GENETIC AND ENVIRONMENTAL TRENDS IN LANDRACE BEEF BREEDS AND THE EFFECT ON COW PRODUCTIVITY

by

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Dissertation submitted to the Faculty of Natural and Agricultural Sciences, Department of Animal, Wildlife and Grassland Sciences, University of the Free State,

In partial fulfilment of the requirements for the degree

MAGISTER SCIENTIAE AGRICULTURAE

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Bloemfontein, January 2015

Declaration

"I declare that the thesis hereby submitted by Fransie Johannes Jordaan for the degree *Magister Scientiae* at the University of the Free State is my own independent work and has not previously been submitted by me at another University/Faculty. I further more cede copyright of the thesis in favour of the University of the Free State."

F.J. Jordaan **JANUARY 2015**

ACKNOWLEDGEMENTS

This study was made possible by institutions and various individuals who played a prominent role in my career.

I want to thank the Lord for giving me good health and strength to work and I am honored to work with all role players in agriculture and to support beef breeders in South Africa.

I wish to acknowledge and thank the following people and institutions:

My mentors Prof. Michiel Scholtz, Prof. Frederick Neser and Prof. Azwihangwisi Maiwashe. Prof Scholtz who initiated this study and played a prominent role in the process of my "recognition for prior learning" with the support from the University of the Free State. His experience and knowledge in animal breeding, support and motivation helped me through difficult times. Prof Neser, for his advice, support and leadership during visits to the university. Prof Maiwashe, for his professional advice and supportive role during the study.

Zelda King, a dear friend and colleague, who helped me on a daily basis to complete documents in a professional way. I would have never been able to complete this study without her help.

The two women in my life for whom I have a lot of appreciation; my wife Una-Lou, for your love and understanding and to my dear mother, for her interest and daily prayers.

Dr Ben Greyling, my supervisor and friend, in the National Beef Improvement Scheme, for always understanding and a word of motivation when needed most.

The University of the Free State, for giving me the opportunity through the program of "recognition for prior learning", which enable individuals, based on experience in a specific field, for further studies.

The Agricultural Research Council, colleagues, friends and fellow students for the loyal support and opportunity to be part of an institution which plays an important role in developing professionals, to educate and support breeders of all sectors in the beef industry.

This work is based on research supported in part by Red Meat Research and Development South Africa, The Technology and Human Resources for Industry Programme (THRIP) and the National Research Foundation of South Africa (NRF). The grant-holder acknowledges that opinions, findings and conclusions or recommendations expressed in any publication generated by the NRF supported research are that of the authors and that the NRF accepts no liability whatsoever in this regard.

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Chapter 1

GENERAL INTRODUCTION

1.1 INTRODUCTION

Over the last 50 years there has been much focus on breeding animals to meet specific, sometimes artificial, breed standards and the use of genetic information to select animals that conform to specific production norms. Each breed society has its own unique breed standards and therefore selection between different breeds may differ.

Since the implementation of breeding values in South Africa during 1994 it is still unknown how many breeders actually utilize breeding values in selection decisions. Performance testing was not compulsory in all the Landrace breeds except for the Bonsmara breed. In recent years it was also made compulsory for the Afrikaner and Drakensberger breeds.

Within breeds, individual breeders may concentrate more on fertility than on growth where other breeders may concentrate more on maximum growth up to weaning to meet the commercial market requirements. When selecting for a specific growth trait other traits which are highly correlated to the specific trait may also be increased due to the high correlation between certain traits (e.g. growth traits like birth weight and weaning weight). Single trait selection can also influence other traits negatively, for example, single-trait selection for maximum growth can also result in a decrease in milk production in the cow herd or increase calving difficulties. (Bullock *et al.*, 2000)

An important feature of BLUP (Best Linear Unbiased Prediction) estimated breeding values (EBV's) is that they can be used to estimate genetic trends for a population by averaging the EBV's of groups of animals (e.g. per generation or year of birth) over time (Henderson, 1973). The impact of the use of breeding values on the performance of beef cattle as a selection tool over time is still largely unknown in South Africa. Furthermore it is not clear how many breeders effectively use breeding values. The question is whether the breeds that promote the use of breeding values made any genetic improvement or was the improvement due to better management and a more favourable environment? Trend lines give the direction and magnitude of genetic change (Wilson & Willham, 1986).

South Africa has a very diverse climate ranging from subtropical savannah, grassland, dry arid to winter rainfall areas. Beef cattle are present in all these areas and need to be adapted to the conditions for survival and performance. Frame size and mature weight can also vary considerably between and within breeds depending on the environment. (Arango & Van Vleck, 2002)

According to Garrick & Enns (2010) it is easy to achieve genetic change through selection. Selection normally leads to simultaneous changes in a variety traits. The changes in these traits are not always in a favourable direction due to different genetic correlations which may be negative or positive. Genetic improvement is much more difficult to achieve. Some beef breeds have shown remarkable genetic change for specific traits. Whether this resulted in genetic improvement in efficiency of production is not clear.

The phenotype and breeding values for weaning weight, cow weight and the calf/cow ratio of seven major seed stock breeds, of which the data was stored on the Integrated Registration and Genetic Information System (INTERGIS), are summarized in Table 1.1 (obtained from Scholtz, 2010) and indicate the difference in phenotypic and genetic values between 1988 and 2008.

Table 1.1: Phenotype and direct breeding values in weaning weight, cow weight and the ratio between the two over 20 years for seven South African Breeds (obtained from Scholtz, 2010)

Breed	**Trends in weaning weight, cow weight and the ratio**				
	Weaning weight (kg)		**Cow weight (kg)**		**Calf/cow ratio in % units**
	Phenotype	**Genetic**	**Phenotype**	**Genetic**	
A	+12	+6	+15	+3	+3.2
B	+15	+7	+52	+16	-4.2
C	+6	+5	+35	+3	-1.9
D	-19	+5	+4	+22	-2.8
E	+1	+2	+34	0	-1.4
F	+17	+9	+55	+15	-0.9
G	-5	0	-18	-3	+0.3

From Table 1.1 it is clear that the phenotype and genetic changes in weaning and cow weights were positive for the majority of the breeds, except for breeds D and G. In breeds B and F there were a drastic increase in cow weight over the 20 year period from 1988 to 2008, but weaning weight did not respond accordingly. This resulted in a decrease of the calf/cow ratio.

It is not clear as to whether these improvements in the different breeds resulted in improving the production efficiency of the beef cow herd or not. The uncertainties and what actually happened historically over time can only be determined once genetic and environmental trend lines have been studied over a period of time and then linked to a measure of production efficiency.

1.2 MOTIVATION AND AIM OF THE STUDY

The anticipated climate change will have a negative effect on livestock production environments and matching the genotype with the production environment will become important. The selection of animals and genotypes that are better adapted to the anticipated environment, should be pursued to ensure sustainable production (Scholtz *et al.*, 2013). In South Africa the indigenous Sanga and Sanga derived cattle can form the basis for increased productivity and product quality (Lepen, 1996; Mpofu, 2002; Scholtz & Theunissen, 2010). In terms of the regulations of the Animal Improvement Act (Act 62 of 1998) the Afrikaner, Bonsmara, Drakensberger and Nguni are classified as Landrace breeds. It is anticipated that these breed types will increasingly be used as dam lines, as they mostly have smaller frames with lower feed requirements, good maternal abilities, low birth weights and mortality at birth (Scholtz, 1988; Schoeman, 1989) as well as good meat quality characteristics (Strydom, 2008). However, it is important to understand what happened genetically in these breeds over the past years and what the current levels of productivity are in the breeds.

The aim of this study is therefore to use the genetic and environmental trend lines from the routine genetic evaluations that were done on these Landrace breeds to study the genetic and environmental changes that occurred in the cow herds of the different breeds over time. In addition it will be estimated if any of these changes (if there are any) had an effect on cow efficiency and can be used as a measure of cow productivity, since an increase in productivity will reduce the carbon footprint of beef production from these breeds.

By using the available data on the INTERGIS it is possible to do a genetic evaluation for each of the Landrace breeds in this study. Separate genetic and environmental trend lines in addition to the phenotypic trend lines are necessary for adequate interpretation of the data.

1.3 BACKGROUND

Historically SA Studbook did the registration on several beef breeds in South Africa while the Agricultural Research Council (ARC) was responsible for collecting the performance data under the National Beef Recording and Improvement Scheme (NBIS) and stored on the INTERGIS. Organizational and Institutional conflict in the breeding industry of South Africa resulted in SA Studbook taking over the responsibility for registration, performance recording and breeding value estimation since January 2012 for the breeds in this study (Scholtz, 2014).

The result of this was that virtually no data were made available to the INTERGIS and the consequence was that no data after December 2011 were available for this study. However, the data used for the routine breeding value analyses, executed by the ARC, was complete until 30 November 2011 and available for this study.

By doing genetic analyses for these breeds it will be clear if any genetic improvement has been achieved over a period of 25 years. If no genetic improvement occurred, it will indicate that a positive phenotypic improvement was due to a better environment such as improved management and other conditions.

The objective of the NBIS is the promotion of economically and biologically efficient beef production by recording traits in beef cattle that enhance production efficiency (Scholtz, 2010). Due to the diversity of the environments and production systems in South Africa there can be differences in focus from one system to another. For this reason not all measurements are compulsory but fertility traits as well as production traits form part of the study as most of the breeders select for more fertile animals and higher production. This study will assist both breed societies and breeders to determine the genetic improvement in the respective breeds. It will also enable stud breeders to develop breeding objectives based on principles that increase production efficiency.

There are varies options in which cow efficiency can be expressed, e.g. the calf/cow weight ratio and calf weight/cow weight$^{0.75}$. For this study cow efficiency was defined as the weaning weight of the calf in relation to its mother, expressed as a Large Stock Unit (LSU), as proposed by Mokolobate *et al.* (2013).

In South Africa the official definition of a LSU is the equivalent of an ox with a live weight of 450kg which gains 500g per day on grass pasture with a mean digestible energy of 55% (to maintain this 75MJ per day is required) which are based on scientific principles (Meissner *et* *al.,* 1983). This is similar to the Animal Unit used in North America (Thorne & Stevenson, 2007).

One of the responsibilities of the livestock industries is to limit the release of greenhouse gases (i.e. the carbon footprint) and water use (i.e. the water footprint) in order to ensure future sustainability. This can be done through inter alia improved production efficiency. Improved cow productivity and efficiency will have a permanent mitigating effect on the production of GHG's, as higher productivity will probably lead to higher gross efficiency (Wall *et al.,* 2010; Scholtz *et al.,* 2011). Increased productivity generates less GHG emissions per unit of livestock product (Scholtz *et al.,* 2013).

A study by Capper (2011) compared the environmental impact of modern (2007) beef production in the USA with production practices of the beef production system in 1977 and demonstrated that modern beef production requires considerably fewer resources than the equivalent system in 1977. This study indicated that improving productivity is the key to reducing the environmental impact of beef production. Capper (2011) recommended further investigation into improving productivity, through which the industry can continue to provide sufficient animal protein to satisfy the market while continuing to reduce the resource use. It is therefore important to understand the current cow productivity of the Landrace beef breeds of South Africa in the era of climate change and for various reasons as described previously.

