in practical terms, between stocking rate and grazing capacity of the veld can be explained as follows: the grazing capacity refers to the true number of animals that the vegetation can sustain and the stocking rate to the number of animals the manager perceived that the vegetation can sustain (Smit, 2009).

3.3.3.3 Browsing capacity

Grass is not necessarily the only forage source on a farming unit. Aucamp and Barnard (1980) showed that two clearly differentiated forage sources occur in grass/bush communities: firstly, that provided by the woody (tree) component of the vegetation and then that provided by the grass component. It is therefore logical that the productivity of the two components of the vegetation should be described separately. The carrying capacity of veld, where woody vegetation occurs, is the sum of its browsing capacity and its grazing capacity.

3.3.3.4 Ecological status of grasses

According to Van Oudtshoorn (1999) the ecological status of grasses refers to the grouping of grasses on the basis of their reaction to different levels of grazing. Grasses may increase or decrease in number as a reaction to grazing. Grasses and herbaceous plants have thus been classified as follows (Van Oudtshoorn, 1999):

- Decreasers – Grasses that are abundant in good veld, but that decrease in number when the veld is overgrazed or undergrazed. These grasses are palatable climax grasses such as *Themeda triandra* and *Digitaria eriantha*.
- Increaser I – Grasses that are abundant in underutilized veld. These grasses are usually unpalatable, rust climax species that can grow without any defoliation, such as *Trachypogon spicatus* and *Hyperthelia dissolute*.
- Increaser II – Grasses that are abundant in overgrazed veld. These grasses increase due to the disturbing effect of overgrazing and include mostly pioneer and subclimax species such as *Eragrostis rigidior* and *Aristida adscensionis*.
- Increaser III – Grasses that are commonly found in overgrazed veld. These are usually unpalatable, dense climax grasses such as *Elionurus muticus* and *Aristida junciformis*. These grasses are strong competitors and increase because the palatable grasses have become weakened through overgrazing.
- Invaders – Invaders are all plants that are not indigenous to an area. These plants are mostly pioneer plants or plants that invade the habitat of indigenous species and are difficult to eradicate. Examples of this plant species include *Lantana camara*, *Arundo donax* and *Tagetes minuta*.

3.3.3.5 Practical implications of stocking rate and carrying capacity of veld

Stocking rate is generally defined as the area of land in a management system that the farmer has allocated to each animal unit. Stocking rate is therefore an expression of the number of animals that the farmer actually runs on his veld. In a livestock enterprise, the stocking rate has the greatest influence on animal production, profitability and the long-term condition of the veld (Booyesen, 1975). It is necessary to stress that stocking rate is considerably more important than factors such as the grazing management system applied and the number of camps on a farm. A correctly stocked four-camp system is far more desirable than an overstocked multi-camp system (Danckwerts & Drewes, 1989).

For a farmer to make a success of a livestock enterprise, the stocking rate that is set, must fulfil

- (a) his financial requirements, and
- (b) the biological requirements of the veld.

If either is neglected, the system will ultimately fail (Danckwerts & Teague, 1989).

Although the farmer knows that overgrazing is one of the most important reasons for veld deterioration, the temptation is always there to increase animal numbers to increase income. However, if this results in stocking rates being applied in excess of the carrying capacity, then such action is short-sighted. In the long term, overstocking will result in veld deterioration and decreased financial return. Increasing the stocking rate beyond the carry capacity of the veld may well even result in immediate decrease in financial return (Danckwerts & Teague, 1989).

When studying the generalised relationship between stocking rate and animal production per head (be it live weight gain, milk production or wool production) it can be seen that animal production per head will remain constant at very light stocking rates, after which it drops as the stocking rate increases. In contrast, total animal production per hectare increases with increasing stocking rate up to a critical stocking rate, after which it drops rapidly (Jones & Sandland, 1974).

The carrying capacity of veld is generally somewhere between the two stocking rates where maximum production per hectare (the critical stocking rate) and maximum production per head and occur. When operating at the critical stocking rate, any increase in stocking rate will result in decreased overall production of saleable animal products, resulting in decreased financial returns. A farmer would therefore, under these circumstances be investing in his own insolvency (Danckwerts & Teague, 1989).

3.3.3.6 Rotational grazing

Booyesen (1967) defined rotational grazing as the type of management which requires that the grazing allocated to a group or groups of animals for the entire grazeable period be subdivided into at least one enclosure more than the number of animal groups. Successive grazing of these enclosures in rotation is thus involved so that not all the veld is grazed simultaneously (Trollope *et al.*, 1990). Rotational grazing involves greater animal concentrations than is characteristic of continuous grazing (Tainton, 1999).

Rotational grazing has 3 primary objectives:

- 1.) to control the frequency at which the plants are grazed by controlling the frequency at which each camp in the system is being grazed;

- 2.) to control the intensity at which the plants are grazed by controlling the number of animals which graze each camp and their period of occupation; and
- 3.) to reduce the extent to which the veld is selectively grazed by confining a relatively large number of animals to a small proportion of the veld so as to offer them little opportunity to select.

3.3.3.7 High utilization grazing (HUG) and controlled selective grazing (CSG)

Controlling the intensity of defoliation of individual plants is difficult since animals invariably graze selectively. Rotational grazing systems include non-selective grazing (NSG), controlled selective grazing (CSG), high-utilization grazing (HUG) and high-performance grazing (HPG). These systems vary in grazing intensity and the degree of selection (Tainton, 1999). Diagram 3.3.1 shows the procedures to achieve optimum animal production and maintenance of plants in a rotational grazing system. In the current study the two grazing systems applied were CSG, where animals were moved from one camp to the next when approximately 30% of available grass dry matter was utilized and HUG where animals were moved from one camp to the next when approximately 60% of available grass dry matter was utilized.

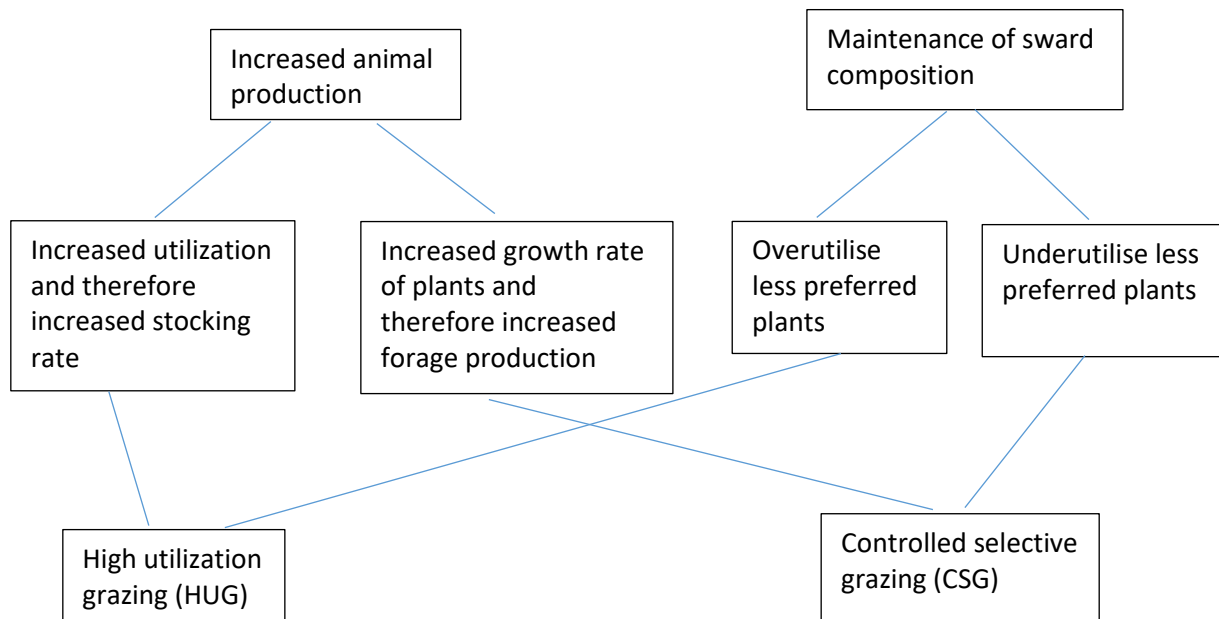


Diagram 3.3.1 Alternative procedures for achieving the objectives of rotational grazing (Tainton & Booysen, 1978).

CHAPTER 4

The effect of controlled breeding on the reproductive performance of an extensive beef cattle enterprise

4.1 Introduction

Reproduction performance can be regarded as one of the main components influencing total herd efficiency in extensive beef cattle production systems. It is therefore essential that the local quoted calving percentage of 62% (Scholtz *et al.*, 2008) in the commercial beef sector of South Africa needs to be improved. If the generally long calving seasons are shortened and calving percentage increase, more and heavier calves of a uniform age can be weaned (Grobler *et al.*, 2013). Cows calving earlier in the season have an extended “recovery period” and have the opportunity to calve in a better body condition during the next season, compared to cows calving late in the season (Odhiambo *et al.*, 2009).

4.2 Aim

The aim of the study was to evaluate the effect of oestrous synchronization, followed by natural mating on calving percentage and the distribution of actual calvings. This was done to establish if oestrus synchronization can lead to an increase in the total weight of calves weaned from a limited calving season, most likely by decreasing the days to calving, but also by increasing the number of calves born from a limited calving season.

4.3 Materials and methods

The study initially started in 2009 with 92 Bonsmara cows in an extensive production system, grazing natural vegetation described as Savanna (Rutherford & Westfall, 1994) or Sourish Mixed Bushveld (Veld Type 19) (Acocks, 1988). The cows were divided into two herds. Each herd was divided into two sub-herds ($n = 23/\text{sub-herd}$ in 2009).

All four sub-herds had similar weights, age structure, calving parity and were genetically comparable. Herd A was subjected to high utilization grazing and Herd B was subjected to controlled selective grazing. Results regarding grazing strategies are discussed in Chapter 6 and Chapter 7.

In each of the four sub-herds approximately half the cows were oestrus-synchronized prior to breeding and the other half served as the control within each individual herd (Table 4.1).

Table 4.1 Layout of oestrous synchronization of the four sub-herds

	Herd A				Herd B			
Sub-herds	A1		A2		B1		B2	
Synchronization	Yes	No	Yes	No	Yes	No	Yes	No

The breeding season commenced early January until March every year and the calving season commenced in October until end of December. The same individual cows were subjected to synchronization throughout the project (2009-2014). Each year heifers were included and approximately half of them were synchronized. Results of heifers calving for the first time are discussed in Chapter 5. Synchronization was done at the onset of the breeding season within the first week of January of each consecutive year from 2009-2014.

One fertile breeding bull was used in each sub-herd (2009-2011) for 90 days after the onset of the breeding season. All breeding bulls used were 3 years old at the onset of the project in 2009. According to Deutscher, (1991) variation in cows serviced per bull can vary between 5 and 20 during a 24-hour period. Two fertile breeding bulls were included in each sub-herd from 2012 to 2014, due to the increase in cow numbers of the sub-herds as no cows were culled from 2012 onwards.

Calves were weaned at an average age of 7 months each year and performance traits, including reproduction performance, were recorded throughout the project. A detailed description of the study layout is discussed in Chapter 2.

4.4 Results and discussion

The calving percentage of cows and heifers will be discussed separately as a significant difference ($P>0.05$) was found between calving percentage of multiparous cows, heifers mated for the first time at 14 months and heifers mated for the first time at 26 months. Reproduction of the heifers is discussed in detail in Chapter 5.

4.4.1 Calving percentage

Over the six-year period, no significant difference ($P=0.52$) was recorded in calving percentage of cows that were either synchronized at the beginning of the breeding season and cows that were bred naturally without synchronization (Table 4.2). There was however, a significant difference ($P=0.04$) between years in respect of calving percentage over the six-year period indicating that other factors, such as climate and weather patterns may have a big effect on reproduction over the six-year project results. Calving percentage was the highest during the first calving season (2009) and lowest in the second calving season (2010).

Table 4.2 Mean calving percentage of cows mated naturally with or without Oestrus synchronization \pm SD over a six-year period

Synchronization			
Year	Yes	No	Mean ^A
2009*	93.0 \pm 8.8	86.3 \pm 4.3	89.6 \pm 7.4 ^a
2010*	61.5 \pm 8.4	60.3 \pm 7.9	60.9 \pm 7.6 ^b
2011*	77.5 \pm 17.1	68.7 \pm 16.5	73.1 \pm 16.2 ^b
2012*	62.2 \pm 19.6	80.0 \pm 20.0	71.1 \pm 20.6 ^b
2013**	65.7 \pm 18.5	72.4 \pm 9.1	69.1 \pm 14.0 ^b
2014**	62.0 \pm 15.6	85.9 \pm 4.7	61.5 \pm 12.4 ^b
Mean over 6 years	70.3 \pm 17.9	71.4 \pm 14.7	71.4 \pm 14.7 ^b

^A ^{a,b}Means with different superscripts in this column differ significantly ($p \leq 0.05$)

LSD($p=0.05$) Years = 15.8

*Oestrous synchronization product: Crestar®

**Oestrous synchronization product: CIDR®

A possible factor that could have contributed to the highest calving percentage in 2009 and the lower calving percentage in 2010 and 2014 is differences in the rainfall and ambient temperature over the six-year period. Table 4.3 indicates that the annual rainfall was below 700mm in 2010 and above the average rainfall with 1324mm in 2009.

Table 4.3 Average annual rainfall during the study period for the respective years in the Central Bushveld bioregion (AgroClimatology Staff., 2015)

Year	Rainfall (mm)
2009	1324
2010	772
2011	1025
2012	676
2013	685
2014	664
mean	858

Table 4.4 shows the minimum and maximum temperature - indicating that 2009 and 2011 were the only two years with maximum temperature for the warmest month (February), below 30°C.

Table 4.4 Monthly minimum and maximum temperatures (°C) over the six-year project period at Roodeplaat, Pretoria (AgroClimatology Staff., 2015)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2009	18/30	16/29	14/28	9/28	6/22	4/22	1/20	4/23	9/29	14/29	14/28	16/29
2010	18/29	16/31	15/30	13/24	8/24	2/21	4/21	4/25	9/30	14/32	16/30	16/29
2011	17/28	16/29	15/30	12/25	6/24	1/21	1/20	4/24	8/29	12/29	14/30	17/29
2012	17/31	17/31	14/30	9/26	6/26	2/22	3/23	5/25	9/26	12/28	14/29	16/29
2013	17/31	16/32	14/30	9/26	5/25	2/23	3/22	4/24	11/29	12/29	15/30	16/28
2014	17/31	17/30	17/24	10/25	6/25	2/22	2/21	5/23	10/29	12/29	15/27	17/28

Bedell and Ganskopp (1980) reported that in extensively managed cows, oestrus can be delayed, pregnancy rates decreased and calf body weight at weaning reduced, during drought conditions. However, Mulliniks *et al.* (2012) found that yearly rainfall did not account for variation in days to first postpartum ovulation, pregnancy rates or days to lowest body weight, meaning that rainfall distribution, temperature, humidity and other climatic factors may also play an important role in annual cow productivity. However, rainfall prior to the breeding season and rainfall within the breeding season may have

had an effect on forage quality, forage quantity, as well as cow comfort. This may be the reason for the high calving percentage in 2009.

The mean calving percentage including all treatment groups varied between 61% and 90%, which is in line with results of Patterson *et al.* (2005b) who reported calving percentages of between 60% and 94% for different experimental herds, while Deutscher (1991) reported pregnancy rates after synchronization making use of natural service by bulls of 60 to 80 %. The calving percentage for the project in 2010 (61%) and 2014 (62%) were close to the quoted national calving percentage of 62% in the commercial beef sector of South Africa (Grobler *et al.*, 2013) and 2009 (90%), 2011(73%), 2012 (71%) and 2013 (69%) were above the national average.

The statistical analysis indicate that only year has a significant influence on calving percentage as indicated in Table 4.5.

Table 4.5 Analysis of variance (ANOVA) table for calving percentage of cows – no significant difference between different grazing strategies / sub-herds / synchronization

Source	DF	Mean square	P
Herd (Herd A & Herd B)	1	147	0.15
Rep with Herd (Sub herd:A1,A2,B1,B2)	2	16.0	0.63
Treatment (sync/non sync)	1	15.8	0.52
(Grazing strategy) x (sync/non sync)	1	27.3	0.42
Error (a)	2	27.1	
Year	5	874	0.01
Year x Herd (A & B)	5	417	0.15
Year x Treatment (Sync/non-sync)	5	191	0.54
Year x Herd x Treatment	5	29.5	0.98
Error (b)	20	229	
Total	47		

A1=Herd subjected to high utilization grazing; A2=Herd subjected to high utilization grazing; B1=Herd subjected to controlled selective grazing; B2=Herd subjected to controlled selective grazing; Sync=oestrus synchronization prior to breeding season; Non-sync=Mated naturally without oestrus synchronization

Calving percentage over the different years differed significantly and both the highest calving percentage of 95% in 2009 and lowest calving percentage of 51% in 2014 were obtained for the synchronized cows in Herd B subjected to the controlled selective grazing strategy (Figure 4.1).

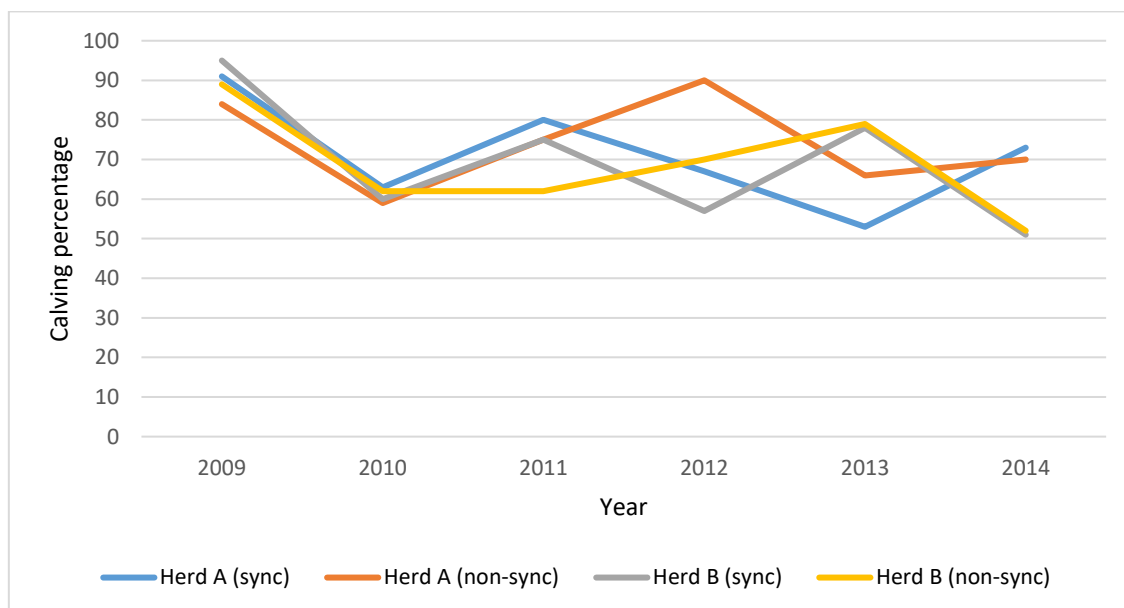


Figure 4.1 Calving percentage of cows in herd A and herd B over a six-year period

4.4.2 Days from breeding to calving

In the current study, the days to calving was calculated by the number of days from when the cows were joined until calving. It was assumed that cows conceiving from the synchronized oestrus mating, will calve within 293 days from breeding. In the study conducted by van Graan *et al.* (2004), it was found that the gestation length of Bonsmara cows is 286 \pm seven days. The days 294-306 after the beginning of the breeding season, accounts for the rest of the first 21 day oestrous cycle within the breeding season. Days 307-327 accounts for the second breeding/oestrous cycle and days 328-348 represents the third oestrous cycle. The days >348 represents the cows which calved late in the breeding season after the third oestrous cycle. In Figure 4.2 average days to calving (including both Herd A and Herd B) after the beginning of the breeding season for synchronized and non-synchronized Bonsmara cows over the six-year project are indicated.

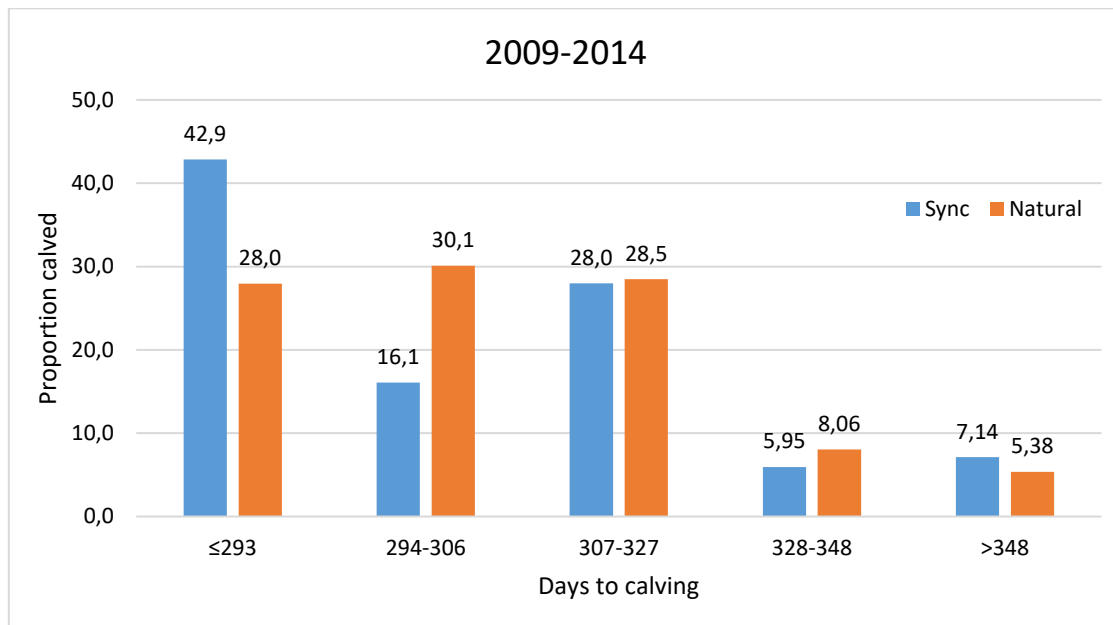


Figure 4.2 Proportion of days to calving from breeding to conceiving for synchronized and non-synchronized multiparous Bonsmara cows over a six-year period (2009-2014).

When looking at the average days to calving after the beginning of the breeding season from 2009 to 2014 in Figure 4.2, it is clear that more synchronized cows calved earlier in the calving season and cows in anoestrous started cycling again. The cows that calved earlier in the season also had a longer recovery period and according to Odhiambo *et al.*, (2009), reduced lactational stress. Cows calving early in the breeding season's calf crop can be weaned earlier or weaned heavier. Earlier weaning may lead to increased body energy reserves at calving and minimize the effect of a negative energy balance on the postpartum interval and the subsequent breeding performance. In a study conducted by Holm (2006) where beef heifers were inseminated after synchronization, it was concluded that synchronization may lead to an increase in the total weight of calves weaned from a limited calving season - most likely by decreasing the days to calving, but also by increasing the number of calves born. Seasonal patterns in growth and mortality rates (caused by disease or climate) can also contribute to an increase in the total weight of calves weaned if the concentrated calving season is synchronized with the "safe" (season conducive to cow and calf health) season, but can similarly have a negative effect if synchronized with the "unsafe" (season detrimental to cow and calf health e.g. excessive heat, cold, drought conditions) season.

The days to calving after the beginning of the 2009 breeding season is illustrated in Figure 4.3. The average days to calving from the start of the breeding season were 24 days less than that of the non-synchronized cows. Calves born from the synchronized group were therefore on average 24 days older than the calves born from the non-synchronized animals. With an average daily gain of 720g/day, the calves born from the synchronized cows produced calves weighing on average 17kg heavier at weaning, when the calves are weaned on the same date.

The days to calving from 2009-2014 indicate that a higher percentage of synchronized cows calved within the first week of the breeding season. This is higher than the cows that were not synchronized for year 2009, 2010, 2013 and 2014 as shown in Figure 4.3, Figure 4.4, Figure 4.7 and Figure 4.8. In 2011 (Figure 4.5) there was only a difference of 4.33 percent between oestrus synchronized cows and non-synchronized cows which calved within the first week of the breeding season (≤ 294 days). In 2012 there was no difference between the groups when looking at days to calving less than 294 days.

In a study by Nath *et al.* (2004) nine out of ten postpartum anoestrus cows exhibited oestrus after Crestar® treatment and five out of nine cows that ovulated after the induced oestrus conceived. A low conception rate of 55.6% was recorded, but only cows in postpartum anoestrus were used. Nath *et al.* (2004) also reported a fairly low conception rate of 56.2% in postpartum crossbred cows following combined hormonal treatment of progesterone and PMSG.

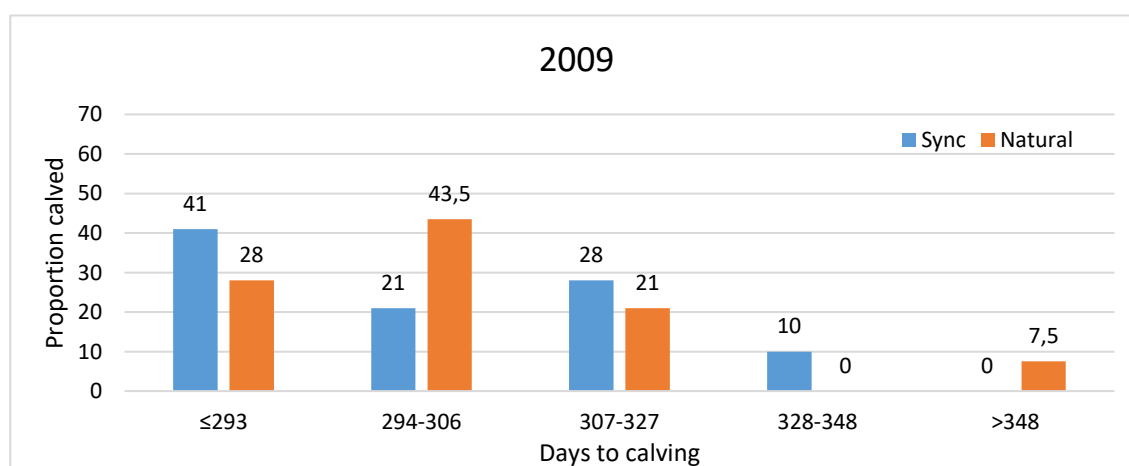


Figure 4.3 Proportion of days to calving from breeding to conceiving for the 2009 breeding season, including synchronized and non-synchronized multiparous Bonsmara cows

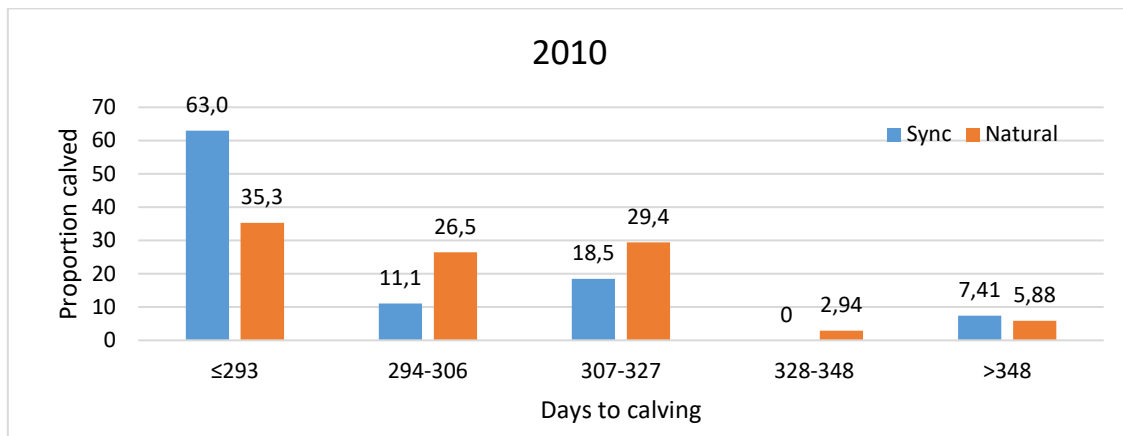


Figure 4.4 Proportion of days to calving from breeding to conceiving for the 2010 breeding season, including synchronized and non-synchronized multiparous Bonsmara cows

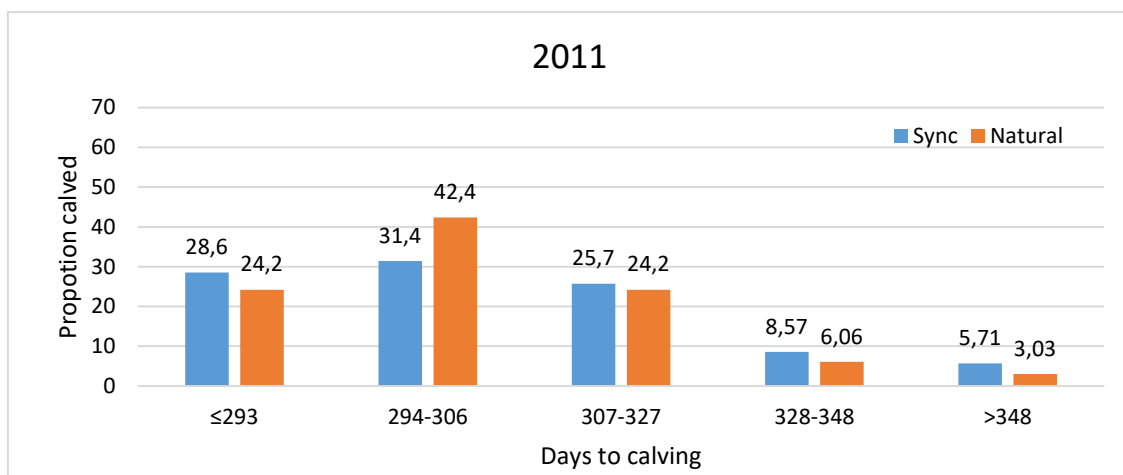


Figure 4.5 Proportion of days to calving from breeding to conceiving for the 2011 breeding season, including synchronized and non-synchronized multiparous Bonsmara cows

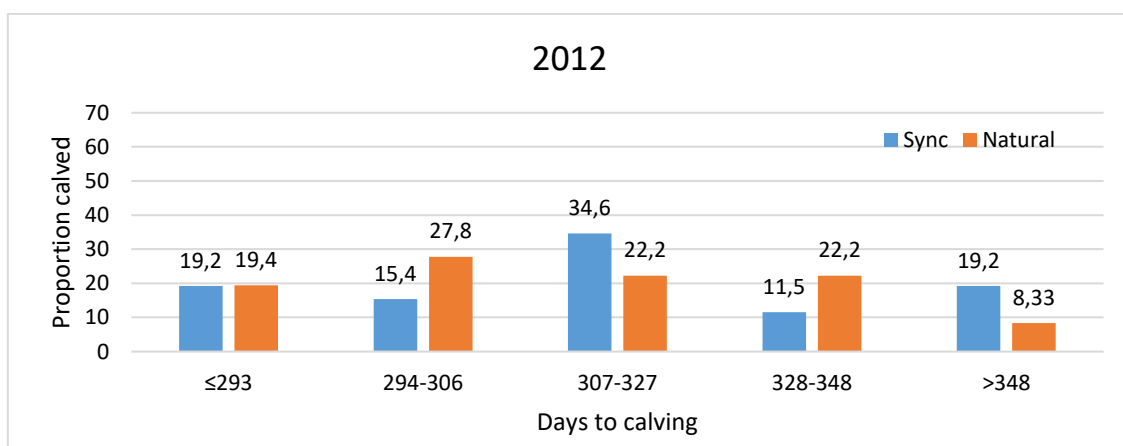


Figure 4.6 Proportion of days to calving from breeding to conceiving for the 2012 breeding season, including synchronized and non-synchronized multiparous Bonsmara cows

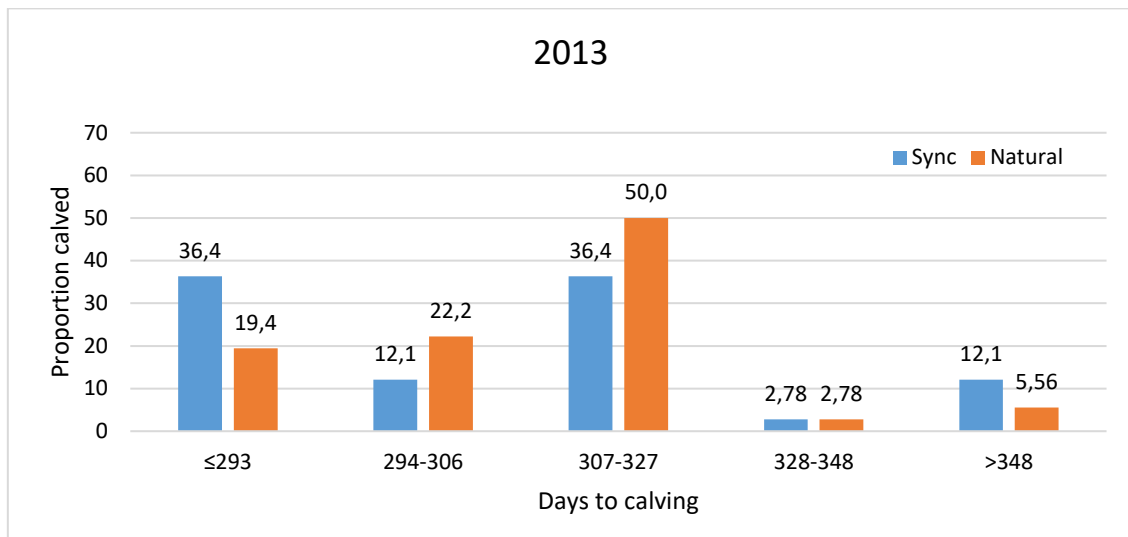


Figure 4.7 Proportion of days to calving from breeding to conceiving for the 2013 breeding season, including synchronized and non-synchronized multiparous Bonsmara cows

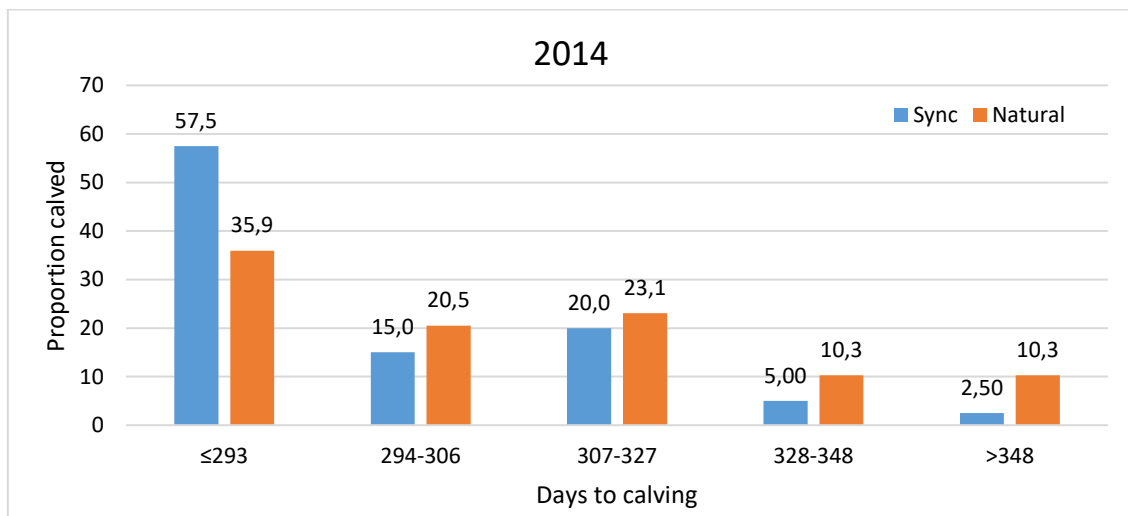


Figure 4.8 Proportion of days to calving from breeding to conceiving for the 2014 breeding season, including synchronized and non-synchronized multiparous Bonsmara cows

In a study conducted by Lamb *et al.* (2007) to determine whether insertion of CIDR® for 7 days prior to the breeding season and removing the CIDR® on the day the bulls were introduced to the cowherd would alter the overall pregnancy rates, average days to conception, and the subsequent calving distribution. Results from the study is indicated in Figure 4.9 and is in line with results from the current study.