Chapter 2

MATERIAL AND METHODS

2.1 INTRODUCTION

The genetic models developed by the ARC for the routine genetic evaluation of beef breeds in 2010, form the basis for the models used in this study. For the purpose of this study phenotypic-, genetic- and environmental trend lines were calculated for the four Landrace breeds (Afrikaner, Bonsmara, Drakensberger and Nguni) using these models. Results from the genetic evaluation were summarized in such a way that the genetic component of the phenotype as well as the environmental effect could be determined. Genetic trend is defined as the change in production per unit due to change in mean breeding value (Wilson & Willham, 1986). Environmental trend is defined as the change in production in unit of time due to change in mean environment (Harville & Henderson, 1967).

Phenotypic performance is not only determined by the collective impact of systematic effects that vary by trait, but may also be effected by herd, year, sex, and age; additive genetic effects; and a remaining component that can be referred to as lack-of-fit or an unexplained residual. It is important to partition observed performance into its respective components in order to determine the extent that genetic or environmental trends or both are influencing the observed phenotypic trends. Linear models can be used as a practical animal breeding approach to separate these components from field data which would include fixed effects for systematic terms and random effects for genetic and residual contributions (Garrick & Enns, 2010).

2.2 REASONING FOR USING THE SAME MODEL FOR ALL BREEDS

In 2010 the ARC developed new models for routine national beef genetic evaluation for South African beef breeds and specifically for the Bonsmara. It was therefore decided to apply these models in this study for the Bonsmara. An attempt was made to estimate (co)variance components for the Drakensberger breed in a multi-trait analyses. However, this was not possible, probably due to the limited number of mature cow weights in the dataset compared to the other weights (Table 2.1). No attempt was made to estimate (co)variance components for the Afrikaner and Nguni because the number of mature cow weights was even less in the case of these breeds (Table 2.1). The Bonsmara genetic parameters and models were used for all the breeds.

There are a number of options that can be followed if (co)variance components are not available for a specific breed. Three options are briefly discussed below (MacNeil, personal communication).

Firstly, there are a number of examples where genetic evaluations (BLUP) was done with parameters estimated from data other than that in the specific analysis. Furthermore, in the case of large populations the parameters are often estimated in a selected subset of the data with better structure than the entire data set (MacNeil, personal communication).

Secondly, if the dataset is sufficient to estimate additive genetic variance (heritability), but not the genetic correlations, the line of reasoning from Koots *et al.* (1994) can be followed where the phenotypic correlations are used as estimates of the genetic correlations, working backwards to get covariance components.

The last option is to use the heritability and genetic correlations from the Bonsmara data, but to scale the estimates of variances and covariances by the ratio of the phenotypic variances relative to the Bonsmara breed estimates. Thus if the Nguni (for example) mean for a particular trait is much less than the Bonsmara mean, it might imply that the variances in Nguni are also smaller as well. In this case where the estimates of heritability and genetic correlation are maintained as constants, it would only alter the magnitude of the trend relative to the first option.

For the purposes of this study, it was decided to use option one. The possible criticism of this option is that the estimates used do not reflect the true population parameters. This criticism, however, can be levelled against any of the options mentioned above. It is important to remember that the assumption in BLUP is that the variances and covariance are the true population parameters. However, in practice estimates of these parameters are used. There are a number of review papers where it is (at least implicitly) assumed that the genetic parameters are constant across breeds (VanRaden *et al.*, 2004; Brochard *et al.*, 2013). For example, this is done every time an average estimate of heritability is calculated from multiple breed-specific estimates (Meyer, 1992; Martinez Nino *et al.*, 2012).

2.3 DESCRIPTION OF THE DATA AND RECORDING PHASES

Complete pedigree and performance data for the breeds under consideration were extracted from the INTERGIS for each of the breeds. Data validation procedures were carried out as part of the routine analyses prior to the BLUP genetic evaluation. A summary of the performance data of the four breeds is presented in Table 2.1 and indicates the number of herds, birth weights (BW), weaning weights (WW), mature cow weights (MW), sires and dams.

Table 2.1: Summary of the number of herds, birth- (BW), weaning- (WW) and mature cow weights (MW), sires and dams used in the BLUP analyses

Breed	Herds	BW	WW	MW	Sires	Dams
Afrikaner	255	28 457	74 752	2 323	3 644	36 455
Bonsmara	1 619	1 058 698	948 225	69 446	19 577	375 944
Drakensberger	381	125 326	110 935	4 428	3 820	45 688
Nguni	423	75 057	55 021	2 684	3 313	35 560

Phase A: Reproduction phase and suckling phase until weaning of the calf

Traits measured in this phase includes production traits such as birth- and weaning weight; as well as cow weight at birth and weaning of the calf. Reproduction traits measured are age of the dam at birth of the calf as well as inter-calving period that is calculated as the difference in days between consecutive calving's for each cow during her reproductive life.

Phase B: Post weaning phase

The traits measured are yearling- and eighteen months weights in heifers and young bull calves that are reared on-farm post-weaning.

Phase C: Centralized intensive measurement of growth and individual feed intake

At these centralized testing stations, mainly bulls are tested to determine average daily gain and feed conversion ratio over a period of 84 days that is preceded by an adaptation period of 28 days. Body weights and feed intake are measured on a weekly basis. Measurements such as scrotum circumference, body height and length, real-time ultrasound scanning, (eye muscle area, inter-muscular and subcutaneous fat) etc. are taken at the end of test to gather carcass data on the live animal.

Phase D: Post weaning on-farm extensive or semi-intensive growth test of bulls

In this phase average daily gain is measured in an extensive or semi-extensive environment. Body weights get measured on a bi-weekly basis. Measurements such as skin thickness, scrotum circumference, body length and hip height are taken. Real-time ultrasound scanning is conducted to gather live animal measures of carcass traits.

2.4 DATA VALIDATION AND EDITING PROCEDURE

Performance data are validated when captured on the INTERGIS according to the business rules and guidelines of the NBIS.

The validation of extracted performance data, for the purpose of BLUP analyses was done using routines specifically developed for this purpose and to generate edited performance and pedigree data files. These routines or scripts were written in Visual dBase. The data files in comma delimited format (csv), was appended into dBase (dbf) table structures developed for the pedigree file and performance data sets for phases A and B and according to the layouts of these files.

A minority of breeders do not measure birth weights, but rather use standard breed specific weights for birth weights. Thus the data were checked to identify these records and exclude them from the subsequent analysis. Contemporary groups without variation were thus identified and weights from these contemporary groups were set to zero. Although no variation exist within these contemporary groups for the same sex, it is preferred to exclude these measurements from the dataset.

It was not necessary to do validations on pedigrees for errors such as unrealistic birthdates, which results in parents born before the progeny since the data gets validated on the INTERGIS and such type of errors did not appear in the data set.

Four breeding and calving seasons for contemporary birth groups, depending on year and month, were identified and are as follows:
Season one (November, December, January), season two (February, March, April), season three (May, June, July) and season four (August, September, October).

Weaning weight records from embryo calves were set to zero. These calves were not raised by their biological dams and the information on recipient dams is incomplete. The embryo calves were included in the pedigree file to ensure that these animals also receive breeding values based on the links between related animals in the pedigree and the performance data sets. Mature cow weight is defined as the first cow weight at weaning of her calf after 48 months of age.

The contemporary group for weaning is a concatenation of the herd in which the calf was weaned, the weaning test group and the treatment code which is used by the breeder to separate animals based on various treatment practises during the suckling phase on the farm. The same contemporary group for weaning was also applied for mature cow weight, since the management or contemporary groups for the cows stays the same during the suckling phase of the calf.

Renumbering of these concatenated contemporary groups was done by using a numeric numbering system according to the PEST program (Groeneveld *et al.*, 1990). This method of creating a pedigree file based on relationships between animals ensures a high level of accuracy of the estimated breeding values for unmeasured animals as well.

2.5 DESCRIPTION OF THE MODELS AND DATA USED

2.5.1 Weight traits

The complete Bonsmara multi-trait model that was used for the genetic evaluation in PEST (Groeneveld *et al.*, 1990) for the traits measured in phase A and B of the NBIS, is given below for birth- (BW), weaning- (WW), yearling- (YW), 18 month- (18M) and mature cow weight (MW):

$\mathbf{y} = \mathbf{Xb} + \mathbf{Z_1a} + \mathbf{Z_2m} + \mathbf{Z_3c_1} + \mathbf{Z_4c_2} + \mathbf{e}$

where:

$\mathbf{y}$ = vector of observations

$\mathbf{b}$ = vector of fixed effects where the following factors were fitted for all traits: sex, contemporary group that consists of herd-year-season, parity (defined as 1 for first calves and 2 for parity 2 and higher), mature cow weight contemporary group only for MW, linear and quadric regressions for dam age and linear regression for measuring age

$\mathbf{a}$ = vector of random animal effects

$\mathbf{m}$ = vector of random maternal (dam) effects for all traits

$\mathbf{c_1}$ = vector of random permanent maternal environment for WW, yearling, 18 month and mature weight

$\mathbf{c_2}$ = vector of random sire by herd year effects fitted for birth and WW

$\mathbf{e}$ = vector of random residual effects

X & **Z** = incidence matrices relating records to fixed and random animal effects, respectively

A simplified description of the models used for each growth trait are given below:

BW = damage + damage^2 + sex + parity + b_ccg + shy + maternal + direct

WW = damage + damage^2 + ww_age + sex + parity + ww_ccg + pe + shy + maternal + direct

YW = damage + $damage^2$ + yw_age + sex + parity + yw_ccg + pe + maternal + direct

18M = damage + $damage^2$ + 18m_age + sex + parity + 18m_ccg + pe + maternal + direct

MW = mw_age + mw_ccg + pe + maternal + direct

The traits are as follows: BW = birth weight, WW = Weaning weight, YW = Yearling weight, 18M = Eighteen month weight and MW = Mature weight

The factors are as follows: damage = age of the dam at birth of the calf, sex = sex of the calf, parity = fixed effect, first calf or subsequent calves, ccg = fixed effect, contemporary group for birth-, weaning-, year-, 18 month and mature weight, shy = sire-herd-year-season, pe = permanent environment of the dam, dam = dam of the calf and animal = calf.

If a genetic and environment interaction is present in the data set the inclusion of a herd-year-season by sire interaction will account for heterogeneous variances and thereby prevents an overestimation of the direct additive components. The inclusion of the permanent maternal environment is also important to avoid the overestimation of the maternal components. Both these factors should be included in a multi-herd genetic analysis for Bonsmara cattle (Neser *et al.*, 1998).

The age-of-dam adjustment factor is also important for the obvious reason that first-calf heifers are not physically or biologically mature. Nutrients consumed by heifers are partitioned not only into lactation, maintenance, and gestation, but also into their own growth and resulted into smaller calves at birth and at weaning. These calves have a disadvantage if compared to their contemporaries from older dams. Therefor adjustment factors are needed to correct this bias and is done by scaling records for calves of heifers to expected weights if those heifers had been mature cows. (Rumph & Van Vleck, 2004)

Heritability estimates (h^2) for the traits and the genetic correlations between them are presented in Table 2.2 (van der Westhuizen *et al.*, 2010). These genetic parameters were estimated in 2010 during the process of updating the genetic models for the Bonsmara. The (co)variance component estimation was done to enable the ARC to estimate breeding values in a new multi-trait model in order to increase the accuracy of estimated breeding values for young animals without measurements for certain traits.

Heritability estimates for growth traits are similar to those found in literature, including the negative correlation between direct and maternal components of weaning weight and high genetic correlations between growth traits (Mwansa *et al.*, 2002).

Table 2.2: Heritability estimates (on the diagonal) and genetic correlations (above the diagonal) for birth-, weaning-, yearling-, 18 month- and mature weights for South African Bonsmara breed (van der Westhuizen *et al.*, 2010)

Traits	Birth Direct	Wean Direct	Yearling	18 Month	Mature	Birth Maternal	Wean Maternal
Birth Direct	**0.39**	0.52	0.49	0.53	0.33	-0.07	-0.03
Weaning Direct		**0.22**	0.91	0.85	0.44	0.10	-0.16
Yearling			**0.27**	0.98	0.49	0.13	-0.03
18 month				**0.29**	0.53	0.12	0.05
Mature					**0.32**	0.45	-0.06
Birth Maternal						**0.08**	0.31
Weaning Maternal							**0.12**

Descriptive statistics for the Afrikaner, Bonsmara, Drakensberger and Nguni breeds are presented in Tables 2.3, 2.4, 2.5 and 2.6 respectively. Minimum values for birth-, weaning-, yearling- and 18 month weights were limited to 15, 100, 120 and 150kg respectively for the growth traits as reflected in the minimum values as indicated in Tables 2.3 to 2.6 for the respective breeds. Although the maximum measurements vary more than 3 standard deviations from the mean, no editing was done on these outlier measurements as is the standard procedure that was followed in the routine analyses executed by the ARC.

Table 2.3: Descriptive statistics of the Afrikaner data set after editing

Weight	n	Mean (kg)	SD (kg)	Min (kg)	Max (kg)
Birth	28 457	32.637	3.378	15	60
Weaning	74 752	187.660	32.960	100	375
Year	20 656	226.565	50.282	120	500
18 month	22 964	304.604	58.879	150	650
Mature	2 323	468.331	52.592	280	838

Table 2.4: Descriptive statistics of the Bonsmara data set after editing

Weight	n	Mean (kg)	SD (kg)	Min (kg)	Max (kg)
Birth	1 058 698	35.408	4.992	15	65
Weaning	948 225	216.027	39.597	100	474
Year	490 572	268.899	61.927	120	633
18 month	351 204	344.310	66.671	150	760
Mature	69 446	502.636	67.098	280	874

Table 2.5: Descriptive statistics of the Drakensberger data set after editing

Weight	n	Mean (kg)	SD (kg)	Min (kg)	Max (kg)
Birth	125 326	35.158	4.459	15	65
Weaning	110 935	210.657	37.686	100	395
Year	66 445	264.649	67.590	120	636
18 month	41 009	348.548	81.435	150	825
Mature	4 428	487.954	64.087	280	775

Table 2.6: Descriptive statistics of the Nguni data set after editing

Weight	n	Mean (kg)	SD (kg)	Min (kg)	Max (kg)
Birth	75 057	25.517	4.089	15	57
Weaning	55 021	161.682	28.294	100	310
Year	21 741	187.381	35.417	120	395
18 month	15 730	251.739	44.518	150	570
Mature	2 684	374.342	48.972	168	555

The Bonsmara data set with over a million measurements for birth weight outnumbered the other breeds, with just more than hundred thousand records in the Drakensberger data set and less than a hundred thousand in the case of the Afrikaner and Nguni.

2.5.2 Fertility traits

Data preparations on the pedigree and performance data set were done prior to the genetic analysis. Data was prepared in the required format specified in the file layout of the PEST (Groeneveld *et al.*, 1990) parameter file. Age at first calving were calculated by subtracting the dam birth date from the birth date of her first born calf to determine her age at first calving.

Traits included in the multi-trait model analyzed with PEST (Groeneveld *et al.*, 1990) were Inter-calving period (ICP) for the first three calvings, measured in days and age at first calving (AFC) measured in months. The following model was used:

$\mathbf{y} = \mathbf{Xb} + \mathbf{Z_1a} + \mathbf{e}$

where:

y = vector of observations

b = vector of fixed effects where the following factors were fitted for age at first calving: weaning weight code (wwc) where 1 = own weaning weight <179kg, 2 = own weaning weight 179 - 254kg, 3 = own weaning weight >254kg, weaning weight contemporary group consisting of herd-year-season of weaning weight measurement and contemporary group for AFC consisting of herd-year-season. For ICP both the dam age at consecutive calvings were used as a linear regression

a = vector of random animal effects

e = vector of random residual effects

X & **Z** = incidence matrices relating records to fixed and random animal effects, respectively

A simplified description of the models used for each growth trait are given below:

AFC = wwc + ww_ccg + ccgafc + direct

ICP1 = damage_icp1 + damage^2_icp1 + ccg_icp1 + direct

ICP2 = damage_icp2 + damage^2_icp2 + ccg_icp2 + direct

ICP3 = damage_icp3 + damage^2_icp3 + ccg_icp3 + direct

where:

The traits are as follows: AFC = Age at first calving, ICP1 = Inter calving period one, ICP2 = Inter calving period two, ICP3 = Inter calving period three,

The fixed factors are as follows: damage = age of the dam at birth of the calf, ccg = contemporary group (breeder, year and season), wwc = weaning weight of the cow

The heritability estimate for AFC is moderate and corresponds to values found in the literature; whereas that of the different ICP's is low (0.08 to 0.11) (Table 2.7). These values for AFC correspond with values found in the literature of 0.27 for Afrikaner and 0.30 for Drakensberger (Rust & Kanfer, 1998), and 0.24 for beef cattle (Gutiérrez *et al.*, 2002).

Table 2.7: Heritabilities (on the diagonal) and genetic correlations (above the diagonal) for reproduction traits (van der Westhuizen *et al.*, 2010)

Traits	AFC	ICP1	ICP2	ICP3
AFC	**0.23**	-0.10	-0.13	-0.13
ICP1		**0.08**	0.78	0.65
ICP2			**0.11**	0.53
ICP3				**0.10**

Heritability estimates for South African Holstein cattle were moderate for age at first calving (0.24 $\pm$ 0.02) and low for inter-calving period (0.03 $\pm$ 0.01) (Makgahlela *et al.*, 2007). Virtually no genetic correlation exists between the age at first calving and the inter-calving periods.

However, there are high genetic correlations between the three calving intervals which indicate that an improvement in one inter-calving period will lead to an improvement in subsequent inter-calving periods.

2.6 ESTIMATION OF COW PRODUCTIVITY

Cow efficiency was defined as kilogram calf weaned per large stock unit. Frame size specific equations as developed by Mokolobate (2015) were used to calculate the LSU for different weights of lactating cows. The following equation for small frame breeds was used to estimate LSU units for lactating Afrikaner and Nguni cows (Mokolobate, 2015):

$y = 0.2871428571 + 0.0025542857*x - 0.0000005714*x^2$

where y = LSU units and x = cow weight

The following equation for medium frame cows was use to estimate the LSU units for lactating Bonsmara and Drakensberger cows (Mokolobate, 2015):

$y = 2.13 - 0.0054*x + 0.000008*x^2$

where y = LSU units and x = cow weight

Cow efficiency, expressed as kg calf weaned per large stock unit (LSU), was estimated and averaged per year of birth. Yearly average cow- and 205 day corrected weights, as well as ICP were obtained from various publications. (Bosman, 1994; Scholtz, 2010; SA Studbook Annual Logix Beef Reports, 2012, 2013).

The predicted calving percentage was calculated according to Roux & Scholtz (1984) using the following equation:

Calving percentage = 100 – ((Average inter calving period per year – 365 days)/365 days X 100)

The average kilogram calf weaned per year was calculated as follows:

Kilogram calf weaned/LSU = (Calving percentage x Average phenotypic weaning weight per year) / large stock unit (LSU)

Cow productivity was then taken as the kilogram calf weaned per cow LSU mated as estimated above.

2.7 PRESENTATION OF DATA

Genetic, phenotypic and environmental trends are plotted for a 25 year period from 1980 to 2005 for mature cow weight, inter-calving period and age at first calving. In the case of birth- and weaning weight trends were also plotted over a 25 year period but from 1985 to 2010. The reason for this apparent discrepancy is to ensure that the same "year of birth groups" is compared due to the time lag that existed between the measurements of the different traits. Data presented in the tables and graphs will however show the data from birth year 1980 until 2010. Linear regressions were fitted and the equations were used to estimate the genetic, environmental and phenotypic changes for birth-, weaning-, mature cow weight, inter-calving period and age at first calving.

Plotting arithmetic means of all the records for each year consolidate the data for easier interpretation and when drawing regression lines to these points, it results in trend lines (Wilson & Willham, 1986). This is the approach that was followed in this study.

Phenotypic trends may give information on the past environmental conditions, breeding and management. The phenotypic measurements are a combination of genetics and environmental effects and the only method to separate these two components is through a genetic analyses. Genetic trends provide an indication of the genetic change that can be used to determine whether there was genetic improvement in efficiency/productivity or not. Thus, genetic trends will also demonstrate how much (or little) selection was actually applied for specific traits. Environmental trends will give an indication of changes in the environment and the management which the specific breeds were subjected to.

Some difficulty in the interpretation for the environmental trends for the fertility traits was also experienced and hence the decision not to report on the environmental trends for fertility was taken.

Chapter 3

PHENOTYPIC, GENETIC AND ENVIRONMENTAL TRENDS IN THE AFRIKANER BREED

3.1 HISTORY OF THE AFRIKANER

The Afrikaner has been closely associated with the people of South Africa. The Portuguese explorers encountered the San cattle, regarded as the Afrikaner's sole or principal ancestors, towards the end of the 14th century (Scholtz, 2010). The breed reached the southern tip of Africa between 590-700AD (Ramsay *et al.*, undated). The Afrikaner Cattle breeder's Society was founded on 19 June 1912 which makes it the oldest Breed Society in South Africa (Afrikaner Commemorative Journal, 2012). The Afrikaner is well adapted to extensive conditions. Prior to 1970 the Afrikaner was numerically the most popular breed. Since then its popularity has declined. The Afrikaner played a role in the development of six composite breeds (Scholtz, 2010).

The small- to medium frame size of the Afrikaner cow, with its moderate maintenance requirements, makes it an ideal dam line for the production of heavy calves at weaning when mated to a large frame bull (Scholtz, 2010). Afrikaner cows seldom experience calving difficulties, have outstanding maternal ability, are very protective towards their calves and also known for their longevity (Epstein, 1971). Ten percent of cows in the national herd are 16 years and older (Afrikaner Commemorative Journal, 2012). The average birth weight of Afrikaner calves is approximately 34kg (Scholtz, 2010).

The Afrikaner has tender, juicy and good quality meat and when crossbred with other breeds improves meat quality of these cross-bred progeny, especially with regard to tenderness (Casey *et al.*, 1990). One of the most outstanding characteristics of the Afrikaner is it's suitability for cross-breeding with exotic beef breeds (Theunissen, 2011; Theunissen *et al.*, 2014).