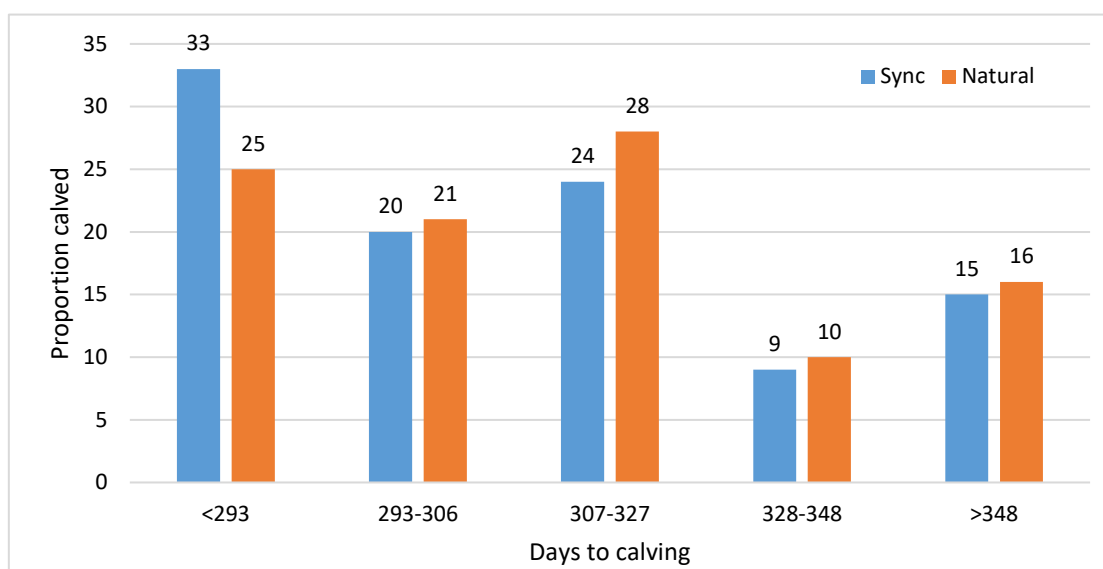


Figure 4.9 Proportion of cows conceiving at various intervals of the breeding season for cows in Control or CIDR® treatments (adapted from Lamb *et al.*, 2007)

In the Lamb *et al.* (2007) study, the pregnancy rates ranged from 59% to 99%, while the pregnancy rates in the current study varied between 60% and 93%. Similar to results found in the current study, no difference in calving percentage was recorded between the CIDR® treated and non-synchronized cows, however the oestrus-synchronized cows average days to conception was shorter ($P \leq 0.05$). Oestrous synchronized cows conceiving within the first 10 days of the breeding season was 8% higher than for the non-synchronized cows. In the current study the difference between synchronized cows conceiving within 293 days after breeding and the non-synchronized cows were 13% higher for synchronized cows in 2009 (Figure 4.3), 27% higher in 2010 (Figure 4.4), 4% in 2011 (Figure 4.5), no difference in 2012 (Figure 4.6), 17% in 2013 and 22% higher for synchronized cows in 2014 than for non-synchronized cows. Over the six-year project period (Figure 4.2) the difference in percentage of cows conceiving within 293 days after the onset of the breeding season between cows that were oestrus synchronized and non-synchronized was 15%.

The direct benefit of a synchronization protocol is the fact that a higher total weight of calves can be weaned (Holm *et al.*, 2008). In the current study the synchronized cows weaned on average calves that were 5kg heavier when looking at the 205-day corrected weaning weight, than the cows that were not synchronized although this difference was not significant (Table 4.6).

Table 4.6 Mean calf weaning weight \pm SD of calves conceived from cows mated naturally with or without Oestrus synchronization over the six-year study period

	Synchronized	Non synchronized
Mean calf weaning weight (kg)	183.3 \pm 33.3	178.8 \pm 30.8

At an assumed weaner price of R18/kg live weight this difference may translate into R90 more per calf. The direct cost of different synchronization products excluding veterinary and labour costs differ currently between R56.30 (14% vat included) for a single treatment of cloprostenol sodium injection to R113 (14% vat included) for a progesterone infused intravaginal device including a 1mg/ml oestradiol benzoate injection treatment. Thus the direct benefit per cow would be between – R23 and R33.70. However, the calving percentage of 71% for both synchronized and cows not being synchronized must also be taken into account as not all treated cows raised a calf. Therefore, it can be concluded that it is not economically viable to synchronize multiparous cows, managed under extensive conditions. The financial benefit of synchronization will thus depend on cost of synchronization weighed against weaning weight, weaning percentage and the price per kg of weaned calves.

4.4.3 Cow weight at calving

Over the study period, the mean cow age of different sub-herds changed over time due to subsequent mortalities and heifers calving to become cows. Therefore, cow weight was corrected for cow age by using cow age as covariate in the weight analysis.

No significant difference in cow weight at calving ($P \leq 0.05$) was recorded in 2009, 2010, 2011, 2012 and 2014 respectively, for cows in different sub-herds that were either synchronized or not synchronized prior to the mating season. There was however a significant difference between cow weight at calving between herd A (HUG) and herd B (CSG) that were either synchronized or not synchronized in 2013 (Table 4.7). When looking at mean body weight at calving for synchronized and non-synchronized cows over the six-year observation period, in all four sub-herds, the group of cows that were synchronized recorded an average weight that was slightly higher than that for the non-synchronized cows - indicating that synchronization may have a positive impact on cow weight at calving over time. This may be due to synchronized cows having a longer

recovery period before the next calving when compared to cows that were not synchronized.

Table 4.7 Adjusted Means \pm SE for cow weight at calving (kg) for cows in different sub-herds that were either synchronized or not synchronized prior to the mating season

Herd	Synchronized	2009	2010	2011	2012	2013	2014
A	Yes	445 \pm 17.1	486 \pm 18.4	421 \pm 15.5	431 \pm 16.1	457 \pm 16.6 ^b	404 \pm 16.1
A	No	448 \pm 19.0	465 \pm 16.2	440 \pm 14.1	436 \pm 12.2	406 \pm 12.5 ^{a,b}	424 \pm 16.6
B	Yes	439 \pm 17.7	456 \pm 18.3	418 \pm 14.7	469 \pm 15.0	431 \pm 12.2 ^{a,b}	430 \pm 19.8
B	No	469 \pm 17.7	437 \pm 17.7	448 \pm 16.5	454 \pm 14.2	410 \pm 12.2 ^b	395 \pm 18.4
Mean	Yes	442 \pm 12.3	471 \pm 13.0	420 \pm 10.5	450 \pm 11.0	444 \pm 10.3 ^a	417 \pm 12.7
Mean	No	458 \pm 13.0	451 \pm 12.0	444 \pm 10.8	445 \pm 9.4	408 \pm 8.7 ^b	409 \pm 12.4

^{a,b}Means in a column with different superscripts differed ($P \leq 0.05$)

Body condition score was measured at breeding from 2012 onwards. Table 4.8 shows cow body condition score at breeding, from cows that weaned a calf the previous season. Mean body condition score did not differ significantly ($P \leq 0.05$) between cows that were either synchronized or not synchronized. However, there was a significant difference ($P \leq 0.05$) between years (Table 4.8). Body condition score from 2014 differed significantly from both 2012 and 2013. The highest body condition score at breeding was achieved in 2014 for synchronized cows in herd A and the lowest body condition score of 2.41 was found in 2013 for non-synchronized cows also from herd A.

Table 4.8 Mean body condition score \pm SD for cows at breeding from different sub-herds 2012 to 2014

Herd	Synchronized	2012	2013	2014
A	Yes	2.63 \pm 0.55 ^{cd}	2.95 \pm 0.98 ^{abc}	3.35 \pm 0.37 ^a
A	No	2.72 \pm 0.67 ^{bcd}	2.41 \pm 0.67 ^d	3.34 \pm 0.41 ^a
B	Yes	2.79 \pm 0.75 ^{bcd}	3.00 \pm 0.80 ^{abc}	3.12 \pm 0.42 ^{ab}
B	No	3.11 \pm 0.53 ^{ab}	3.08 \pm 0.73 ^{abc}	2.97 \pm 0.55 ^{abc}
Mean		2.81 \pm 0.64 ^b	2.86 \pm 0.81 ^b	3.21 \pm 0.45 ^a

^{a,b,c,d}Means followed by the same letter are not significantly different at the 5% significance level

LSD($p=0.05$) Year x Herd x Treatment = 0.456

LSD($p=0.05$) Year = 0.223

4.5 Conclusion

Results from this study showed that calving percentage did not differ significantly ($P=0.54$) between cows that were either synchronized by administration of exogenous progestogens in combination with oestrogen by means of Crestar® (2009-2012) and CIDR® B (2013-2014) or not synchronized followed by natural mating. These results are consistent with other similar studies (Hanlon, 1995; Lamb *et al.*, 2007). Body condition score from cows at breeding, from cows that weaned a calf the previous season, did not differ significantly between synchronized and non-synchronized cows. The average weaning weight of calves born from synchronized cows tend to be heavier than for calves born from non-synchronized cows over the six-year study period. This result is however not significant.

Oestrous synchronization prior to natural mating did influence the average days to conception. Oestrous synchronized cows calved earlier in the calving season, except for 2012 leading to a longer recovery period. This finding is also consistent with previous published reports and may provide a practical way to decrease the length of the breeding season and increase the cow “recovery period” before the next breeding season to improve subsequent reproductive performance in beef cows (Lamb *et al.*, 2007; Odhiambo *et al.*, 2009 and Grobler *et al.*, 2013). In the current study there was no cost benefit from synchronizing the cows prior to natural mating.

CHAPTER 5

The effect of age at mating on cow productivity

5.1 Introduction

In general, beef heifers are managed to calve for the first time at three years of age, but in many studies calving at two years of age have been advocated (Fahmy *et al.*, 1971; Meaker *et al.*, 1980; Nunez-Dominguez *et al.*, 1991). According to van Niekerk *et al.*, (1990) replacement heifers are not generally mated before the age of 24 months because of the extensive nature of the majority of beef enterprises in South Africa. Scholtz *et al.*, (1991) concluded that there is no consensus on the advantages of early breeding of beef heifers in South Africa.

5.2 Aim

The aim of the study was to establish if breeding replacement heifers at 14 months have an economic advantage over breeding heifers at 26 months in terms of reproductive performance in an extensively managed beef herd.

5.3 Materials and methods

The Bonsmara heifers were divided, together with the multiparous cows, into two herds (Herd A and B), subdivided into four sub-herds (Sub-herd A1 and A2 and Sub-herd B1 and B2). Breeding took place during a three-month summer breeding season (January to March) in an extensive production system on natural Sourish Mixed Bushveld.

Heifers were bred when at either 26 months (Sub-herd A1 and Sub-herd B1) or 14 months (Sub-herd A2 and Sub-herd B2) of age at the onset of the breeding season (January). In each of the four sub-herds approximately half the heifers were oestrus-synchronized prior to breeding and the other half served as the control within each individual herd as discussed in Chapter two.

One fertile breeding bull was included in each sub-herd (2009-2011) for 90 days after the onset of the breeding season (ration of bulls to females varied from 21 to 34). Two fertile breeding bulls were included in each sub-herd from 2012 to 2014, due to the increase in animal numbers of the sub-herds, as no cows were culled from 2012 onwards (ration of bulls to females varied from 13 to 21). Heifers were managed throughout the study period with the multiparous cows and not kept separate from the multiparous cows.

A detailed description of the study layout is discussed in Chapter two.

5.4 Results and discussion

5.4.1 Calving percentage

The average calving percentage of 14 month old mated heifers varied between 0 and 67% and average calving percentage of 26 month old mated heifers varied between 58 and 100%. A significant difference ($P < 0.05$) was found between calving percentage of multiparous cows, 26 month old and 14 month old mated heifers. The average calving percentage over the six-year project period was 74% for the heifers mated at 26 months of age, much higher than the 18% for heifers mated at 14 months of age (Table 5.1). However, genetic and seasonal differences must account for most of the variation in age at puberty among uniform heifers that were managed together as a group. The calving percentage of heifers mated at 26 months, was in line with the average of the multiparous cows of 71%. Only project progeny was available as replacement heifers and therefore only a few heifers were available for breeding and this may limit the results. It must be noted that this project was conducted in an extensive production system and available literature indicates that conception rates of 14 month old heifers, may be higher in semi-extensive production systems (Meaker *et al.*, 1980; Nunez-Dominguez *et al.*, 1991; Lepen *et al.*, 1993).

Table 5.1 Mean calving percentage of heifers \pm SD over the six-year (2009-2014) project period

Years	Heifers 14 months Calving %	Heifers 26 months Calving %
2009	66.7 \pm 27.2 (n=12)	75.0 \pm 50.0 (n=8)
2010	25.0 \pm 16.7 (n=12)	100 (n=12)
2011	8.3 \pm 16.7 (n=11)	79.2 \pm 25.0 (n=9)
2012	0.00 (n=8)	70.8 \pm 21.0 (n=10)
2013	0.00 (n=12)	58.3 \pm 41.9 (n=12)
2014	8.33 \pm 16.7 (n=12)	62.5 \pm 16.6 (n=18)
Mean	18.1 \pm 27.8 ^a (n=67)	74.3 \pm 30.3 ^b (n=69)

^{a,b}Means with different superscripts in the bottom row differ significantly ($P \leq 0.05$)

LSD_(p=0.05) = 16.106

From Table 5.2 it can be seen that heifers that were synchronized prior to breeding had a slightly higher conception rate than heifers that were not synchronized prior to the breeding season on average over the six-year period. Calving percentage for heifers mated at 14 months was 19% for synchronized heifers and 17% for non-synchronized heifers whereas calving percentage for heifers mated at 26 months was 75% for synchronized heifers and 74% for non-synchronized heifers.

Table 5.2 Mean calving percentage of heifers \pm SD mated naturally with or without oestrus synchronization over a six-year period

Year	14 months (Synchronized)	14 months (Non-synchronized)	26 months (Synchronized)	26 month (Non-synchronized)
2009	66.7 \pm 47.1 (n=6)	66.7 (n=6)	50.0 \pm 70.7 (n=4)	100 (n=4)
2010	16.7 \pm 23.6 (n=6)	33.3 (n=6)	100 (n=6)	100 (n=6)
2011	16.7 \pm 23.6 (n=5)	0.00 (n=6)	83.3 \pm 23.6 (n=5)	75.0 \pm 35.4 (n=4)
2012	0.00 (n=4)	0.00 (n=4)	75.0 \pm 35.4 (n=4)	66.7 (n=6)
2013	0.00 (n=6)	0.00 (n=6)	83.3 \pm 23.6 (n=6)	33.3 \pm 47.1 (n=6)
2014	16.7 \pm 23.6 (n=6)	0.00 (n=6)	57.5 \pm 24.7 (n=9)	67.5 \pm 10.6 (n=9)
Mean	19.4 \pm 30.0 ^b	16.7 \pm 26.6 ^b	74.9 \pm 32.1 ^a	73.8 \pm 29.8 ^a

^{a,b}Means with different superscripts in the bottom row differ significantly ($P \leq 0.05$)

LSD_(p=0.05) = 22.777

Over the six-year period, no difference in calving percentage could be found between the two herds (Herd A and Herd B) or between heifers that were either synchronized or not synchronized. A significant difference was found between different years ($P = 0.02$) and heifer age at breeding ($P = 0.01$) as can be seen in Table 5.3.

Table 5.3 Analysis of variance (ANOVA) table for calving percentage of heifers over the observation period (2009-2014)

Source	DF	Mean square	P
Herd (Herd A & Herd B)	1	102	0.54
Heifer age at breeding (14 months/26 months)	2	19343	0.01
Treatment (sync/non sync)	1	14.1	0.81
(Herd) x (sync/non sync)	1	76.0	0.60
Error (a)	2	188	
Year	5	2198	0.02
Year x Herd (A & B)	5	1543	0.06
Year x Treatment (Sync/non-sync)	5	603	0.45
Year x Herd x Treatment	5	829	0.28
Error (b)	19	608	
Total	46		

5.4.2 Heifers mated at 14 months of age

The age when a heifer displays visual signs of oestrus for the first time can be defined as puberty (Pineda, 2003). Other authors prefer to use the age at first ovulation for the definition of puberty. This is not easily observed, and because it precedes first oestrus only by a few days, it does not have significant practical implication (Foster, 1994). However, a genetic relationship between age at puberty and growth traits (Brinks, 1994), may indicate the possibility of the need for a critical body weight to be reached for puberty to be induced (Stevenson, 1997). The heifers mated at 14 months in the current project had a significant lower calving percentage ($P \leq 0.05$) than the heifers mated at 26 months. Age at puberty is a moderately heritable trait ($h^2 = 0.43$) with a favourable correlation with yearling weight, weaning weight of the offspring, as well as lifetime production of the cow (Brinks, 1994). The onset of puberty in heifers is also affected by other factors including breed, seasonal effects, climate, bio-stimulation (presence of

bull) and nutrition. Seasonal differences, although less important in cattle (Pineda, 2003), may be caused due to heifers being at different stages of their development at varying times of the specific season. However, this variation in age at puberty will be relatively small in a group of heifers that were born during a short calving season. Seasonal and genetic differences must account for most of the variation in age at puberty between uniform heifers that are managed together as a group (Holm, 2006). King *et al.* (1983) reported that heifers born later in the calving season, reached puberty at a younger age than the heifers born early in the season, although their actual dates of onset of puberty in the breeding season were later.

Heifer weights at calving are indicated in Table 5.4. Although heifer weight at calving differed slightly from year to year, there was no significant difference over years for heifers bred at 14 months of age. Heifers mated at 14 months had a lower body weight at calving compared to heifers mated at 26 months (see Table 5.6), except for 2014 where heifers mated at 26 months of age had an exceptionally low weight at calving. Although studies have shown that up to 46% of heifers calving as 2-year-olds may experience calving difficulty (Bellows, 1968), in the current study no dystocia cases were reported, even in 2014 when the body weight was exceptionally low.

Table 5.4 The mean \pm SD heifer weight (kg) at calving for heifers mated at 14 months over the six-year period

Year	Herd A	Herd B
2009	320 \pm 15.8	317 \pm 26.7
2010	359	320
2011	310	0
2012	0	0
2013	0	0
2014	308	298.33 \pm 29.38

According to Sprott and Troxel (1988), heifers can be mated successfully at an early age when heifers are separated from the mature cow herd and fed to reach a target weight before breeding. In the current study, heifers were managed within the mature cow herd with no extra feed provided to reach target weights. This may be one of the reasons why conception rate of the yearling heifers was low.

The mean days to calving after the beginning of the breeding season for heifers mated at 14 months is shown in Table 5.5.

Table 5.5 Mean \pm SD days to calving for heifers 2009-2014

Herd	Oestrus synchronised	n	Days to calving \pm SD
A (14 months)	Yes	3	286 \pm 3.21 ^b
A (14 months)	No	3	321 \pm 30.2 ^a
B (14 months)	Yes	3	302 \pm 17.6 ^{ab}
B (14 months)	No	3	316 \pm 34.8 ^a

The heifers mated at 14 months conceived mostly from the synchronized oestrus and calved on average earlier in the calving season than the non-synchronized heifers. However, the average calving percentage over the six-year period for 14 heifers bred at 14 months was 18% (see Table 5.1)

The days to calving after the beginning of the breeding season for heifers mated at 14 months is shown in Figure 5.1.

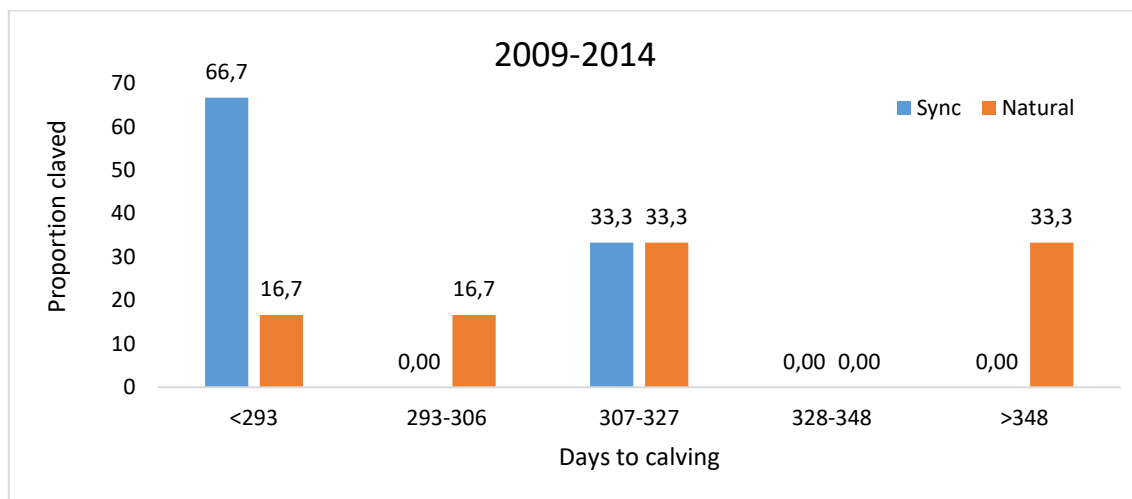


Figure 5.1 Proportion of days to calving from breeding to conceiving for synchronized (n=7) and non-synchronized (n=6) Bonsmara heifers mated at 14 months over a six-year period (2009-2014).

With the low calving percentage, it seems that mating heifers at 26 months of age in an extensive bushveld system may have an advantage over mating heifers at 14 months. This results are in line with Van der Merwe and Schoeman (1995) who concluded that early breeding of extensively managed Simmentaler heifers should not be considered as

a standard management practice. It seems unlikely that such a system can improve on the traditional extensive system on natural veld in South Africa and that an early breeding system was not self-maintaining (Van der Merwe & Schoeman, 1995).

5.4.3 Heifers mated at 26 months of age

When comparing calving percentage, heifer weight at calving and calf birth weight between heifers mated at 14 months and heifers mated at 26 months, there is a definitive advantage in mating heifers in an extensive system in the Sourish Mixed Bushveld area at 26 months.

Heifer weight at calving is shown in Table 5.6. There was a significant difference ($P \leq 0.05$) between 26 month old bred heifers weight at calving over the six-year project period. Calving weight was the highest in 2009 and 2010 for both herd A and herd B while the lowest weight at calving was recorded in 2014 for both herds.

Table 5.6 The mean \pm SD heifer weight (kg) at calving over the six-year period

Heifers mated 26 months		
Year	Herd A	Herd B
2009	401 \pm 43.8 ^{abc}	426 \pm 34.7 ^a
2010	413 \pm 29.3 ^{ab}	409 \pm 38.7 ^{ab}
2011	326 \pm 29.1 ^{de}	371 \pm 50.0 ^{bcd}
2012	371 \pm 22.2 ^{bcd}	324 \pm 20.5 ^{de}
2013	355 \pm 84.9 ^{cd}	335 \pm 31.3 ^{de}
2014	298 \pm 36.2 ^e	287 \pm 25.0 ^e

^{a,b,c,d,e}Means with different superscripts differ significantly ($P \leq 0.05$)

LSD($p=0.05$) = 54.28

Heifers bred at 26 months had a mean calving percentage of 74% while the heifers bred at 14 months had a mean calving percentage of 18% over the six-year project period (see Table 5.1).

Table 5.7 shows the mean days to calving after the beginning of the breeding season for both herd A (sub-herd A1 and A2) and herd B (sub-herd B1 and B2) for heifers mated at 26 months.

Table 5.7 Mean \pm SD days to calving for heifers bred at 26 months 2009-2014

Herd	Oestrus synchronised	n	Days to calving \pm SD
A	Yes	12	306 \pm 24.5
A	No	11	299 \pm 21.0
B	Yes	14	309 \pm 19.1
B	No	14	313 \pm 17.8

From Table 5.7 it is clear that there was no advantage in synchronizing 26 months old heifers at the beginning of the breeding season to ensure early conception. Patterson *et al.* (2007) also found inconsistent pregnancy rates in beef heifers being synchronized prior to breeding or fixed time artificial insemination. This may be attributed to an inability to synchronize follicular waves in heifers with the same degree of success that has been achieved in cows (Lamb *et al.*, 2006; Lamb *et al.*, 2010). In a study by Mallory *et al.* (2011) pregnancy rates of pubertal beef heifers treated with CIDR®'s after fixed time artificial insemination was found to be 59% with a pregnancy rate of 92% at the end of the breeding season.

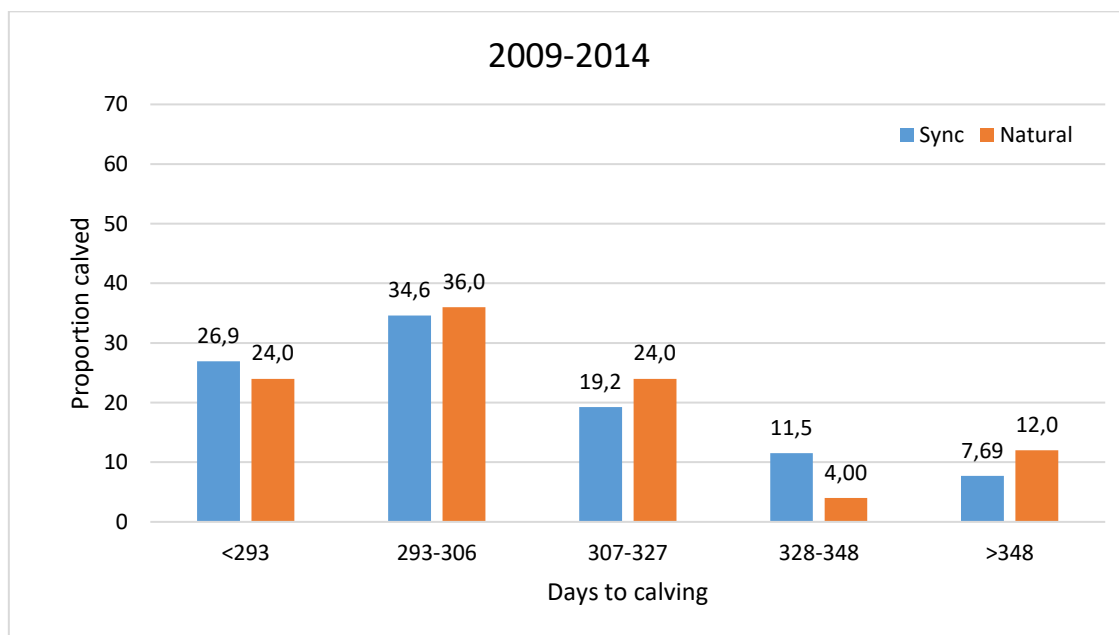


Figure 5.2 Distribution of days to calving from breeding to conceiving for synchronized (n=26) and non-synchronized (n=25) Bonsmara heifers mated at 26 months, over a six-year period (2009-2014).

From Figure 5.3, “Sync” refer to the current study where heifers were synchronized by means of a 12 day CIDR® insertion with 1mg oestradiol benzoate at time of device insertion followed by natural mating. “Natural” refers to natural mating without synchronization. Larson and Lamb (2005) followed the following protocols:

- (a) CIDR® insert for 7 days with 25mg PG on day of removal followed by timed artificial insemination;
- (b) CIDR® insert for 7 days with 100µg GnRH at CIDR® insertion and 25mg PG on day of removal followed by timed artificial insemination;
- (c) CIDR® insert for 7 days with 25mg PG on day of removal, followed in 60h by a second injection of GnRH followed by timed artificial insemination;
- (d) CIDR® insert for 7 days with 25mg PG on day of removal followed by timed artificial insemination and/or heat detection

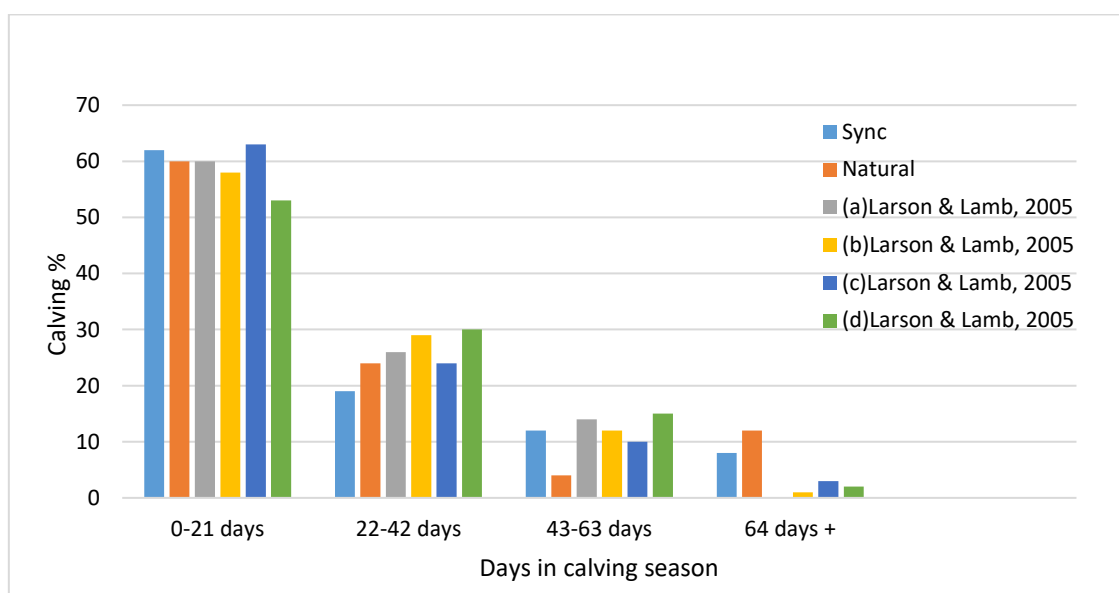


Figure 5.3 Distribution of calving season using different oestrous synchronization programs in post pubertal heifers, calving with their first calf

Results from the current study are in line with results found by Larson and Lamb (2005) who investigated different oestrous synchronization protocols - using CIDR® devices for post pubertal beef heifers following artificial insemination (Figure 5.3). It was found that calving percentages for synchronized heifers within the first 21 days of the calving season ranged between 53% and 63% while the calving percentage within the first 21 days of the calving season for heifers bred at 26 months was 62% for synchronized heifers and 60% for heifers bred without synchronization.

5.5 Conclusion

Conception rates of heifers mated at 26 months were significantly ($P < 0.05$) higher than heifers mated at 14 months of age. Seasonal differences must account for most of the variation in age at puberty amongst uniform heifers managed together as a group. It would seem that it may be more viable to breed Bonsmara heifers in an extensive production system in the Sourish Mixed Bushveld region at 26 months of age for the first time. The success of implementing mating heifers at 14 months of age will depend on nutritional and management levels, which under extensive farming conditions, will require additional supplementary input.

In the current study synchronization of 14 month old heifers did not improve conception rate over 14 month old heifers bred naturally. In the current study, results indicated that oestrous synchronization of 14 month old heifers did not show any economic benefit. Calving percentage of heifers bred at 14 months was very low and varied between 0% in 2012 and 2014 to 67% in 2009 with an average calving percentage of 19% over the six-year period.

Heifers bred at 26 months had a much higher calving percentage, varying between 58% in 2013 to 100% in 2010 with an average calving percentage over the six-year period of 74%. From the current study, it seems unlikely that breeding heifers at 14 months of age can improve on the 26-month old heifer breeding system on natural veld, with only lick supplementation without keeping heifers in separate groups. It must be noted that this research was conducted in an extensive production system and available literature indicates that conception rates of 14 month old heifers may be higher in semi-extensive production systems.

Geographical-region differences in the age at which heifers are first exposed for breeding will depend mainly on adaptation of respective breed types to specific environmental conditions, management systems as well as forage quality and availability. In some cases, the economic advantage of early calving and breeding may be counterbalanced by biological limitations of the animal and management constraints of the environment (Short *et al.*, 1990; Patterson, *et al.*, 2005a; Ahmadzadeh, *et al.*, 2011).

Furthermore, it must be noted that calving percentage of synchronized heifers bred at 26 months was 6% higher than the non-synchronized heifers which means not only heavier calves, but more weaner calves were available to the market. The financial benefit of synchronization will thus depend on cost of synchronization weighed against weaning weight, weaning percentage and the price per kg of weaned calves.

CHAPTER 6

Effect of Climate and grazing system on animal productivity

6.1 Introduction

The development of different grazing strategies came about the need to sustain the efficient use of natural veld by livestock over long periods of time (Manley, 1997). Several studies have been conducted in the past to measure the increase in cow-calf productivity by either utilizing different cattle breeds in grazing systems (Gregory *et al.*, 1978; Oliver, 1978; Knox *et al.*, 1982), utilizing legumes in grazing systems (Hoveland *et al.*, 1978; Stricker *et al.*, 1979; Morrow *et al.*, 1988) or by utilizing different calving seasons (Bagley *et al.*, 1987; Gaertner *et al.*, 1992; Ivy *et al.*, 1995). Although each of these management tools may have an impact on forage-livestock system productivity, the effects of forage-livestock management systems need to be evaluated in the specific climate, veld type and type of cattle.

6.2 Aim

The aim of this study was to measure the effects of climate and grazing systems on cow-calf production characteristics over a six-year period.

6.3 Materials and methods

The vegetation in the study area has been described as Savanna (Rutherford & Westfall, 1994), Sourish Mixed Bushveld (Veld Type 19) (Acocks, 1988), Clay Thorn Bushveld (Low & Rebelo, 1996) and Marikana Thornveld (Mucina & Rutherford, 2006) in the Savanna Biome, Central Bushveld bio-region. The stocking rate of 7ha/LSU, was strictly adhered to. The experimental herd, including 92 Bonsmara cows were divided into two herds, subdivided into two sub-herds (n=23 in 2009) of similar age and weight, subjected to either controlled selective grazing (related to the use of 30% available grass dry matter) or high utilization grazing (related to the use of 60% of the available grass

dry matter). The effect of the two grazing strategies on the veld is discussed in Chapter 7. A detailed description of the study layout is discussed in Chapter 2.

6.4 Results and discussion

6.4.1 Weather and discomfort index (DI)

The growing season for vegetation commences in early summer, which coincides with the summer rainfall period. The beef breeding season commenced early in January and ended in March each year. The calving season commenced in early summer, to likewise coincide with the active growing season of the natural veld from October to December. Calves were weaned in the dry winter season May/June as soon as the calf crop reached an average age of 7 months. This was the motivation for presenting the climatic data from July to June - to include a full growing season and animal production cycle, rather than presenting the data from the first calendar month of the year.

Table 6.1 summarizes the minimum and maximum temperatures (°C) over the observation period. The warmest months of the year were January and February and the coldest month, July. Mean daily minimum/maximum temperatures ranged from a minimum of 16 °C to a maximum of 30 °C in February (summer) to a minimum of 2 °C and a maximum of 21 °C in July (winter).