In 1980 there were 355 registered Afrikaner herds of which only 65 participated in Performance Testing, whereas in 2010 there were just 66 Afrikaner herds of which 43 participated in Performance Testing (Table A1).

3.2 MATERIALS AND METHODS

All tables are presented in Addendum A, starting with Table A1 and ending with Table A8.

The number of records available for this study and models used in the analysis of the different traits have been described in Chapter 2. Sixty eight percent of all registered Afrikaner breeders participate in performance testing (Bergh & Havenga, 2011).

Phenotypic averages per year of birth for birth weight (BW), weaning weight (WW), mature weight (MW), inter-calving period 1-3 (ICP1, ICP2, ICP3) and age at first calving (AFC) were obtained from the edited data set used for the annual routine BLUP analyses (Table A1).

Corresponding genetic and environmental averages were obtained from the output of the BLUP analyses using the Pest program (Groeneveld *et al.*, 1990). Regression equations were used to estimate the phenotypic, genetic and environmental trends for the different traits and the results are summarized in Table A8.

In the case of birth- and weaning weight the period from 1985 until 2010 was used. For mature cow weight, inter-calving period 1-3 and age at first calving 1980 to 2005 was used.

3.3 RESULTS & DISCUSSION

3.3.1 Phenotypic records

The number of records for birth weight varied over time with no specific pattern. The number of records for weaning weight increased until 1990, where after it decreased. The number of mature cow weights is much less than the weaning weights and that is an indication that few Afrikaner breeders measure cow weight at weaning on a regular basis (Table A1).

3.3.2 Trends in birth weight

The number of records and the average phenotypic, genetic and environmental values per year of birth for birth weight are summarized in Table A2. The phenotypic, genetic and environmental trends in birth weight of the Afrikaner are presented in Figures 3.1 to 3.3.

The phenotypic trend for birth weight from 1985 to 2010 is presented in Figure 3.1. There is a tendency for phenotypic birth weight to decrease by approximately 58g per year.

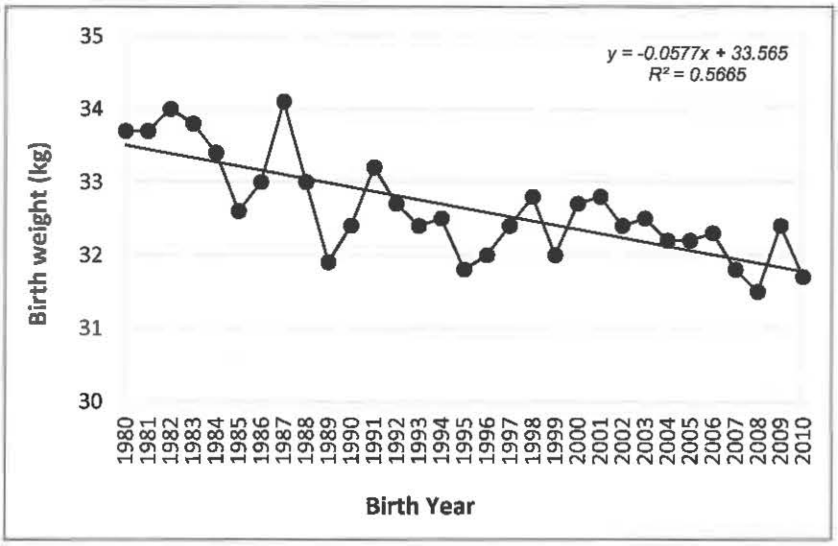

Figure 3.1: Phenotypic trend for birth weight for the Afrikaner

A regression of means of annual direct breeding values on year of birth for birth weight is presented in Figure 3.2. The genetic change in birth weight is +18g per year or +0.45kg over the 25 years from 1985 to 2010, as calculated from the regression line.

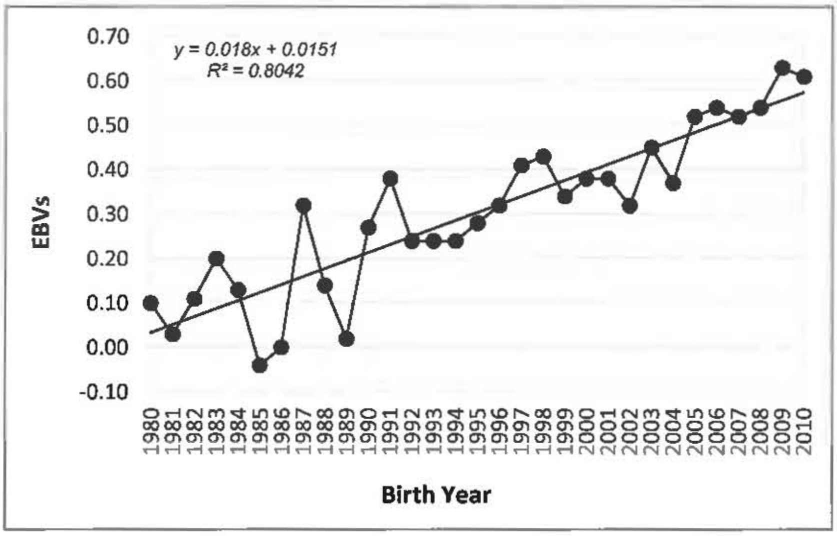

Figure 3.2: Genetic trend for birth weight for the Afrikaner

The environmental trend for birth weight (Figure 3.3) shows a slight decrease (-1.54kg) over the 25 year period, from 1985 to 2010, which can be due to a decrease in quality of grazing and extensive farming practises and possibly the harsh conditions to which the Afrikaner was recently exposed to. However, this is only speculation since it was fairly stable from 1990 onwards.

Figure 3.3: Environmental trend for birth weight for the Afrikaner

3.3.3 Trends in weaning weight

The number of records and the average phenotypic, genetic and environmental values per year of birth for weaning weight are summarized in Table A3.

A linear regression was fitted to determine the phenotypic trend for weaning weight for the period 1985 to 2010 and is presented in Figure 3.4. This indicates an increase of 818g per year or 20.4kg (180kg to 200kg) over the 25 year period from 1985 to 2010. This phenotypic trend line is a combination of both the genetic and environmental influences and it is therefore important to understand the relative contribution of each component.

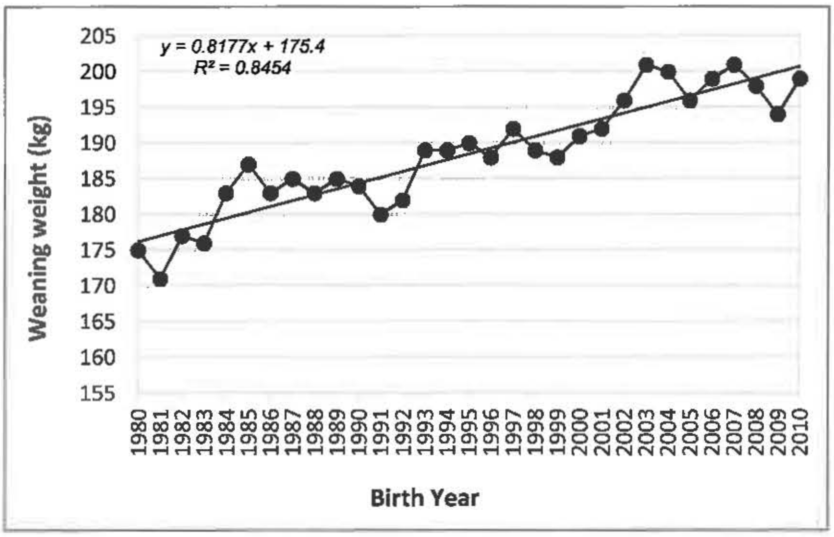

Figure 3.4: Phenotypic trend for weaning weight for the Afrikaner

There is a positive linear genetic trend for weaning weight of 277g per year or 7.0kg in the 25 years (from -0.1 in 1985 to 6.9 in 2010) as illustrated in Figure 3.5. This indicates a genetic improvement for the breed and the result of selecting breeding stock that produce progeny that is genetically superior to the parent stock.

The genetic trend for wean maternal is also positive. In this case there is a genetic change of 84g per year which has resulted in an improvement for weaning weight maternal of +2.2kg over the 25 year period (1985-2010).

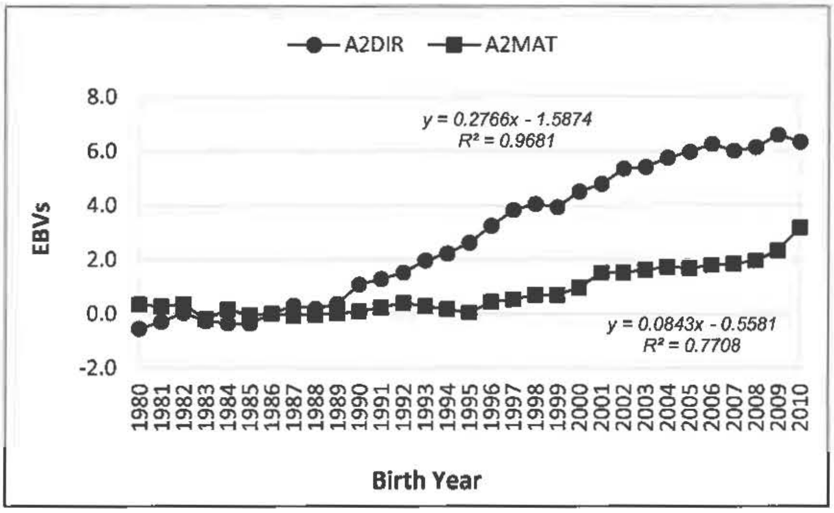

Figure 3.5: Genetic trend for weaning weight for the Afrikaner

The increase in the environmental trend for weaning weight of the Afrikaner is presented in Figure 3.6. The positive trend (+11.9kg) may be an indication of an improvement of management systems over time for weaning weight, or even better adaptation to environmental conditions. However, this speculation is contrary to that for the environmental decrease in birth weight. It is however important to note that the environment for birth weight might not be necessarily be the same for weaning weight.

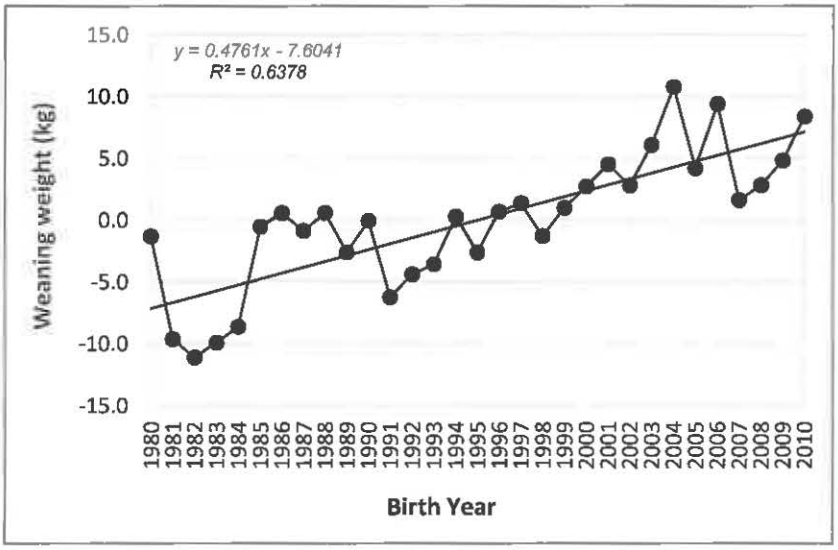

Figure 3.6: Environmental trend for weaning weight for the Afrikaner

3.3.4 Trends in mature cow weight

The number of records and the average phenotypic, genetic and environmental values per year of birth for mature cow weight are summarized in Table A4. The number of mature cow weights for the Afrikaner is much less than the number of weaning weight measurements as indicated in Table A3 and illustrates the practise of breeders not weighing the cows as well while weighing calves at weaning. This is a common occurrence with most "field" data sets.