Table 6.1 Monthly minimum and maximum temperatures (°C) over the six year study period at Roodeplaat, Pretoria (AgroClimatology Staff., 2015)

Year	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
2008/2009	3/22	6/26	8/29	14/31	16/29	16/31	18/30	16/29	14/28	9/28	6/22	4/22
2009/2010	1/20	4/23	9/29	14/29	14/28	16/29	18/29	16/31	15/30	13/24	8/24	2/21
2010/2011	4/21	4/25	9/30	14/32	16/30	16/29	17/28	16/29	15/30	12/25	6/24	1/21
2011/2012	1/20	4/24	8/29	12/29	14/30	17/29	17/31	17/31	14/30	9/26	6/26	2/22
2012/2013	3/23	5/25	9/26	12/28	14/29	16/29	17/31	16/32	14/30	9/26	5/25	2/23
2013/2014	3/22	4/24	11/29	12/29	15/30	16/28	17/31	17/30	17/24	10/25	6/25	2/22
2014/2015	2/21	5/23	10/29	12/29	15/27	17/28	17/30	16/31	15/30			

Roodeplaat experimental farm is situated in a summer rainfall area with a mean annual rainfall for the past 10 years of 768 mm, of which 83% occurred from October to March. Table 6.2 shows that during the study period, the mean annual rainfall was 951mm, ranging from 676mm to 1324mm.

Table 6.2 Monthly total rainfall(mm) over the six-year study period at Roodeplaat, Pretoria (AgroClimatology Staff., 2015)

Year	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
2008/2009	3	0	0	38	107	108	212	128	74	3	30	31	734
2009/2010	2	125	386	93	94	147	126	33	48	178	53	0	1285
2010/2011	0	0	0	50	68	216	431	40	128	112	5	12	1062
2011/2012	0	5	1	64	68	164	65	104	81	7	1	0	560
2012/2013	0	0	74	109	81	154	90	32	79	98	1	0	718
2013/2014	0	0	7	104	87	187	68	181	86	26	1	0	747
2014/2015	0	1	1	30	95	175	136	34	72				
Average	1	19	67	70	86	164	161	79	81	71	15	7	851

From Figure 6.1, it can be seen that the rainfall distribution pattern follows a wet season, commencing in September/October and ends around March, followed by a dry season from April to September. The highest amount of rainfall occurred in December/January. A very high above average rainfall of 386mm was experienced in the month of September 2009, as well as January 2011 when the rainfall for the month was 431mm.

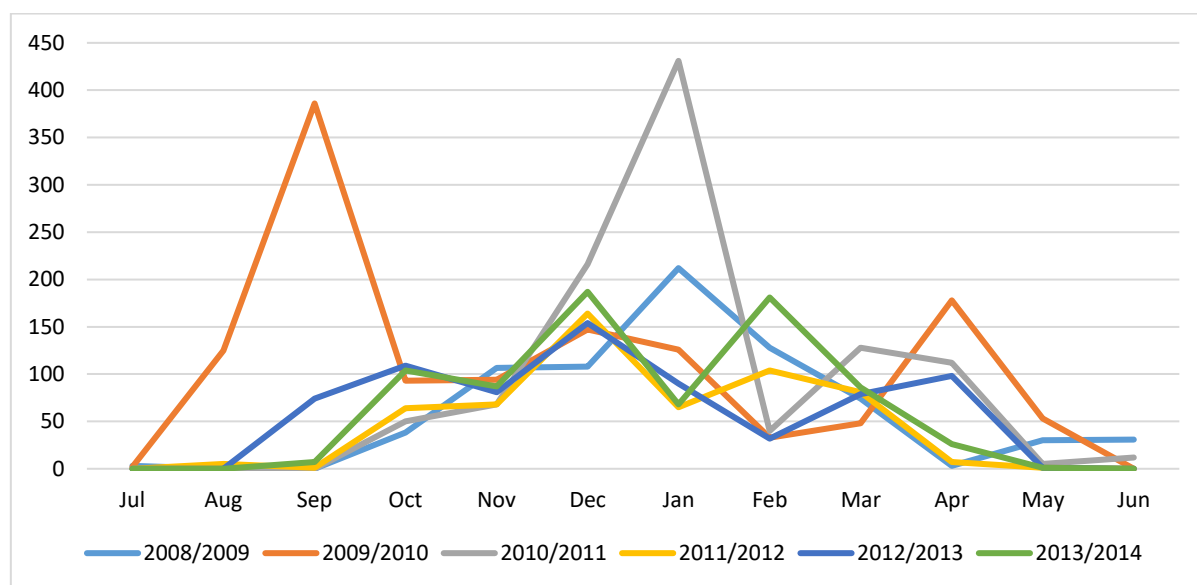


Figure 6.1 Rainfall (mm) distribution from July 2008 to March 2015 at the Roodeplaat experimental farm.

The average monthly minimum and maximum relative humidity (%) is set out in Table 6.3. Relative humidity, together with temperature were used to calculate a discomfort index. This index evaluates the impact of heat stress, taking into account the combined effect of temperature and humidity.

Table 6.3 Monthly minimum and maximum relative humidity (%) over the observation period at Roodeplaat, Pretoria (AgroClimatology Staff., 2015)

Year	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
2008/2009							42/89	41/90	34/91	26/90	29/91	28/87
2009/2010	20/85	21/84	1976	29/86	36/89	40/90	43/90	31/89	31/89	49/93	34/92	24/89
2010/2011	25/85	17/83	17/77	19/78	32/87	36/89	44/91	36/90	34/91	45/93	33/94	23/89
2011/2012	20/84	21/82	15/77	21/82	26/83	39/89	33/88	32/89	28/88	27/90	20/94	22/89
2012/2013	18/81	16/74	26/77	34/87	31/87	38/89	35/87	28/89	31/90	32/92	23/90	21/89
2013/2014	22/85	19/80	16/77	26/84	27/85	41/90	32/88	34/89	67/92	36/92	27/91	21/86
2014/2015	21/82	19/74	15/71	21/78	37/85	43/89						

The discomfort index calculated for each month during the project period is indicated in Table 6.4. It would seem that the equation by Thom (1959), Kibler (1964), and the NRC (1971) are popular methods of calculating a temperature humidity index by including different variables in different units (Gantner, *et al.*, 2011; Yousif & Tahir, 2013; Herbut & Angrecka, 2012; Hartman *et al.*, 2015). However, for the current study, the formula used to calculate a discomfort index was obtained from the local South African Weather Service (South African Weather Service, 2015), which is also used in livestock.

Table 6.4 Average monthly discomfort index (formula adapted from South African Weather Service) for the Roodeplaat experimental farm over the observation period

Year	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mr	Apr	May	Jun
2008/2009	55	63	69	80	83	85	89	87	82	73	64	56
2009/2010	50	60	77	85	84	91	91	91	88	73	62	52
2010/2011	56	62	79	91	90	91	91	89	88	72	63	51
2011/2012	51	60	76	84	91	91	95	94	87	72	67	54
2012/2013	57	63	73	83	88	91	96	94	86	72	61	62
2013/2014	62	64	79	85	90	88	95	91	73	70	64	54
2014/2015	53	59	71	75	79	84	86	85	82			

The index gives the following degrees of discomfort: 90 – 100 very uncomfortable (90-100), extremely uncomfortable (100-110) and hazardous to health (110+)

It must be noted that Table 6.4 indicates the average discomfort index per month and not an index at a specific date and time. There is a possibility that the discomfort index may have reached 110+ for a few hours around mid-day on any given day, within a month with high temperatures and/or a high humidity percentage.

It would seem as if the possibility of heat stress over the project period was the highest during the hot summer months of the year, between December and February. This time coincides with the breeding season (January to March) which may have had a negative effect on the conception rate and resorption rate as it is well documented that heat stress may lower reproduction efficiency in extensive beef cattle (Etim & Oguike, 2014). According to Gantner *et al.* (2011) heat stress also induces an increase in body temperature and when body temperature is significantly elevated, feed intake, metabolism, body weight and milk yield decreases to assist with alleviating the heat imbalance (Etim & Oguike, 2014).

Heat stress may also delay puberty by depressing the appetite and slowing growth rate. According to Gwasdauskas *et al.* (1975), puberty was delayed in Hereford heifers reared at 27°C, when compared with Hereford heifers reared at 10°C. Similarly, it was found that puberty was delayed in Jersey bulls exposed to 35°C for a period of 8 hours a day. Delayed onset of puberty, particularly, in *Bos indicus* cattle, constitutes a major limiting factor in the breeding of yearling heifers for beef production (Etim & Oguike, 2014). Bonsma *et al.* (1972) reported that two-year-old *Bos taurus* heifers, when imported from a temperate region to subtropical region, suffered an overall drop in calving percentage from 80 to 43%.

Semen quality can be adversely affected by hot conditions in warm summer months in most parts of the world, resulting in lower conception rate. Spermatozoa in semen collected from bulls during the hot summer months showed an increase in abnormal morphology and reduce binding to glycosaminoglycan's such as heparin (Etim & Oguike, 2014). Skinner and Louw (1966) reported that as little as 12 hours' exposure to temperatures of 40°C, proved critical for optimum spermatogenesis, and a decline in semen quality occurred after a week at this temperature. Field studies by Venter *et al.* (1973) showed that, at temperatures of more than 18°C, 11 out of 12 Short Horn bulls

were culled either on the basis of poor semen quality or abnormalities of the genitalia, while only one of 10 Afrikaner bulls was culled.

It was also found by Gwasdauskas *et al.* (1975) that European type cattle in the sub-tropic regions have shorter periods of oestrus, more silent ovulations and missed detection of oestrus during the hot summer months, when compared to the cooler seasons. According to Hafez (1967) heifers maintained under temperatures of 10°C reached sexual maturity at 10 months, while those kept at temperatures of 27°C matured only at 13 months, possibly as a result of a reduced growth at high temperatures.

The birth weight of calves born to unadapted European breeds following a summer pregnancy in the tropics is also often found to be lower than that of indigenous breeds (Hafez, 1967). This effect was quantified by Bonsma *et al.* (1972), who found that 33% of calves born following a summer gestation in the subtropics, were classified as dwarfs.

Heat stress most likely played a role in the current study's reproduction performance (especially with the breeding season coinciding with the two warmest months of the year). Figure 6.2 indicates the relation between calving percentage and heat stress over the six-year project period. The number of months with a discomfort index above 90 was taken into account for the following period: two months prior to the breeding season (November and December), three months within the breeding season (January to March) and two months after the breeding season (April and May) over the six-year project period. The highest calving percentage of 89.6% was obtained when the discomfort index did not rise above 89 within two months prior to the breeding season, during the three months breeding season or two months after the breeding season. The lowest calving percentage of 60.9% was obtained with an average monthly discomfort index rising above 90 within the month just before breeding and during the first two months of the breeding season.

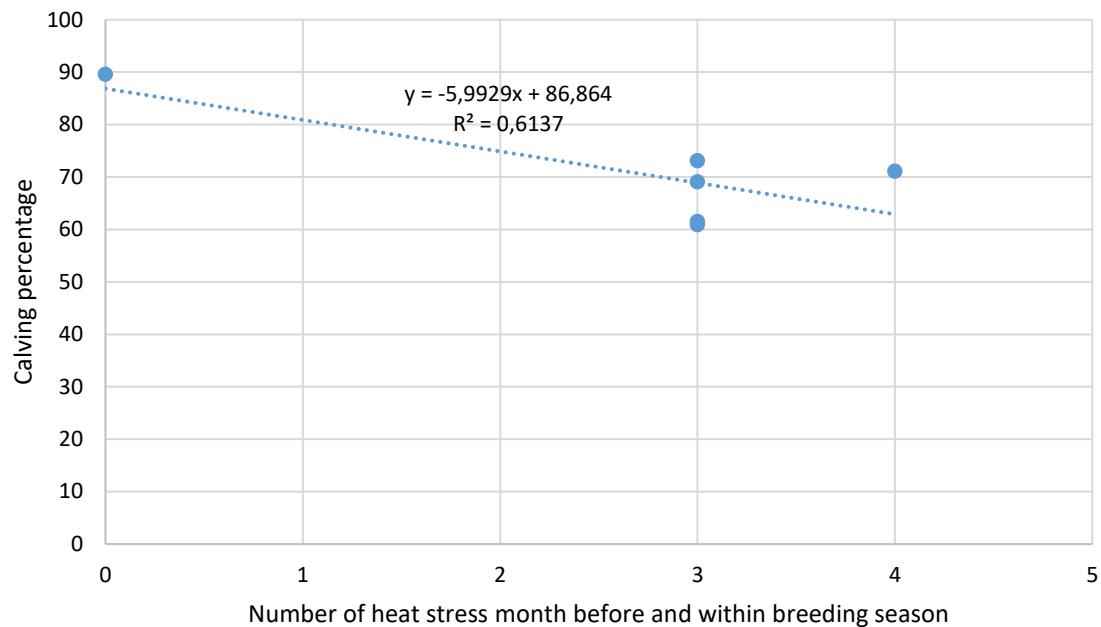


Figure 6.2 Relationship between calving percentage over the five breeding seasons and number of heat stress months three months before- and during the preceding breeding season

However, with the current study being conducted in the Sourish Mixed Bushveld, ample shade from trees were available at all times and there is well documented evidence that the provision of shade for cattle can mitigate the adverse effects of heat on health and production (Mader *et al.*, 1999; Kendall *et al.*, 2006; Hartman *et al.*, 2015).

6.4.2 Weight and body condition score

Over the study period, the mean cow age of different sub-herds changed with time due to subsequent mortalities and heifers calving to become cows. Therefore, all weight data presented is corrected for cow age and weight of calves is corrected for gender.

6.4.2.1 Cow weight at calving

There was no significant difference ($P \leq 0.05$) between the different herds for cow weight at calving for each year, indicating that the different grazing strategies didn't have a pronounced effect on cow weight at calving (Table 6.5). The highest average cow weight at calving was achieved in 2012 on the controlled selective grazing strategy and the lowest cow weight at calving was recorded in 2014 for both herd A (HUG) and herd B (CSG). The lowest mean cow weight at calving for all four sub-herds was 413kg in 2014 and the highest mean cow weight at calving including all four sub-herds was 461kg

obtained in 2010. However, there was a significant difference ($P \leq 0.05$) between cow weight at calving over the years, possibly due to temperature, relative humidity, precipitation and subsequent veld condition.

Table 6.5 Adjusted Means \pm SE for cow weight (kg) at calving

Herd	2009	2010	2011	2012	2013	2014	Mean
A	446 \pm 12.8	475 \pm 12.3	431 \pm 10.5	433 \pm 10.2	431 \pm 10.3	414 \pm 11.7	438
B	454 \pm 12.5	446 \pm 12.8	433 \pm 11.2	461 \pm 10.4	421 \pm 8.6	412 \pm 13.5	438
Mean	450	461	432	447	426	413	

6.4.2.2 Cow weight at weaning

No significant difference ($P \leq 0.05$) for the different herds for cow weight at weaning was found, except for 2014 (Table 6.6). When comparing data from cow weight at calving (Table 6.5) and cow weight at weaning (Table 6.6) from herd A and herd B over the project period, all herds gained weight from calving to weaning. The highest mean cow body weight at weaning of 510kg was achieved in 2009 by both herd A (HUG) and herd B (CSG) and the lowest cow weight at weaning 459kg was recorded in 2014 for herd B subjected to controlled selective grazing. With no significant difference ($P \leq 0.05$) between the herds subjected to either the high utilization grazing or controlled selective grazing strategy, except for 2014, and a mean difference of only 6kg over the six-year period, it is indicated that grazing strategy was not the determining factor influencing cow weight at weaning.

Table 6.6 Adjusted Means \pm SE for cow weight (kg) at weaning

Herd	2009	2010	2011	2012	2013	2014	Mean
A	510 \pm 13.6	484 \pm 11.7	498 \pm 12.9	483 \pm 10.2	481 \pm 10.5	488 \pm 9.6 ^a	491
B	510 \pm 14.1	477 \pm 11.9	481 \pm 12.1	477 \pm 9.9	507 \pm 10.1	459 \pm 9.4 ^b	485
Mean	510	481	490	480	494	474	

^{a,b}Means in columns with different superscripts differed ($P \leq 0.05$)

Body condition score was only measured for the last four years of the study. No significant difference could be found for body condition score at weaning for cows that were subjected to either high utilization grazing or controlled selective grazing over the four-year period 2011-2014 (Table 6.7).

Table 6.7 Analysis of variance (ANOVA) for body condition scores for cows at weaning showing no difference between different grazing strategies / synchronization

Source	DF	Mean square	P
Herd (Herd A (HUG) & Herd B (CSG))	1	0.75	0.24
Rep with Herd (Sub herd:A1,A2,B1,B2)	2	0.01	0.95
Treatment (sync/non sync)	1	0.96	0.21
(Grazing strategy) x (sync/non sync)	1	0.24	0.45
Error (a)	2	0.28	
Year	3	0.19	0.69
Year x Herd (A & B)	3	0.29	0.52
Year x Treatment (Sync/non-sync)	3	0.48	0.29
Year x Herd x Treatment	3	0.16	0.74
Error (b)	227	0.38	
Total	246		

The highest body condition score for cows at weaning was achieved in 2013 on the high utilization grazing strategy and the lowest body condition score for cows weaning a calf was also recorded in 2013 on the controlled selective grazing strategy (Table 6.8). However, this difference was not significant ($P \leq 0.05$).

Table 6.8 Mean body condition score \pm SD for cows at weaning subjected to either high utilization grazing (HUG) or controlled selective grazing (CSG)

Grazing strategy	2011	2012	2013	2014	Mean
HUG	2.34 \pm 0.66	2.49 \pm 0.84	2.54 \pm 0.56	2.40 \pm 0.52	2.44 \pm 0.66
CSG	2.29 \pm 0.74	2.38 \pm 0.62	2.23 \pm 0.40	2.46 \pm 0.44	2.33 \pm 0.56

The ANOVA results of the mean cow body condition score at breeding from cows that weaned a calf the previous season (2012-2014) are shown in Table 6.9 and Table 6.10. Over the period 2012 to 2014, no difference in body condition score could be found between the two herds subjected to either high utilization grazing (Herd A) and controlled selective grazing (Herd B) or between cows that were either synchronized or not synchronized. A significant difference was found between different years ($P = 0.02$) and grazing strategy over time ($P = 0.007$) as can be seen in Table 6.9. This may indicate

that year and therefore climate have a bigger impact on cow body condition score at breeding, after weaning a calf the previous season, than grazing strategy.

Table 6.9 Body condition scores of cows at breeding (2012-2014) – no difference between different grazing strategies / synchronization (ANOVA)

Source	DF	Mean square	P
Herd (Herd A (HUG) & Herd B (CSG))	1	0.29	0.40
Rep within Herd (Sub-herd A1, A2, B1, B2)	2	1.61	
Treatment (sync/non sync)	1	0.28	0.41
(Grazing strategy) x (sync/non sync)	1	1.05	0.18
Error (a)	2	0.26	
Year	2	2.51	0.002
Year x Herd (A & B)	2	2.04	0.007
Year x Treatment (Sync/non-sync)	2	0.38	0.38
Year x Herd x Treatment	2	0.54	0.26
Error (b)	170	0.39	
Total	185		

Mean body condition score for cows at breeding, after weaning a calf the previous season, subjected to either high utilization grazing and controlled selective grazing is shown in Table 6.10. Mean body condition score differed significantly ($P=0.0002$) between years and grazing strategy. The highest body condition score was achieved in 2014 for cows subjected to high utilization grazing and the lowest body condition score was obtained in 2013, also for cows subjected to high utilization grazing.

Table 6.10 Mean body condition score \pm SD for cows at breeding subjected to either high utilization grazing (HUG) or controlled selective grazing (CSG)

Grazing strategy	2012	2013	2014
HUG	$2.69 \pm 0.62^{c,d}$	2.61 ± 0.82^d	3.35 ± 0.38^a
CSG	$2.96 \pm 0.65^{b,c}$	$3.04 \pm 0.76^{a,b}$	$3.04 \pm 0.49^{a,b}$
Mean*	2.82 ± 0.64^b	2.86 ± 0.81^b	3.22 ± 0.45^a

^{a,b,c,d}Means with different superscripts differed ($P \leq 0.05$)

^{*a,b}Means within the same row with different superscripts differed ($P \leq 0.05$)

LSD_($p=0.05$) Year x Grazing strategy = 0.32

LSD_($p=0.05$) Year = 0.22

6.4.2.3 Calf birth weight

Mean calf birth weight varied between 35.9kg and 40.5kg over the observation period as indicated in Table 6.11. It is a bit higher than results found by Collins-Lusweti, (2000) who recorded a mean calf birth weight for Bonsmara cows of 31.1kg in Ganyesa and Madikwe districts in the North West Province of South Africa.

Over the six-year study period, the lowest mean calf birth weight in the study was recorded for herd A, subjected to high utilization grazing, in 2014 (Table 6.11) and the highest mean herd birth weight of 40.5kg was recorder for herd B, subjected to controlled selective grazing, in both 2011 and 2012.

Table 6.11 Adjusted means \pm SE for calf birth weight (kg)

Herd	2009	2010	2011	2012	2013	2014	Mean
A	36.7 \pm 1.0	39.5 \pm 1.0	39.5 \pm 1.0	40.3 \pm 0.9	37.0 \pm 1.2	35.9 \pm 1.0	38.2
B	37.5 \pm 1.0	38.1 \pm 1.0	40.5 \pm 1.0	40.5 \pm 1.0	38.6 \pm 1.0	37.8 \pm 1.2	38.8
Mean	37.1	38.8	40.0	40.4	37.8	36.9	

Mean calf birth weight was the lowest in 2009 and 2014, birth weight was higher in 2010 and 2013 with the highest mean birth weight in both 2011 and 2012. The mean calf birth weight was lower in 2010 than in both 2011 and 2012 but higher than in 2009, 2013 and 2014. No difference between the two grazing strategies and calf birth weight were recorded. There was however, a significant difference ($P < 0.05$) over years.

6.4.2.4 Calf weaning weight

Calves were weaned as soon as the calf crop's average age was seven months. For individual calves within the different sub-herds, a 205-day corrected weaning weight (cww) was calculated to standardize the age at weaning:

$$205 \text{ day cww} = [(\text{weaning weight} - \text{birth weight})/\text{age at weaning}] \times 205 + \text{birth weight}$$

The weaning weight as summarized in Table 6.12, include the mean 205-day calf weaning weight for calves in herd A subjected to high utilization grazing and herd B subjected to controlled selective grazing over the six-year period. Weaning weight was

lower than initially expected, but not uncommon for calves produced in an extensive production system. Corrected weaning weight was highest in 2011 and lowest in 2014. There was only a significant difference ($P \leq 0.05$) between weaning weight of calves from herd A and herd B in 2010. Calf weaning weights differed with only 3kg over the six-year project period between herd A subjected to high utilization grazing and herd B subjected to controlled selective grazing.

Table 6.12 Adjusted means \pm SE for 205 day calf weaning weight (kg)

Herd	2009	2010	2011	2012	2013	2014	Mean
A	188 \pm 4.6	212 \pm 4.6 ^a	215 \pm 4.5	163 \pm 3.7	155 \pm 5.0	163 \pm 4.3	183
B	198 \pm 4.3	195 \pm 4.8 ^b	203 \pm 5.4	173 \pm 3.5	163 \pm 3.8	150 \pm 5.6	180
Mean	193	204	209	168	159	157	

^{a,b}Means within a column with different superscripts differed significantly ($P \leq 0.05$)

6.4.2.5 Herd production

Table 6.13 shows that there was no significant difference ($P \leq 0.05$) in animal production between herd A (Sub-herd A1 and A2) subjected to high utilization grazing and herd B (Sub-herd B1 and B2) subjected to controlled selective grazing over the six-year project period. This is an indication that grazing strategy did not have a clear impact on animal production.

Table 6.13 Herd production over the six year project period

Herd	birth weight (kg)	days to calving (days)	cow weight calving (kg)	cow weight weaning (kg)	calf 205 weaning weight (kg)	calf ADG (kg)
A	38.2	304	438	491	183	0.71
B	38.8	305	438	485	180	0.70
Mean	38.5	305	438	488	182	0.71

6.5 Relationship between climatic data and calving percentage

Forward stepwise regression procedures were performed to determine what climatic data were involved in cow and calf weight at birth and weaning as well as calving percentage. The variables included in the regression equation included maximum and minimum temperature, maximum and minimum relative humidity, discomfort index and rainfall.

Forward stepwise regression procedures were performed for the dependant variable calving percentage (calving %). Specifying P = 0.01 to enter and P = 0.05 to stay for the independent variables. (XLSTAT, 2014). The only regression equation that was significant was that for calving percentage as presented below.

The equation of the model for calving percentage:

$$\text{Calving \%} = 1024.123 - 11.271 \times 1 \text{ VD max H} + 3.47400000 \times \text{Dek 3 min T}; R^2=99.4; P=0.001$$

(SE=45.4) (SE=0.56) (R²=90%) (SE=6.62) (R²=9.4%)

With:

1 VD max H = max relative humidity one month prior to the start of the breeding season

Dek 3 min T = min temperature within the last month of the 3 month breeding season

Maximum relative humidity one month prior to the start of the breeding season, had a high negative Pearson's correlation coefficient of - 0.95 and minimum temperature within the last month of the 3 month breeding season had a low negative Pearson's correlation coefficient of - 0.35 to explain calving percentage.

It is a well-known fact that humidity influence cow comfort. It can be speculated that high humidity in the study region (Sourish Mixed Bushveld) is an indication of warm and wet conditions, negatively impacting cow and bull comfort, leading to lower conception rates. The negative correlation between minimum temperature within the last month of the breeding season and calving percentage may indicate that the cows were unable to cool down at night during the warmer summer months of the year, leading to lower conception rates and resorptions.

6.6 Conclusion

It would seem that grazing strategy did not have a significant influence on cow weight and calf growth over the six-year period. This observation is in line with previous results, indicating that stocking rate has a greater influence on animal production than grazing system [(Carew 1980; Gammon 1983; Fourie *et al.*, 1984; Kreuter *et al.*, 1984; Donaldson, 1986; O'Reagain & Turner, 1992)] and concur with Tainton (1999). Average stocking rate was adhered to throughout the study period, and this may be one of the reasons why differences between the two grazing systems (HUG and CSG) were not observed. However, relatively few stocking rate trials have been conducted and these have not clearly elucidated a stocking rate:veld condition or animal production response. Consequently, quantitative data for the determination of stocking rates for particular veld types are seldom available. While techniques for the determination of stocking rate on the basis of veld condition do exist, they are problematic - firstly, because the relationship between veld condition and carrying capacity is often indirect (O'Reagain & Mentis, 1990) and, secondly, because it is difficult to predict the impact of a particular stocking rate on veld condition. Body condition score for cows at weaning did not differ significantly between the high utilization grazing strategy and controlled selective grazing strategy ($P \leq 0.05$).

Mean cow body condition score at breeding from cows that weaned a calf the previous season (2012-2014), showed no significant difference ($P \leq 0.05$) between the two herds subjected to either high utilization grazing (Herd A) and controlled selective grazing (Herd B) or between cows that were either synchronized or not synchronized. A significant difference was found between different years ($P = 0.02$) and grazing strategy over time ($P = 0.007$). With the significant differences between years ($P \leq 0.05$) for calving percentage, cow weight at calving, cow weight at weaning, calf birth weight and calf weaning weight over the six-year observation period, the effect of seasonal temperature, relative humidity and rainfall is elucidated and it can be assumed that weather e.g. rainfall, humidity and temperature had the biggest impact on animal production over years and not the well managed grazing systems.

CHAPTER 7

The impact of two grazing strategies on the vegetation

7.1 Introduction

When the project was originally planned in 2009, only a general overview including biomass and carrying capacity of the allocated project camps were calculated. A detailed vegetation survey was only performed from the active growing season 2011/2012 and therefore results are discussed over a four-year period. The focus of the veld evaluation was to compare change over time for each grazing strategy instead of only comparing the two grazing strategies with each other.

7.2 Aim

The aim of the study was to evaluate the effect of a high utilization grazing system and controlled selective grazing system over a four-year period (20010/2011 – 2014/2015). The two grazing systems were related to the use of 30% or 60% of the available grass dry matter in the Savanna Biome, Central Bushveld Bioregion that is described as Marikana Thornveld. As the study already commenced two years prior to the first detailed veld evaluation, the focus of the veld evaluation was to compare change over time for each grazing strategy instead of only comparing the two grazing strategies with each other. However, it must be noted that the veld condition and plant communities were evaluated to be homogenous enough within the allocated project camps as illustrated in Figure 2.1 in Chapter 2 not to affect stocking rate or animal production before commencement of the project.

7.3 Physical environment/study area

7.3.1 Climate

Schulze (1965) has categorized the study area as the Northern Transvaal climatic region, which receives an annual precipitation of between 380 and 700 mm. Mean rainfall for

the past 10 years has been 768mm, of which 83% occurred from October to March (spring and autumn). During the study period, the mean annual rainfall was 858mm, ranging from 664mm in 2012 to 1325mm in 2009. Mean daily minimum/maximum temperatures ranged from 16°C (min) to 32°C (max) in February to 1°C (min) to 23°C (max) in July. Monthly rainfall and temperature over the six-year study period is discussed in detail in Chapter 2 and Chapter 6.

7.3.2 Vegetation

The vegetation in the study area is described as Savanna (Rutherford & Westfall 1994), Sourish Mixed Bushveld (Veld Type 19) (Acocks, 1988), Clay Thorn Bushveld (Low & Rebelo, 1996) and Marikana Thornveld (Mucina & Rutherford, 2006). Van Rooyen (1983) mapped the vegetation of the Roodeplaat Dam Nature Reserve (RNR) which is adjacent to the south-eastern boundary of the REF at a scale of 1:33 000. The nature reserve was classified into six communities, two of which were subdivided into another seven variations. Three of these vegetation units adjoined the REF, namely: the *Acacia karroo* closed woodland; the *Setaria perennis* - *Polygala hottentotta* grassland; and the *Acacia caffra* - *Setaria perennis* closed woodland (Van Rooyen, 1983). Work done in Sourish Mixed Bushveld (Acocks, 1988) on a less detailed scale, but not near REF, includes classifications of the vegetation of the western Transvaal (mapped at 1:250 000) (Van der Meulen, 1979), the Loskop Dam Nature Reserve (mapped at 1:36 000) (Theron, 1973) and at a more detailed scale, the Soutpan Experimental Farm (Grunow, 1965).

The following plant communities (Panagos, 1995) occur in the study area:

- *Acacia tortilis* subsp. *heterocantha* – *Brachiaria nigropedata* low open woodland
- *Acacia tortilis* subsp. *heterocantha* – *Digitaria argyrograpta* short thicket
- *Acacia tortilis* subsp. *heterocantha* – *Bothriochloa bladhii* low open woodland

7.4 Results and discussion

7.4.1 Vegetation survey

When the project was originally planned in 2009, a general overview including biomass and carrying capacity of the allocated project camps were calculated. The original survey indicated a carrying capacity of 7ha per LSU (large stock unit) which was adhered to for the duration of the study. From the active growing season 2011/2012, a detailed vegetation survey was done and the following components were monitored over a four-year period:

- vegetation species composition,
- basal cover of the grass species,
- canopy cover of the grass species,
- standing biomass and
- veld condition (veld condition scores).

As explained in Table 2.6 three survey sites were monitored within the camps that were allocated to each of the sub-herds during the active growing seasons of 2011/2012, 2012/2013, 2013/2014 and 2014/2015. The detail and location of each survey site is summarized in Table 2.7.

7.4.2 Species composition

Decreaser and Increaser species and their ecological status is discussed in paragraph 3.3.3.4. The dominant grass species, in terms of canopy cover percentage and number of individuals, recorded in camps subjected to HUG were *Setaria sphacelata*, *Eragrostis curvula*, *E. gummiiflua*, *E. racemose*, *Heteropogon contortus*, *Elionurus muticus* and *Themeda triandra* and in the camps subjected to CSG *Setaria sphacelata*, *Eragrostis curvula*, *Eragrostis racemose*, *Digitaria argyrograpta*, *Elionurus muticus*, *Themeda triandra*, *Heteropogon contortus* and an *Aristida* species. These species compare well with decreaser and increaser species recorded by Smit (1988) for the Sourish Mixed Bushveld, as summarized in Table 7.1.

Table 7.1 Decreasers and Increasers for the Sourish Mixed Bushveld (Smit, 1988).

Species	Status	Species	Status
<i>T.triandra</i>	Decreaser	<i>E.rigidior</i>	Increaser IIb
<i>H.hirta</i>	Decreaser	<i>D.eriantha</i>	Increaser IIb
<i>E.muticus</i>	Decreaser	<i>B.nigropedata</i>	Increaser IIb
<i>C.plurinodis</i>	Increaser Ia	<i>C.virgata</i>	Increaser IIb
<i>D.argyrograpta</i>	Increaser Ia	<i>S.nitens</i>	Increaser IIb
<i>H.contortus</i>	Increaser IIa	<i>B.insculpta</i>	Increaser IIc
<i>P.maximum</i>	Increaser IIa	<i>U.mosambicensis</i>	Increaser IIc
<i>S.pappophoroides</i>	Increaser IIa	<i>T.racemosus</i>	Increaser IIc
<i>E.scoparius</i>	Increaser IIa	<i>T.grandiglumis</i>	Increaser IIc
<i>P.squarrosa</i>	Increaser IIa	<i>Forbes</i>	Increaser IIc
<i>H.dissoluta</i>	Increaser IIa	<i>C.ciliaris</i>	Unsure
<i>Aristida species</i>	Increaser IIb	<i>M.repens</i>	Unsure

There was an increase in the mean canopy cover and individuals of the declared invader *Campuloclinium macrocephalum* in both areas of HUG and CSG. The contribution of forb species in terms of mean canopy cover for HUG varied from 8% in 2012 to 6% in 2015 and for CSG from 5% in 2012 to 4% in 2015. The dominant forbs in terms of mean canopy cover for the area of HUG are *Campuloclinium macrocephalum*, *Justicia anagaloides*, *Menodora africana* and an *Osteospermum* species and for area of CSG *Campuloclinium macrocephalum*, *Monsonia angustifolia* and an *Indigofera* species.

The percentage contribution of the decreaser grass species over the four-year period is illustrated in Figure 7.1. The decreaser grass species percentage contribution to the total grass species recorded mean, over the four-year period, was 79.7% for the HUG and 70.8% for the CSG, respectively. The dominant decreaser grass species for HUG were *Setaria sphacelata*, *Diheteropogon amplexans*, *Themeda triandra* and *Digitaria argyrograpta* and for the CSG *Setaria sphacelata* and *Heteropogon contortus*. The dominant increaser grass species for HUG were *Eragrostis curvula* and *Aristida* species and for CSG, *Eragrostis curvula* and *Eragrostis gummiflua* respectively.