The phenotypic trend in mature cow weight as illustrated in Figure 3.7 shows three different trends for the period from 1980 to 2005. Three regression lines were fitted as illustrated in Figure 3.7. The trend initially decreased in the period from 1980 until 1988 by 27.9kg (473kg to 446kg), and in the period from 1989 to 1995 it increased by 25kg, where after it seems to stabilize for the birth years 1996 to 2005. The net effect is a decrease of 4.2kg in mature cow weight.

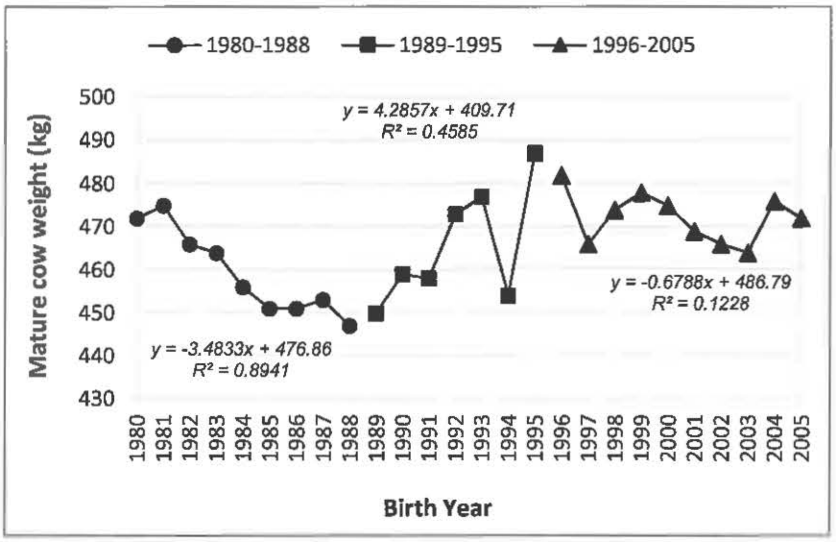

Figure 3.7: Phenotypic trend for mature cow weight for period 1980–2005

The Afrikaner show no definite genetic trend for mature cow weight for the 25 year period (1980 to 2005) as illustrated in Figure 3.8. Reasons can either be that not enough measurements are available for the trait to show a trend or it can be an indication that mature cow weight did not increase over the time period. Although the correlated traits within the multi trait model would help with the prediction for mature cow weight, the trend was derived only on cows with measurements. There is no indication of a clear selection aim amongst the Afrikaner breeders in respect of mature cow weight.

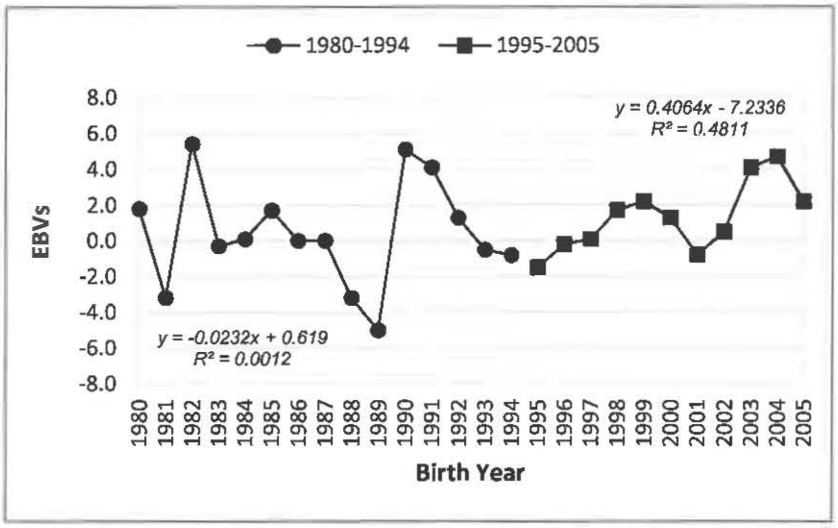

Figure 3.8: Genetic trend for mature cow weight for the Afrikaner

The environmental trend for mature cow weight indicates no clear trend over the period from 1980 to 2005 as illustrated in Figure 3.9.

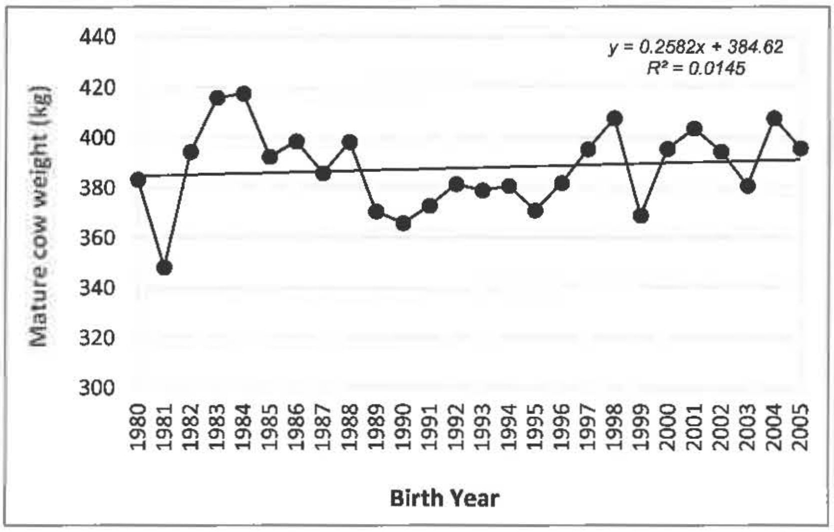

Figure 3.9: Environmental trend for mature cow weight for the Afrikaner

3.3.5 Trends for the first three inter-calving periods and age at first calving

The number of records and the average phenotypic, genetic and environmental values per year of birth for the first three inter-calving periods (ICP1-3) are summarized in Table A5.

The phenotypic trend for ICP1-3 in days for the Afrikaner is illustrated in Figure 3.10 and shows a decreased of 19.6 days (473 to 453 days) which shows an improvement in fertility for the 25 year period from 1980 to 2005 for Afrikaner cows. This may be the result of an improvement in management, e.g. a decision to cull the cows that did not calf in a season. However the reason is unknown and cannot be determined from the phenotypic trend.

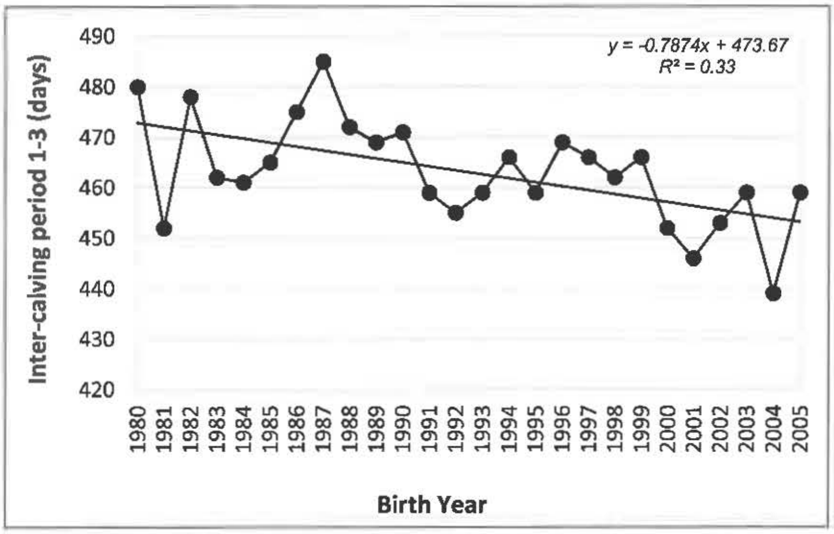

Figure 3.10: Phenotypic trend for ICP1-3 in days for the Afrikaner

There is no indication of a definite genetic trend for ICP1-3 as illustrated in Figure 3.11 for the same 25 year period from 1980 to 2005. For the period 1980 to 1994 there seems to be a slight decrease where after there is a slight increase again from 1995 to 2005 as illustrated in Figure 3.14. However, the changes are so small that it can be ignored for all practical purposes.

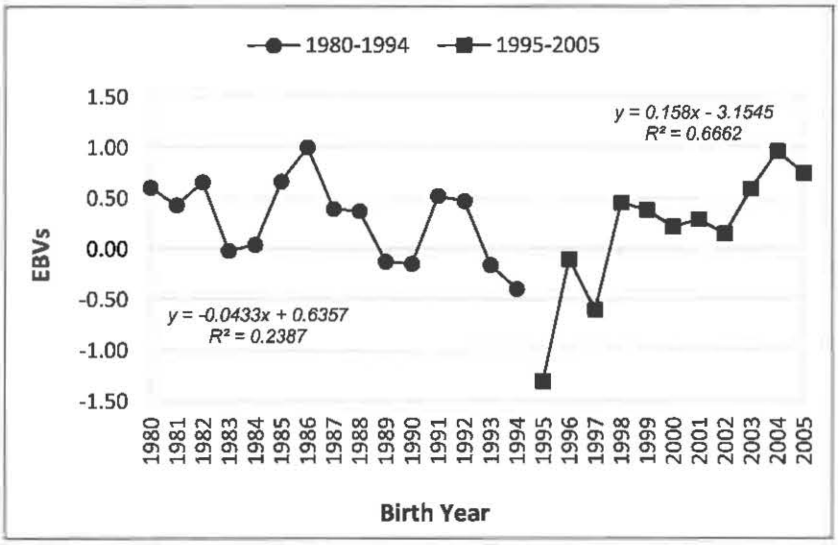

Figure 3.11: Genetic trend for ICP1-3 for the Afrikaner

The age at first calving showed no phenotypic trend over the 25 year period from 1980 to 2005 (Figure 3.12). Age at first calving can easily be manipulated by breeders by mating heifers at an earlier age, or a change or improvement in the feeding of heifers. Management may therefore have an important influence on age at first calving.

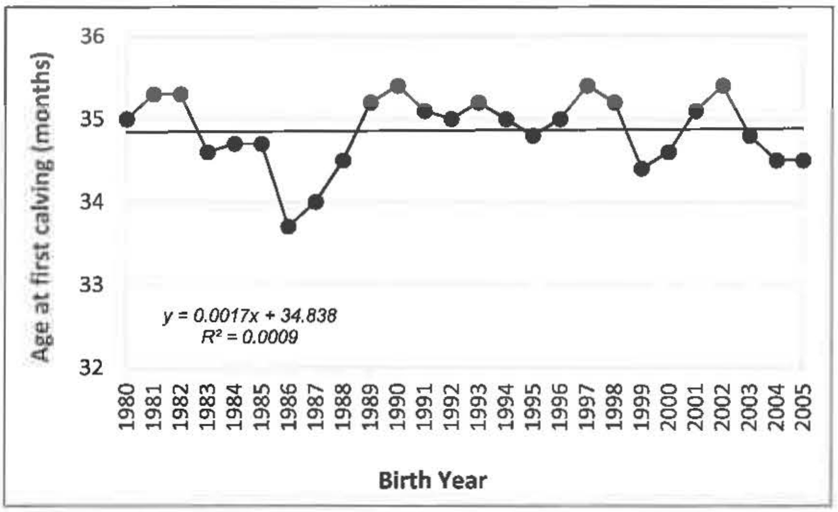

Figure 3.12: Phenotypic trend for age at first calving in months for the Afrikaner

There is no genetic trend for age at first calving as illustrated in Figure 3.13 for the period 1980 to 2005 with a very low R^2 value of 0.03.

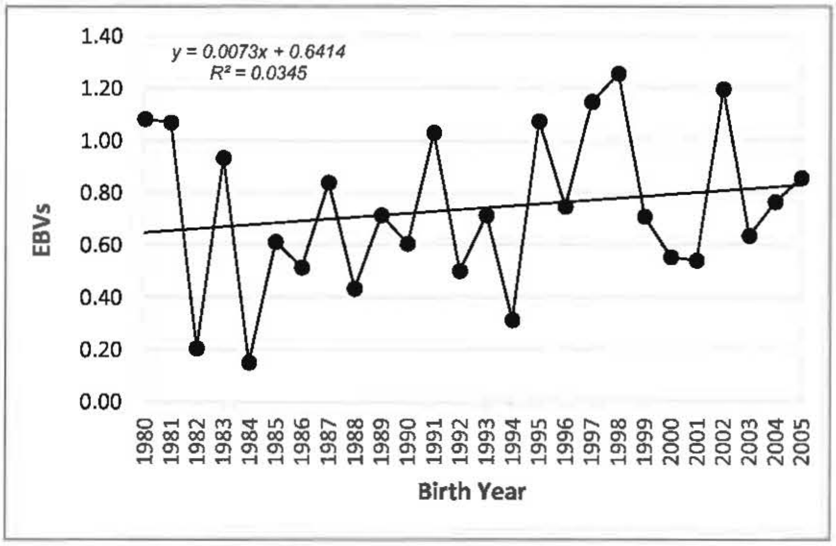

Figure 3.13: Genetic trend for age at first calving for the Afrikaner

3.3.6 Cow productivity

Cow productivity was measured in kilogram calf weaned per large stock unit (KgC/LSU) per cow calved (estimated from ICP). Cow weights and ICP were obtained from Table A7. The estimated KgC/LSU is also summarized in Table A7.

The Afrikaner showed a decrease of 14kg in KgC/LSU from 1980 to 1986, and there after an increase from 98 KgC/LSU to 107 KgC/LSU in 2005 as illustrated in Figure 3.14 and summarized in Table A7. The net effect is an increase of 16kg (from 94kg to 110kg) in KgC/LSU from 1980 until 2013 as observed from all phenotypic data available for the Afrikaner, although from 1996 until 2013 no obvious trend is clear for KgC/LSU.

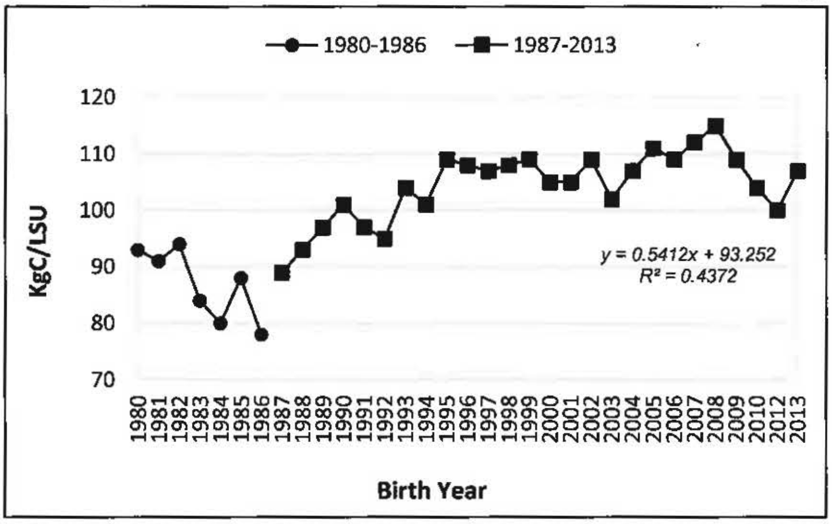

Figure 3.14: Kilogram Calf per LSU for the Afrikaner

3.3.7 Discussion

It should be noted that the number of Afrikaner breeders decreased from 355 in 1980 to only 66 in 2010. However, the number of herds participating in Performance Testing decreased only from 65 to 43 (Table A1). Although there was a large decrease in the number of breeders the participation in Performance Testing did not decrease to the same extend, albeit that the gene pool decreased drastically. The aforementioned probably contributed to the observed trends, but this possible effect was not investigated.

Trends

The phenotypic trend for birth weight (-1.45kg) and ICP (-19.6 days) is negative whereas that of mature cow weight is variable but the net effect is a small decrease of 4.2kg. The phenotypic trend for weaning weight was positive with a net effect of 20.4kg. In the case of age at first calving there were no phenotypic trend.

Genetic change and genetic improvement for certain traits was achieved in the Afrikaner breed. The genetic trends for birth- and weaning (direct and maternal) weights are positive. The genetic trends for mature cow weight, inter-calving period 1-3 and age at first calving was non-significant. The breeding strategy recently followed by the Afrikaner breeders managed to increase calf weaning weight genetically (Table A3 and Figure 3.5), while maintaining mature cow weight (Table A4 and Figure 3.8).

There is no obvious improvement in the environment.

Cow productivity

The phenotypic increase of 16kg in cow efficiency (Table A7 and Figure 3.14), resulted in more efficient breeding cows with less maintenance requirements per unit of product, and thus reducing the carbon footprint of weaner calf production from Afrikaner cows. Selection that only focus on growth traits will result in an increase of mature weight and an increase in maintenance requirements. However this did not happen in the Afrikaner. Selection should be used as a tool to increase profitability, and not just revenues (Enns *et al.*, 2001), as was the case in the Afrikaner.

Chapter 4

PHENOTYPIC, GENETIC AND ENVIRONMENTAL TRENDS IN THE BONSMARA BREED

4.1 HISTORY OF THE BONSMARA

It is claimed that the Bonsmara is the only beef breed that was created through a well-documented crossbreeding programme with the aid of objectively recorded performance data combined with visual evaluation for functional efficiency. The Bonsmara (*Bos taurus africanus*) was bred at the Mara and Messina Research Stations from 1937 to 1963 by animal scientists under the guidance of the late Prof Jan C. Bonsma. The name Bonsmara was derived from "Bonsma" and "Mara". (Scholtz, 2010)

Results of crossbreeding trials with British beef breeds then present in South Africa indicated that the best results were obtained with the locally adapted Afrikaner breed and the Hereford and Shorthorn breeds. The optimal combination was found to be 5/8 Afrikaner and 3/8 Exotic (Shorthorn, Hereford). This combination performed the best in warm subtropical environments with an abundance of ticks. The first pure Bonsmara calves were produced in 1943. After the successful testing of the breed under practical farming conditions, the breed society was formed in 1964, but only promulgated in 1972. (Bosman, 1994; Scholtz, 2010).

It is the only Landrace breed in South Africa which enforced participation in performance testing since its inception. Since 1964 the breed has grown to the most numerous beef cattle breed in South Africa and currently has more than 100 000 active registered animals. Since 1995 Bonsmara cattle are also found in countries such as Namibia, Uganda, Zambia Argentina, Australia, Brazil, Paraguay, Colombia, USA and Uruguay (Scholtz, 2010).

There were 315 registered Bonsmara herds in 1980 and it has grown to 353 in 2010. It is also important to note that the number of weaning weights increased from 7 394 to 30 687 per year during the same period (Table B1).

4.2 MATERIALS AND METHODS

All tables are presented in Addendum B, starting with Table B1 and ending with Table B8.

The number of records available for this study and models used in the analysis for the different traits has already been described in Chapter 2.

The average Bonsmara phenotypic, genetic and environmental measurements per year of birth for birth weight (BW), weaning weight (WW), mature cow weight (MW), inter-calving period 1-3 (ICP1, ICP2, ICP3) and age at first calving (AFC) were obtained from the edited data set used for the annual routine BLUP analyses (Table B1). The genetic and environmental trends were obtained from the output of the BLUP analyses using Pest (Groeneveld *et al.*, 1990) and averaged by year of birth. Linear regression equations were used to estimate the phenotypic, genetic and environmental trends for the different traits and the results are summarized in Table B8.

In the case of birth- and weaning weights the period from 1985 until 2010 was used. For mature cow weight, inter-calving period1 and age at first calving 1980 to 2005 was used.

4.3 RESULTS & DISCUSSION

4.3.1 Phenotypic records

The number of records for birth weight stabilized at around 40 000 per year since 1988. The number of mature cow weights shows a similar pattern as in the Afrikaner in comparison with the number of weaning weights; an indication that only a minority of Bonsmara breeder's measure cow weight at weaning on a regular basis (Table B1).

4.3.2 Trends in birth weight

The number of records and the average phenotypic, genetic and environmental values per year of birth for birth weight are summarized in Table B2. The phenotypic, genetic and environmental trends for birth weight of the Bonsmara are graphically presented in Figures 4.1 to 4.3 below.

The number of records increased from 1980 to 1989, thereafter no specific pattern was observed. The number of measurements started to increase again after 2006. This could be due to the increase in the number of breeders and the simultaneous increase in the number of active animals in the breed (Table B2).

The phenotypic trend for birth weight in kg from 1987 to 2010 for the Bonsmara is presented in Figure 4.1. A very small change of only 16g per year is recorded for the phenotypic measurement of birth weight for the period 1985-2010 from 35.7kg in 1987 to 35.3kg in 2010.