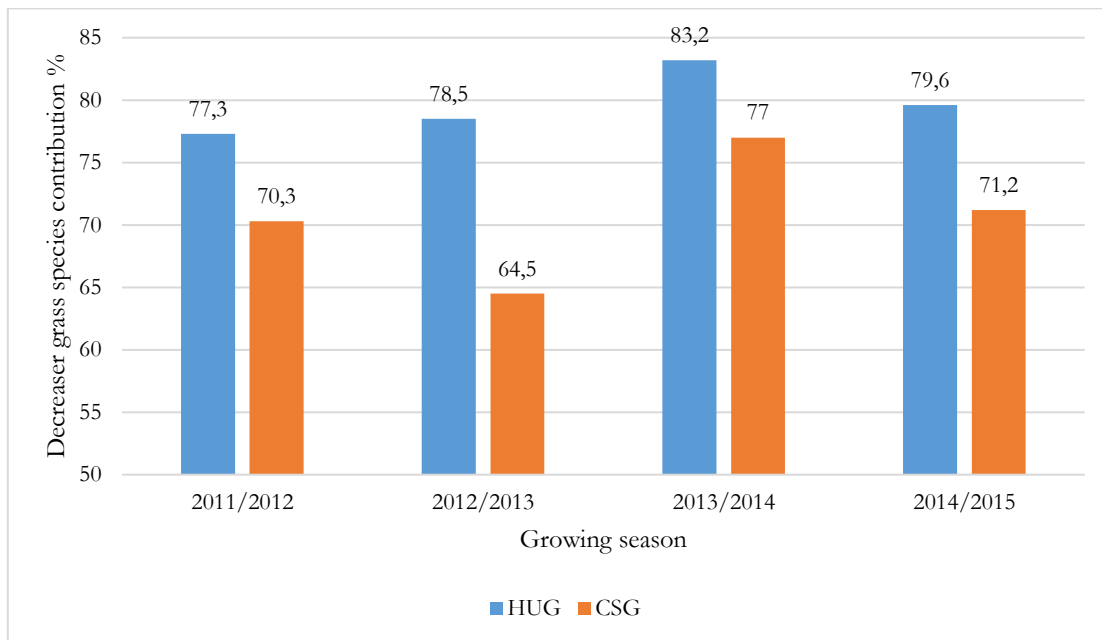


Figure 7.1 The decrease in grass species contribution for both high utilization grazing (HUG) and controlled selective grazing (CSG) over four consecutive growing seasons.

Veld in good condition was characterized by a high contribution of decrease in grass species. From Table 7.2 it is clear that the already high contribution of the decrease in grass species increased slightly from the first evaluation in 2011/2012 to the last evaluation in 2014/2015, for both treatments.

Table 7.2 Decreaser grass species contribution \pm SD for high utilization grazing (HUG) and controlled selective grazing (CSG,) over a four-year period.

Grazing strategy	2011/2012	2012/2013	2013/2014	2014/2015
HUG	77.3 \pm 13.1 ^{ab}	78.5 \pm 10.5 ^{ab}	83.2 \pm 6.91 ^a	79.6 \pm 8.05 ^{ab}
CSG	70.3 \pm 11.6 ^{bc}	64.5 \pm 11.6 ^c	77.0 \pm 10.2 ^{ab}	71.2 \pm 10.0 ^{bc}

^{a,b,c}Means with the same superscript are not significantly different ($p \leq 0.05$)

LSD($p=0.05$) = 9.969

These results indicate that neither the HUG nor CSG had a negative impact on the veld in relation to the decrease in grass species composition. It is also an indication that the veld was not undergrazed or overgrazed and that the same stocking rate was adhered to for the duration of the project period.

7.4.3 Cover

Cover can be defined as a measure of the proportion of ground covered by individual species or whole vegetation (Thomas & Barton, 1995). Canopy Cover can be defined as the vertical projection of the crown or shoot area of a species to the ground surface - usually expressed as a fraction or percentage of a reference area but could also imply the projection of the basal area or area outline of a plant near the ground surface (Mueller-Dombois & Ellenberg 1974; Panagos, 1995). When referring to canopy cover, the combined projected crown cover on the ground of a number of plants is included (Westfall *et al.*, 1996). Basal cover refers to the area of ground covered by the living basal portions of plants (Trollope *et al.*, 1990) and is defined more specifically by Westfall *et al.*, 1996 as the basis of the basal rooted portions of the plants, based generally on frequency type data and derivatives. Therefore, basal cover also relates to frequency of the plants (Westfall *et al.*, 1996). Cover was measured by means of point samples (basal cover) and quadrat samples (canopy cover).

7.4.3.1 Canopy cover

For this study, the method used to determine canopy cover in conjunction with the quadrat method of floristic sampling, was the plant number scale (Westfall & Panagos, 1988) which is based on Edwards (1983) definition of crown cover and is a function of the relation between mean crown diameter and mean spacing of plants. Canopy cover was determined simply by a count of the plants in 10m x 20m-sized transects. Using the point canopy intercept method, the percentage canopy cover for each species was derived from this technique, and does not have to be measured separately (Panagos, 1995).

As shown in Figure 7.2, the total canopy cover of the plants - including trees, shrubs, dwarf shrubs and graminoids in camps subjected to HUG varied between 28% in the 2012/2013 growing season to 32% in the 2011/2012 growing season. Camps subjected to CSG mean canopy cover varied between 28% in the growing seasons 2011/2012, 2012/2013, 2013/2014 and 30% in the 2014/2015 growing season. There was no significant difference between total canopy cover between CSG and HUG treatments and/or over different years ($P = 0.649$).

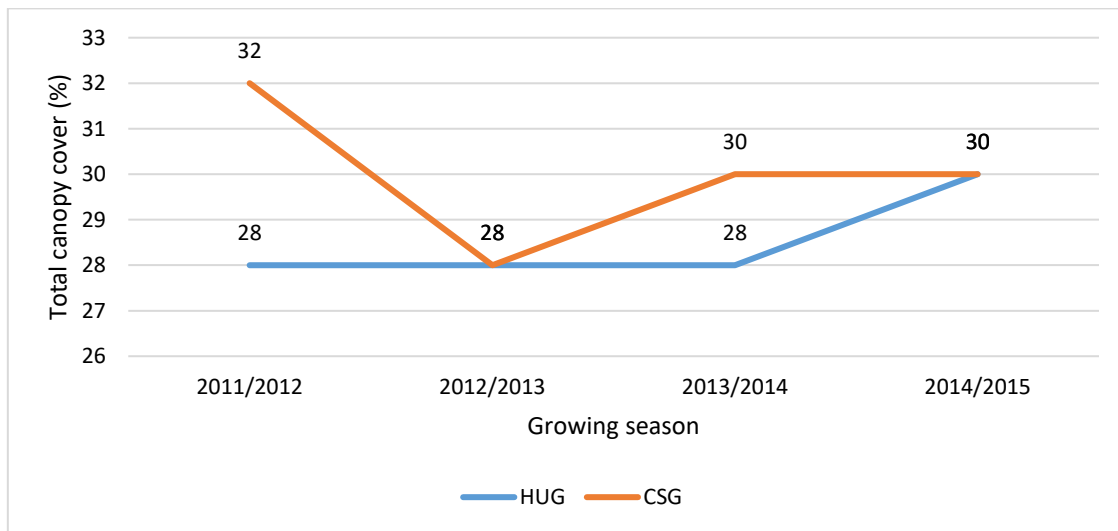


Figure 7.2 Total canopy cover percentage of vegetation subjected to either high utilization grazing or controlled selective grazing over four consecutive growing seasons

The proportional canopy cover percentage of grasses relates to the percentage of canopy cover responsible by the grass species only - thus excluding the trees, shrubs, dwarf shrubs and graminoids contribution to canopy cover. Usually canopy cover is not as stable as basal cover, since canopy cover is influenced by grazing and defoliation. From Figure 7.3 it is clear that the proportional percentage canopy cover did not change significantly over the four-year period. These results can be attributed to the fact that veld evaluation was done at the same time of year at the same survey sites with the same stocking rate over the four-year evaluation period.

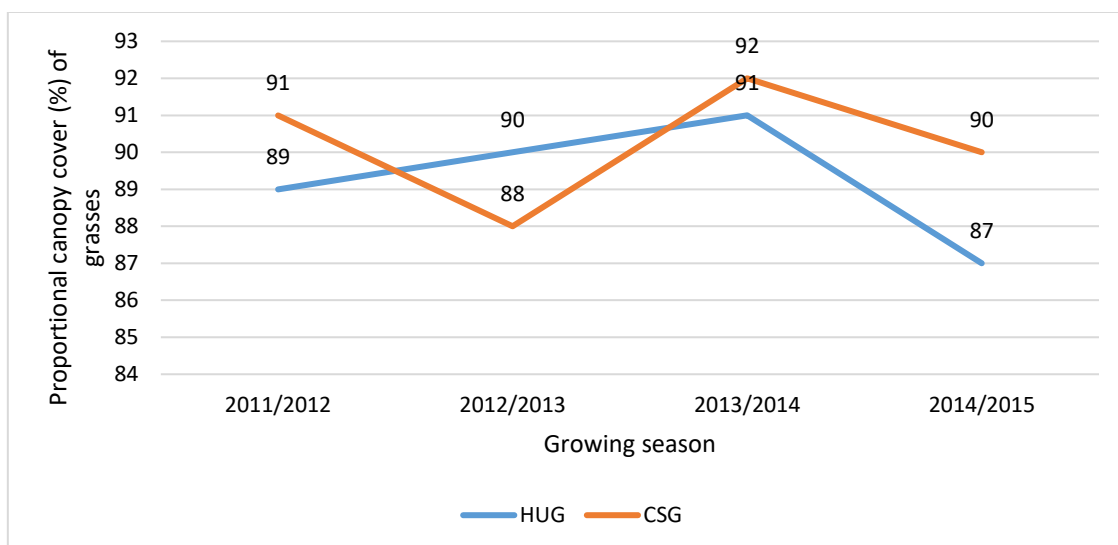


Figure 7.3 Proportional canopy cover of vegetation subjected to either high utilisation grazing (HUG) or controlled selective grazing (CSG) over 4 consecutive growing seasons

Proportional canopy cover was good over the four-year evaluation period for both high utilization grazing and the controlled selective grazing treatments. The good proportional canopy cover being an indication of soil protected against erosion caused by rain splash and grass seedlings adequately protected against the elements.

When looking at the total canopy cover and the proportional contribution of the grass canopy cover of the high utilization grazing treatment (HUG) and controlled selective grazing treatment (CSG) from 2012/2013 to 2014/2015, an increase in total canopy cover (Fig 7.2) can be seen, although a decrease in the proportional canopy cover representing the grass contributions (Fig 7.3) was found. This occurrence demonstrates an increase in annual forbes due to favourable climatic conditions substituting and contributing to the total canopy cover.

7.4.3.2 Basal cover

When compared to canopy cover, basal cover - referring to the proportion of the plant that extend into the soil - is more stable from year to year and less sensitive to changes due to climatic fluctuation. It is further not significantly affected by the grazing of animals. Evans and Love (1957), when describing the step-point method of sampling, concluded that the method's accuracy and objectivity made it suitable for valid analysis of field research plots. In the current study basal hits (100m line for each survey site) were recorded and non-plant hits were also recorded as misses and the species nearest to the point in a forward, 180' arc was recorded. This information was used to determine the basal cover of individual species, their collective total, and for percentage composition.

The basal cover for the camps subjected to HUG ranged from 19% in 2012 to 16% in 2015 and for camps subjected to CSG from 18% in 2012 to 16% in 2015 (Figure 7.4).

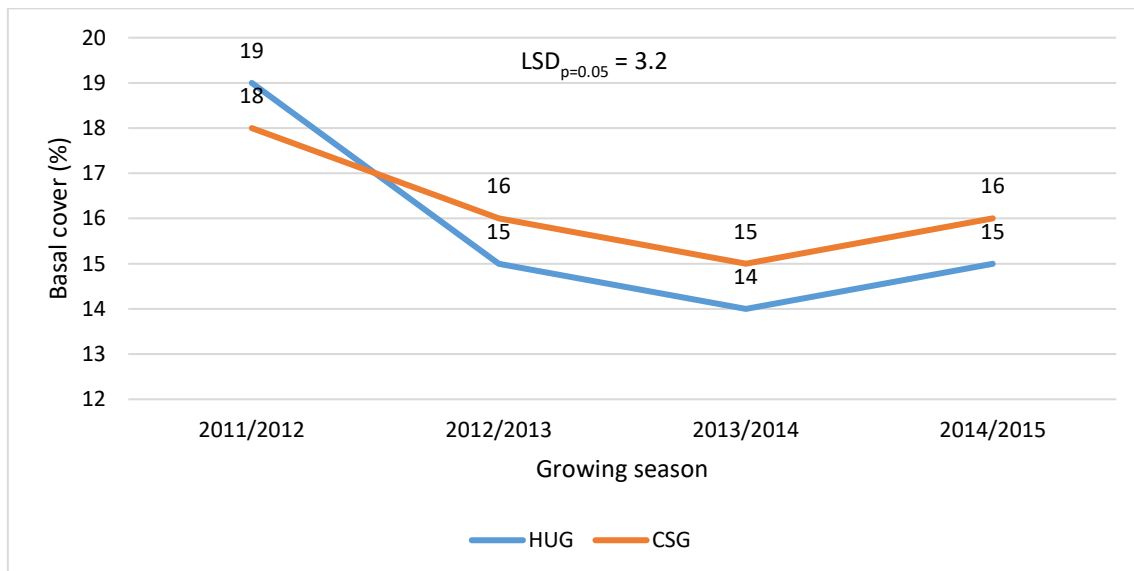


Figure 7.4 Mean basal cover percentage of vegetation subjected to either high utilization grazing or controlled selective grazing over four consecutive growing seasons

The basal cover percentage of the high utilization grazing treatment decreased significantly from 2011/2012 to 2014/2015 and the basal cover for the controlled selective grazing treatment decreased slightly (Table 7.3), although not significantly indicating that the proportion of the grass plants extending into the soil had decreased. The reason for the significant decrease in grass plant basis size for the high utilization grazing treatment may be due to the higher defoliation of grass leaves.

Table 7.3 Mean basal cover percentage \pm SD of vegetation subjected to either high utilization grazing (HUG) or controlled selective grazing (CSG) over four consecutive growing seasons

	2011/2012	2012/2013	2013/2014	2014/2015
HUG	18.7 \pm 2.80 ^a	14.5 \pm 2.51 ^c	13.6 \pm 3.44 ^c	15.2 \pm 2.39 ^{bc}
CSG	18.3 \pm 1.51 ^{ab}	16.3 \pm 2.07 ^{abc}	15.3 \pm 3.77 ^{bc}	16.0 \pm 2.83 ^{abc}

^{a,b,c,d}Means with the same letter are not significant different ($p \leq 0.05$)

LSD_(p=0.05) = 3.22

7.4.4 Veld condition

The veld of each survey site was compared with that of a benchmark, which is a similar veld type taken to be in a good grazing condition. With the point-based surveys being done at the 12 monitoring sites e.g. 3 sites for each “sub-herd”, comparisons were made between these sites, relative to the condition of the benchmark, by determining a veld condition score.

For the determination of a veld condition score, grass species were ecologically classified on the basis of their reaction to grazing including:

Decreaser: Species that decrease under over- or undergrazing

Increase Ia: Species which increase under moderate undergrazing

Increase Ia: Species which increase under moderate overgrazing

Increase Ib: Species which increase under heavy overgrazing

Increase Ic: Species which increase under severe overgrazing

Each of these groups were appointed a weighted value between 1 and 10, based on the grazing/ecological value of the species according to Trollope *et al.* (1988). The condition score for each survey site was thus the sum of the products of the proportion contributed by the different ecological groups and the relative values assigned to each grass species. The total of all species indices contributed to the veld condition score, which was used to indicate veld condition. This score was then compared to the benchmark score for the same ecological zone, which was calculated as 450. The values used for this project differed between 2 and 7 for decreasers; and between 1 and 6 for the increasers. The theoretical maximum value of some decreaser species is 10, indicating a maximum score of 1000, when the survey site consisted of 100% of that specific species and a minimum score of 100.

The maximum value allocated to decreaser species in the Sourish Mixed Bushveld was 7 (Trollope *et al.*, 1988). This implies that the highest score that can be calculated for veld condition scores in this project is 700 and not the theoretical 1000. However, to obtain the theoretical highest score of 700 the veld would need to consist of a uniform decreaser species with an allocated value of 7 (decreaser species with value of 7 x 100 samples = 700). This will only be possible with planted pasture and not in a natural veld environment including a diverse range of grass species. Therefore, a benchmark score

for the same ecological zone in excellent condition, which was calculated as 450, was used to compare the veld condition of the current project, rather than the theoretical value of 700 as shown in Table 7.4

Table 7.4 Veld condition index for natural veld in the Sourish Mixed Bushveld with a 450 benchmark (Aucamp *et al.*, 2004)

Veld condition score	Veld condition
300-450	good
150-299	average
1-149	Poor

Over the four-year period, a significant difference was found between high utilization grazing and controlled selective grazing ($P \leq 0.01$) but the differences over years was not significant ($P = 0.51$) as indicated in Table 7.5.

Table 7.5 Mean veld condition scores for high utilization grazing (HUG) and controlled selective grazing (CSG) (ANOVA)

Source	DF	Mean square	P
Treatment (HUG/CSG)	1	13002	≤ 0.01
Rep within treatment (HUG/CSG)	2	3468	0.03
Season	3	41239	0.26
Treatment (HUG/CSG)	3	1071	0.32
Error	33	880	
Total	42		

When results are compared to the benchmark score of 450 for the same ecological zone, it is clear that the veld condition was good for both treatments over the four-year period (Table 7.4). The high utilization grazing treatment's grass species composition improved slightly over time with a veld condition score increase of 23 over the four-year period. The veld condition score (VCS) of the controlled selective grazing treatment decreased from 290 in 2011/2012 to 266 in 2014/2015. The VCS for the area of HUG and CSG differed slightly from the 2012 to the 2015 surveys as set out in Table 7.6.

Table 7.6 Mean veld condition scores \pm SD for both the high utilization grazing (HUG) and controlled selective grazing (CSG) treatments over a four-year period.