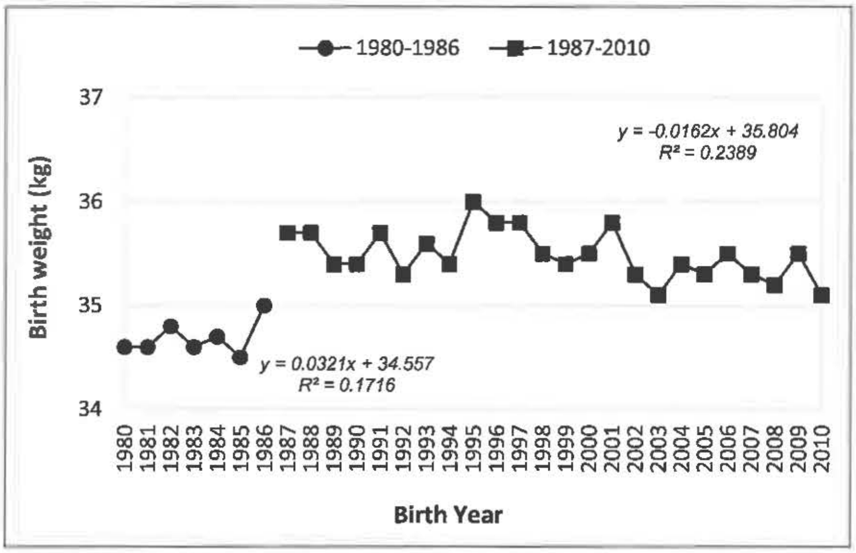

Figure 4.1: Phenotypic trend for birth weight for the Bonsmara

The slope (b-value) (Figure 4.2) indicates a genetic change of 78g per year or 0.7kg from 1985 to 1994 for birth weight. This is in contrast with the very small positive change of less than 10g per year that was observed from 1995 to 2010 (+0.10kg).

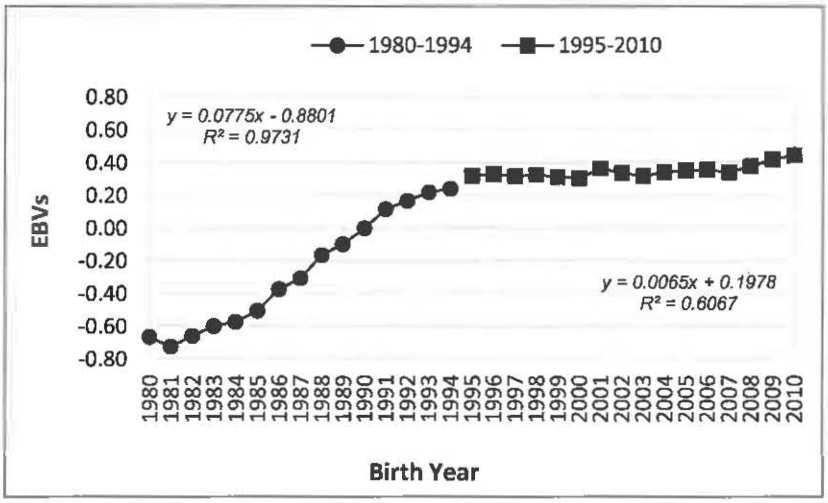

Figure 4.2: Genetic trend for birth weight for the Bonsmara

The environmental trend (Figure 4.3) for birth weight show a gradual decrease over the period from 1985 to 2010 of 60g per year. The Bonsmara breed increased in numbers over the past few years and it is possible that breeders are farming with the Bonsmara in even more extensive areas, possibly leading to this negative trend.

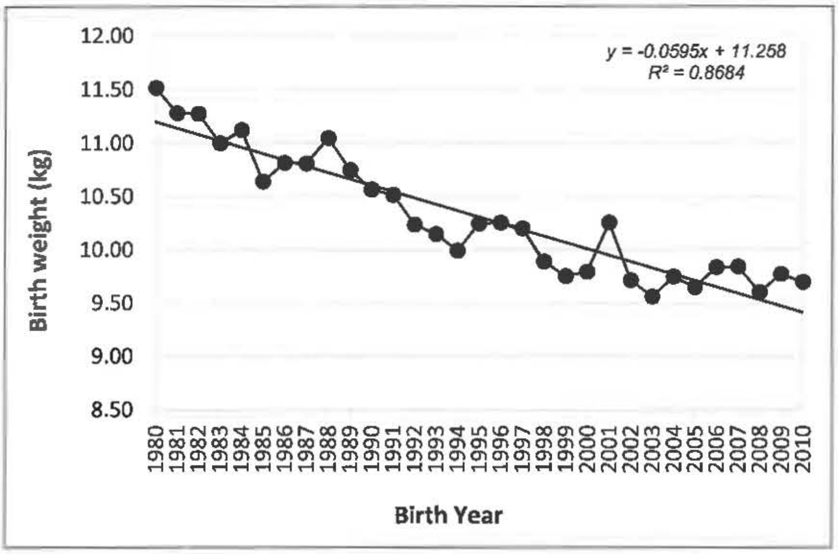

Figure 4.3: Environmental trend for birth weight for the Bonsmara

4.3.3 Trends in weaning weight

The number of records and the average phenotypic, genetic and environmental values per year of birth for weaning weight are summarized in Table B3. A linear regression was fitted to determine the phenotypic trend for weaning weight for the period 1985-2010 and is presented in Figure 4.4. This indicates a positive trend for the period 1985 to 1999 of 671g per year or +9.4kg. However, since 2000 a slight negative trend of 182g per year was observed from 223.8kg in 2000 to 222kg in 2010, which is a negative phenotypic change of -1.8kg.

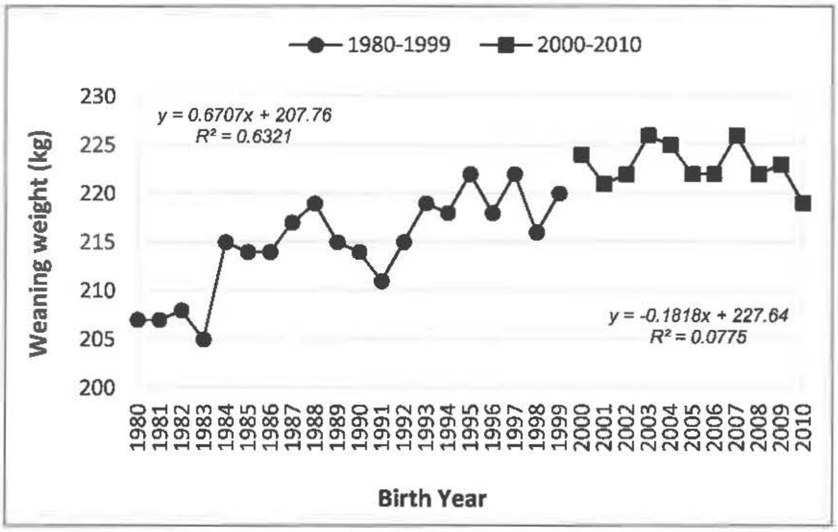

Figure 4.4: Phenotypic trend for weaning weight for the Bonsmara

A positive genetic trend (Figure 4.5) for weaning weight of 467g per year or +11.7kg (from -2.6 in 1985 to a positive average weaning direct breeding value of +9.1 in 2010) was observed. This indicates that Bonsmara breeders do select for higher weaning weights and that they use breeding values as a selection tool to achieve this breeding objective.

The genetic trend for weaning maternal is also positive and the trend is similar. There is a genetic change of 143g per year or +3.5kg for weaning maternal (from -0.5 in 1985 to +3.0 in 2010) as illustrated in Figure 4.5, which indicates an increase in the maternal ability for weaning weight.

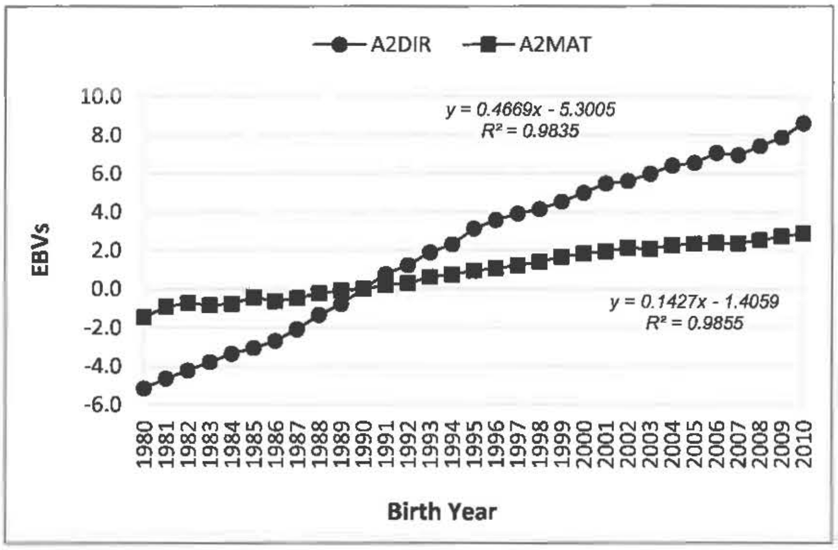

Figure 4.5: Genetic trend for weaning weight for the Bonsmara

The environmental trend for the Bonsmara for weaning weight indicates a decrease over the period from 1985 to 2010 as illustrated in Figure 4.6. There may be many reasons for this trend. One of the reasons may be poorer adaptation, since it appears that the influence of Afrikaner genes in the Bonsmara is currently low as illustrated by Makina *et al.* (2014).

Another reason may be the decrease in number of breeders from 510 to 353 (Table B1), while the number of weaning weights increased from 18 000 to more than 30 000. This indicates more measurements from less farms and a possible lack of adaptability to the change in environments.

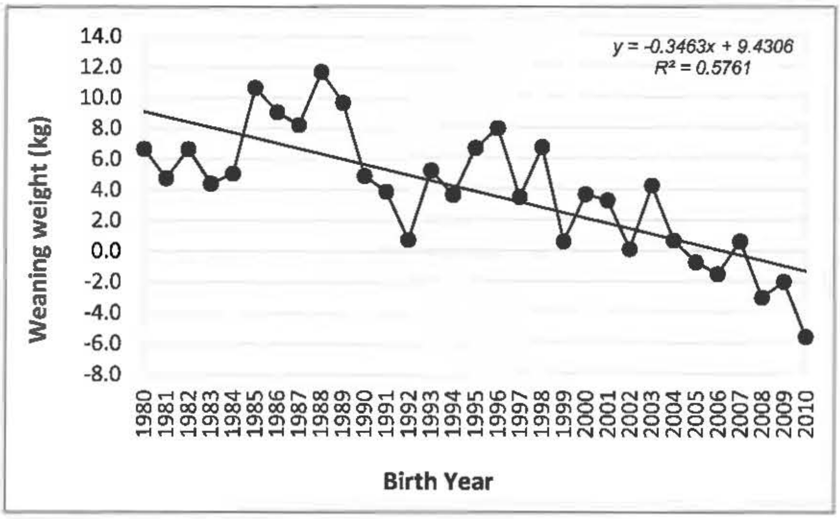

Figure 4.6: Environmental trend for weaning weight for the Bonsmara

4.3.4 Trends in mature cow weight

The number of records and the average phenotypic, genetic and environmental values per year of birth for mature cow weight are summarized in Table B4. Although the number of mature cow weights for the Bonsmara is much less than the number of weaning weight measurements as indicated in Table B3, the numbers seems to be sufficient.

The number of records for mature cow weight does not show an increase in numbers over the 25 year period as indicated in Table B4 and the assumption can be made that not all Bonsmara breeders measure mature cow weight. The phenotypic mature cow weight increased by 700g per year or +17kg (494kg to 511kg) over the 20 year period as illustrated in Figure 4.7.