	2011/2012	2012/2013	2013/2014	2014/2015
HUG	306 \pm 36 ^{ab}	302 \pm 24 ^{abc}	296 \pm 41 ^{abcd}	329 \pm 43 ^a
CSG	290 \pm 38 ^{abcd}	273 \pm 23 ^{bcd}	259 \pm 24 ^d	266 \pm 22 ^{cd}

^{a,b,c,d} Means with the same superscript are not significantly different ($p \leq 0.05$)

LSD_(p=0.05) = 37.17

The VCS for area of HUG was slightly higher than for the area of CSG (Figure 7.5).

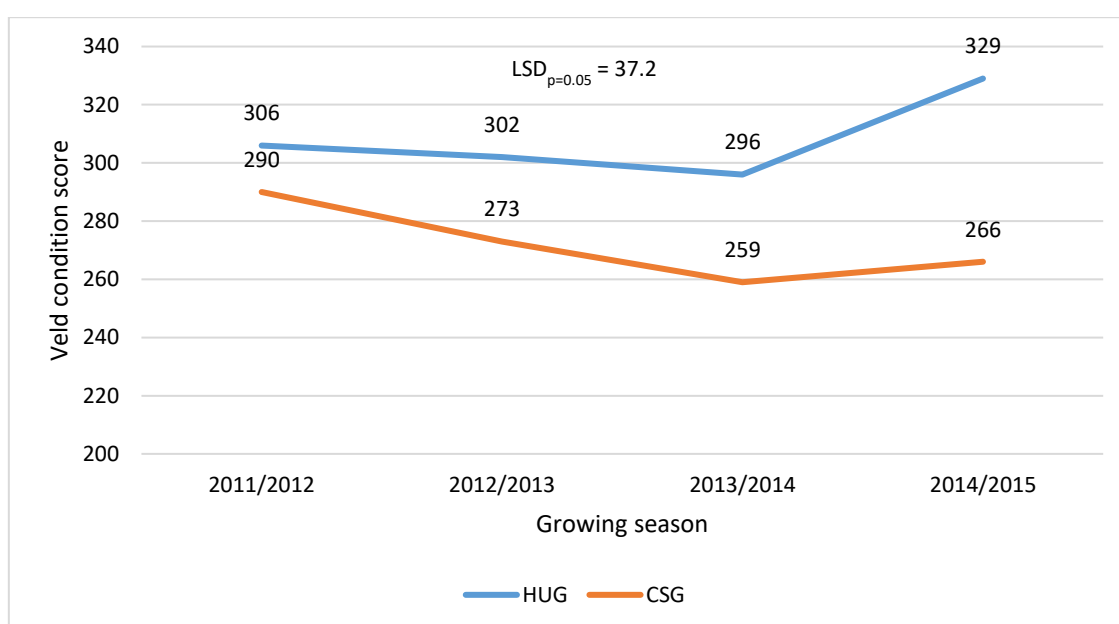


Figure 7.5 Veld condition scores of vegetation subjected to either high utilization grazing or controlled selective grazing over four consecutive growing seasons.

Although four years are too short to make a definite conclusion on the effect of grazing strategy on veld condition, from Table 7.4 and Figure 7.5 it seems that high utilization grazing have the tendency to improve veld condition score and grass species composition in the Sourish Mixed Bushveld when carrying capacity is adhered to under extensive grazing conditions over time. The high error value is probably due to small sample site and limited years of data collection. As this approach is the subjective allocation of species to categories and the assumption is made that all species are equally sensitive to utilisation, it is difficult to compare results with other studies.

7.4.5 Standing biomass

The average standing biomass of the two areas (Figure 7.6) was determined using the PHYTOTAB computer program which make use of a regression analysis to estimate above ground standing biomass and thus the standing biomass is only an estimation and not actual values. The average standing biomass for area of HUG varies from 2994 kg/ha in 2015 to 2394 kg/ha in 2013 and for area of CSG from 3044 kg/ha in 2015 to 2514 kg/ha in 2013 as indicated in Table 7.6.

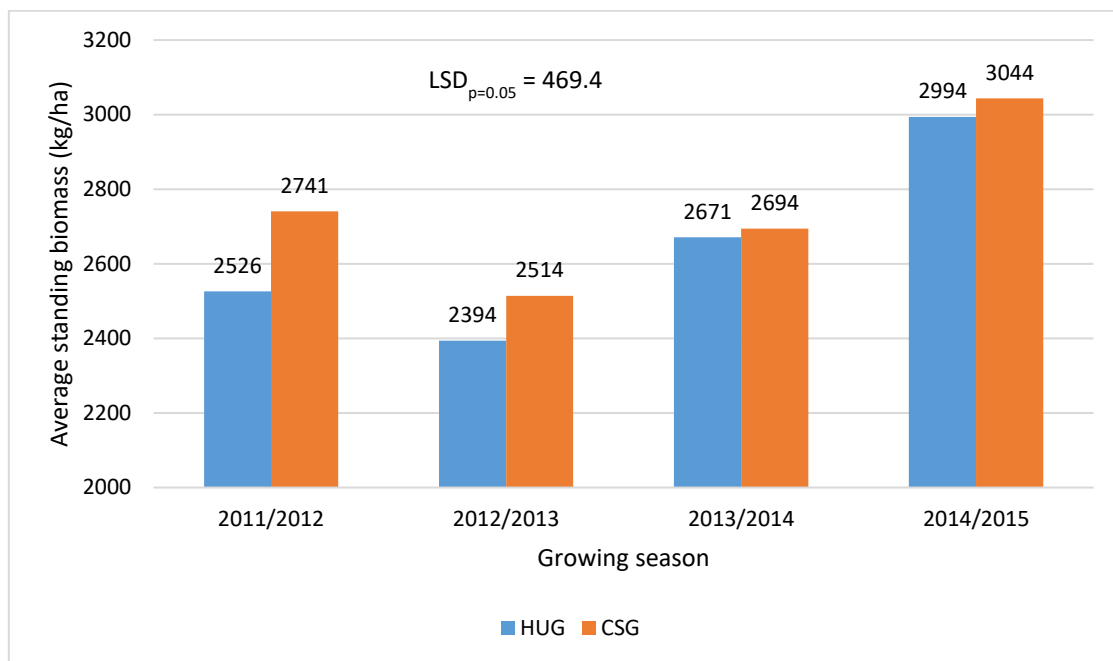


Figure 7.6 Average standing biomass (kg/ha) of vegetation subjected to either high utilization grazing or controlled selective grazing over the four consecutive growing seasons.

Standing biomass (Table 7.7) was used to calculate carrying capacity, as suggested by Moore *et al.*, (1985); Moore & Odendaal, (1987) and Smit, (2009):

$$y = d \div (DM \times f) / r$$

y = carrying capacity (large stock unit (LSU)/hectare (ha))

d= 365 days

DM = standing biomass

f = 0.3

r = 13.5

The carrying capacity was calculated in 2011/2012 to differ between 7ha/LSU (HUG) and 6ha/LSU (CSG) and in the 2014/2015 grazing season the carrying capacity improved to 5ha/LSU for both HUG and CSG treatments. These results indicate that veld condition appears to be more dependent upon stocking rate than the two rotational grazing management systems which is in line with results from Walker and Scott (1968) and O'Reagain and Turner (1992).

Table 7.7 Mean (\pm SD) standing biomass (kg/ha) for both the high utilization grazing and controlled selective grazing treatments over the four-year observation period.

	2011/2012	2012/2013	2013/2014	2014/2015
HUG	2526 \pm 295 ^{bc}	2394 \pm 408 ^c	2671 \pm 255 ^{abc}	2994 \pm 489 ^{ab}
CSG	2741 \pm 459 ^{abc}	2514 \pm 420 ^c	2694 \pm 292 ^{abc}	3044 \pm 709 ^a

^{a,b,c,d}Means with the same superscript are not significantly different ($p \leq 0.05$)

LSD($p=0.05$) = 469.38

7.5 Conclusion

When a study includes grazing animals on a specific veld type in a specific veld condition in a specific climatic region over time it is difficult to compare the study with other studies being done - as the starting points of different studies will be different and therefore give different results. When the two grazing systems namely controlled selective grazing was compared to high utilization grazing over a four-year period, almost no veld condition change was recorded. It must be noted that quality and availability of veld are also subject to differences in annual rainfall and distribution (De Waal, 1990) as well as stocking rate (Fourie, 1983; De Waal *et al.*, 1989).

Almost no veld condition change was observed after 4 years of grazing trials in Montana (Vogel & Van Dyne, 1966) and North Dakota (Hofmann & Ries, 1989), illustrating the need for longer term studies to measure grazing impacts. It must also be noted that carrying capacity was adhered to at all times and results from this study indicate that both grazing strategies are sustainable in the Sourish Mixed Bushveld if carrying capacity is adhered to.

The results indicate a tendency that high utilization grazing improved veld condition score and grass species composition over that of controlled selective grazing in the Sourish Mixed Bushveld when carrying capacity is adhered to under extensive grazing conditions over time. However, the duration of the study is too short to make a definite conclusion on the effect of grazing strategy on veld condition.

CHAPTER 8

Conclusion and recommendations

For an extensive beef producer in South Africa to be successful in this global competitive market, with market fluctuations, it is vital to produce beef as cost effectively and as efficiently as possible, in a sustainable production system. Profitability is largely dependent on the reproductive performance of the cow herd, which is best measured by percentage calves weaned at a given time. Therefore, it is important that the calving percentage of 62% (Scholtz *et al.*, 2008) in the commercial beef sector of South Africa needs to be improved.

In a specific calving season, the cows that calve earlier in the season, may have a better chance of conceiving during the next breeding season and can generally be seen as the more fertile animals (Holm, 2006; Grobler *et al.*, 2014). This implies that cows that calve late in the calving season wean younger and smaller calves, when compared to cows that calve earlier in the season - weaning a bit older calves with a higher body weight. Cows calving earlier in the season also have an extended “recovery period” and have the opportunity to calve in a better body condition during the next season, compared to cows calving late in the season (Odhiambo *et al.*, 2009).

Another crucial component in extensive beef cattle production is the development, production and quality of replacement heifers. A heifer’s lifetime productivity as a productive beef cow is influenced by factors including age at puberty, age at first conception and calving interval. (van der Merwe & Schoeman, 1995). Generally, in South Africa, beef heifers are managed to calve for the first time at three years of age, but in many studies mating of heifers at one year of age have been advocated (Fahmy *et al.*, 1971; Meaker *et al.*, 1980; Nunez-dominguez *et al.*, 1991). The theoretical advantage of mating heifers one year earlier, lies mainly in the potential increase in lifetime productivity and the expectation of an extra calf (Meaker *et al.*, 1980). Little information is published locally on the biological or economic value of early mating of extensive beef heifers while international information is mostly restricted to dairy cattle (Morris, 1980; Scholtz *et al.*, 1991; van der Merwe & Schoeman, 1995). According to van Niekerk *et al.*, (1990) replacement heifers are not generally mated before the age of

24 months due to the extensive nature of the majority of beef enterprises in South Africa while Scholtz *et al.* (1991) concluded that there is no consensus on the advantages of early breeding of beef heifers in South Africa. In the current study the breeding of replacement heifers at either 14 months or 26 months has been investigated to establish if early breeding have an economic advantage over breeding heifers at 26 months in terms of reproductive performance in an extensively managed beef herd.

Another aim was to evaluate the effect of oestrous synchronization, followed by natural mating in the extensively managed beef herd. This was done to establish if oestrus synchronization can lead to an increase in the total weight of calves weaned from a limited calving season, most likely by decreasing the days to calving, but also by increasing the number of calves born from a limited calving season.

Results from this study indicated that calving percentage did not differ significantly ($P=0.54$) between cows that was either synchronized by administration of exogenous progestogens in combination with oestrogen by means of Crestar® (2009-2012) and CIDR® B (2013-2014) or not synchronized followed by natural mating. These results are consistent with other similar studies. However, oestrous synchronization prior to natural mating did influence the average days to conception. Over the six-year period, 60% of cows being synchronized calved within the first week of the breeding season whereas only 47% of the cows not being synchronized calved within the first week of the breeding season (≤ 293 days). Cows that calved earlier in the season had a longer recovery period and better BCS at weaning. This finding is also consistent with previous published reports and may provide a practical way to decrease the length of the breeding season and increase the cow “recovery period” before the next breeding season to improve subsequent reproductive performance in beef cows (Hanlon, 1995; Lamb *et al.*, 2007; Odhiambo *et al.*, 2009 and Grobler *et al.*, 2013).

Conception rates of heifers mated at 26 months were significantly ($P<0.05$) higher than heifers mated at 14 months of age. It would seem that it may be more viable to breed Bonsmara heifers in an extensive production system in the Sourish Mixed Bushveld region at 26 months of age for the first time. The success of implementing mating heifers at one year of age will depend on nutritional and management levels. Under extensive farming conditions it will require additional supplementary input. In the

current study synchronization of 14 month old heifers did not improve conception rate over 14 month old heifers bred naturally. Results indicated that oestrous synchronization of 14 month old heifers did not show any economic benefit. It seems unlikely that such a system can improve on the 26-month old heifer breeding system on natural veld, with only lick supplementation without keeping heifers in separate groups. Calving percentage of synchronized heifers bred at 26 months was 6% higher than the non-synchronized heifers which means not only heavier calves, but more weaner calves was available to the market. The financial benefit of synchronization will thus depend on cost of synchronization weighed against weaning weight, weaning percentage and the price per kg of weaned calves. Geographical-region differences in the age at which heifers are first exposed for breeding will therefore depend on management systems, forage quality and availability, and adaptation of respective breed types to specific environmental conditions. In some cases, the economic advantage of early calving and breeding may be counterbalanced by biological limitations of the animal and management constraints of the environment (Short *et al.*, 1990; Ahmadzadeh, *et al.*, 2011).

It is a common practice to study veld as a separate entity to cattle or beef farming although cattle cannot be separated from the veld on which it is kept - primarily because of a dynamic equilibrium between the animal and the grazing plants the animal utilizes. Grazing strategies have evolved from the need to sustain efficient use of natural veld by livestock over long periods of time (Manley *et al.*, 1997) and it is generally understood that veld management practices may either cause deterioration or improvement of the veld (van Pletzen, 2009). It is further well documented that veld condition has a large influence on a number of beef production parameters (Grobler *et al.*, 2013) and the application of different grazing strategies may have an effect on financial return in the long term or even result in immediate decreases in financial return (Grobler *et al.*, 2013). Although the cost of providing feed to extensive grazing cattle is more complex to quantify, it remains a major input (Foster *et al.*, 2014) and according to Pogue *et al.* (1996) grazed forages are approximately one-third the cost of stored forages, based on total digestible nutrients per kilogram product.

In the current study the effect of a high utilization grazing system and controlled selective grazing system was evaluated over a four-year period. The focus of the veld evaluation was to compare change over time for each grazing strategy instead of only comparing the two grazing strategies with each other. The effects of climate and grazing system on cow-calf production characteristics over time was also evaluated.

When a study includes grazing animals on a specific veld type in a specific veld condition in a specific climatic region over time it is difficult to compare the study with other studies being done - as the starting points of different studies will be different and therefore give different results. When the two grazing systems namely controlled selective grazing was compared to high utilization grazing over a four-year period, almost no veld condition change was recorded. It must be noted that quality and availability of veld are also subject to differences in annual rainfall and distribution (De Waal, 1990) as well as stocking rate (Fourie, 1983; De Waal *et al.*, 1989). It must also be noted that carrying capacity was adhered to at all times and results from this study indicate that both grazing strategies are sustainable in the Sourish Mixed Bushveld if carrying capacity is adhered to.

It would seem that grazing strategy did not have a significant influence on cow weight and calf growth over the six-year period. This observation is in line with previous results, indicating that stocking rate has a greater influence on animal production than grazing system [(Carew 1980; Gammon 1983; Fourie *et al.*, 1984; Kreuter *et al.*, 1984; Donaldson, 1986; O'Reagain & Turner, 1992)] and concur with Tainton (1999). Average stocking rate was adhered to throughout the study period, and this may be one of the reasons why differences between the two grazing systems (HUG and CSG) were not observed.

With the significant differences between years ($P \leq 0.05$) for calving percentage, cow weight at calving, cow weight at weaning, calf birth weight and calf weaning weight over the six-year observation period, the effect of seasonal temperature, relative humidity and rainfall is elucidated and it can be assumed that weather e.g. rainfall, humidity and temperature had the biggest impact on animal production over years and not the well managed grazing systems.

The researcher acknowledge that the available small herd size should have affected the results and that a bigger herd or sub-herds sizes, combined with bigger land size could benefit the project outcome, possibly resulting in more significant differences and/or enhance interpretation of results. However, all animals and available camps for the project at the research station were included in the study.

From this study it can be concluded that oestrus synchronization may have a financial benefit for cows calving earlier in the season, heavier calves weaned and more calves weaned due to higher conception rate from 26 month old heifers. This benefit needs to be re-evaluated on a regular basis with yearly and seasonal differences in weaner prices per kg and synchronization product cost. From this study it is evident that mating of 14 month old heifers in an extensively managed production system without keeping the heifers separate from the herd or providing extra nutrition, is not economically viable.

The impact of climatic conditions can also not be ignored and showed to have a significant impact on animal production, especially calving percentage, over time. The fertility of the bulls may have been compromised by heat stress. Heat stress is a common cause of reproductive inefficiency in mammals. Semen quality decreases when bulls are continually exposed to high ambient temperatures. Furthermore, it decreases sperm concentration, lowers sperm motility and increases percentage of morphologically abnormal sperm in an ejaculate. After a period of heat stress, semen quality does not return to normal for approximately eight weeks because of the length of the spermatogenic cycle, adding to the carry-over effect of heat stress on reproduction.

If bulls cannot increase the rate of heat loss from the body when they are exposed to elevated ambient temperatures, semen quality and potential fertility is therefore reduced. It is important to note that in the South African beef production programs, eight weeks is crucial for resumption of normal semen production after bulls are exposed to elevated ambient temperatures that cause heat stress, especially where fixed summer mating seasons are practised.

When stocking rate is adhered to, it seems that either high utilization grazing or controlled selective grazing can be implemented successfully without having a negative effect on the veld condition.

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