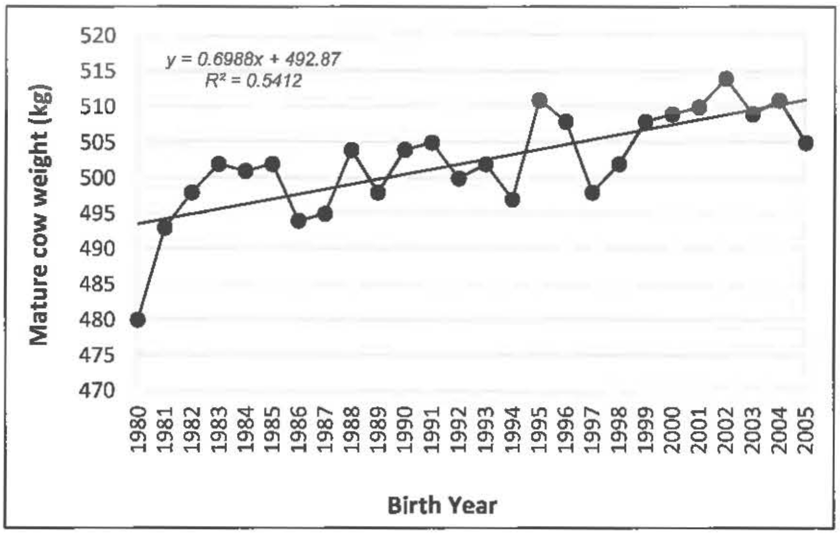

Figure 4.7: Phenotypic trend for mature cow weight for period 1980-2005

The Bonsmara also has a positive genetic trend for mature cow weight of 638g per year or +15.9kg (-8.6kg in 1980 to a positive average mature cow weight breeding value of +7.3kg) in 2005 as illustrated in Figure 4.8. However it tended to stabilize over the last 10 years. This increase in mature cow weight, as mentioned earlier can be due to the selection for other growth traits such as weaning weight and post weaning growth traits and could be the cause for the increase in mature cow weight because of highly correlated growth traits (Chapter 2: Table 2.1).

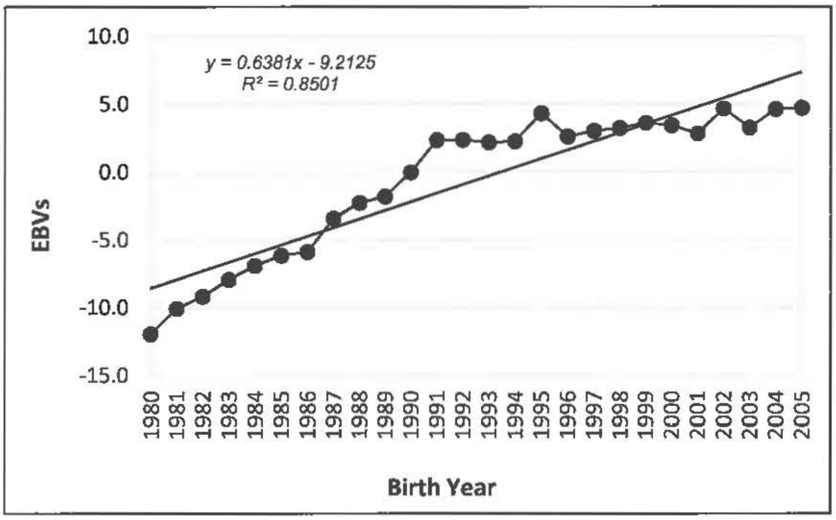

Figure 4.8: Genetic trend for mature cow weight for the Bonsmara

The environmental trend in the Bonsmara for mature cow weight shows an increase of 1.37g per year from 386kg in 1983 to 393kg in 1988, where after no change was observed (R^2 = 0.001) until 2005 as illustrated in Figure 4.9 which indicates that the increase in phenotype is not due to increased feeding or management but rather the high correlation between growth traits.

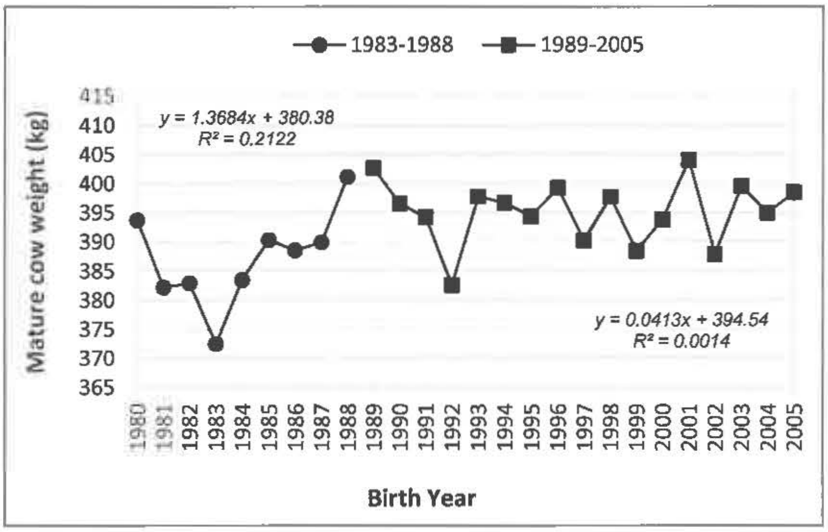

Figure 4.9: Environmental trend for mature cow weight for the Bonsmara

4.3.5 Trends for the first three inter-calving periods and age at first calving

The number of records and the average phenotypic, genetic and environmental values per year of birth for inter-calving period 1-3 (ICP1, ICP2, ICP3) are summarized in Table B5.

The phenotypic ICP1-3 decreased by 17 days (449 to 432 days) which shows an improvement in fertility for the 25 year period from 1980 to 2005 for Bonsmara cows as illustrated in Figure 4.10. This can also be the result of an improvement in management or selection by culling the cows that did not calf in a season, but the reason is unknown and cannot be determined from the phenotypic trend.

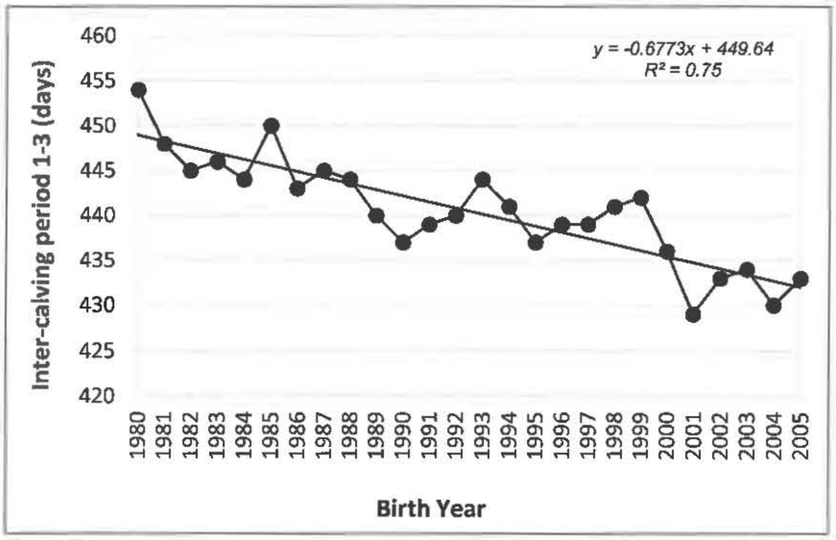

Figure 4.10: Phenotypic trend for ICP1-3 in days for the Bonsmara

Overall there was no genetic trend in ICP1-3 over the 25 year period as illustrated in Figure 4.11. Initially a negative genetic trend of 0.07days for ICP1-3 from 0.69 in 1980 to -0.62 in 1998 was observed, where after it increased by 0.18 days per year for the period 1999 to 2005, resulting in a negligible change.

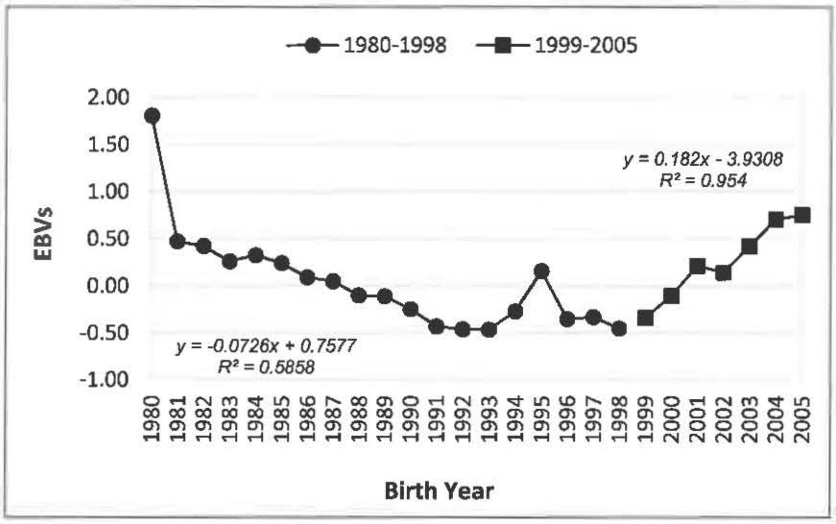

Figure 4.11: Genetic trend for ICP1-3 for the Bonsmara

The number of records and the average phenotypic, genetic and environmental values per year of birth for age at first calving are summarized in Table B6. There is no phenotypic trend (R^2 = 0.13 and b = -0.017) over the 26 year period from 1980 to 2005, for age at first calving as illustrated in Figure 4.12.

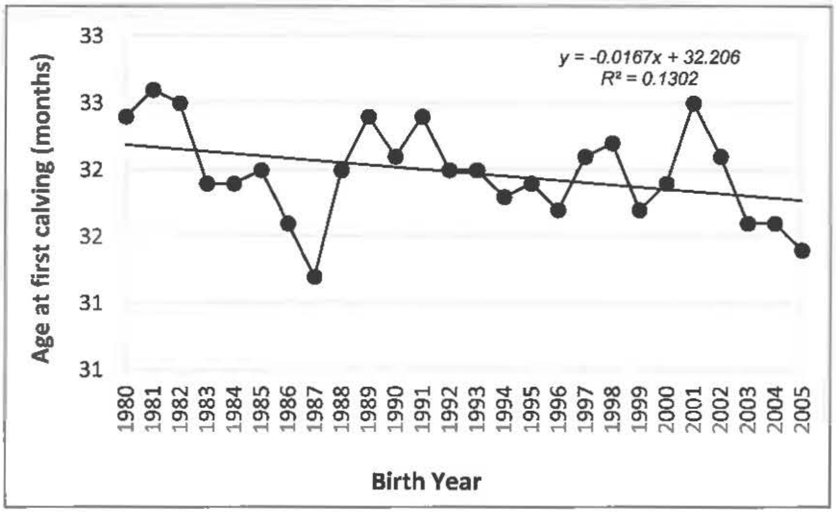

Figure 4.12: Phenotypic trend for age at first calving in months for the Bonsmara

There was a significant increase in the genetic trend for age at first calving of 0.123 days per year or 3 days from -1.16 in 1980 to 1.91 in 2005 as illustrated in Figure 4.13.

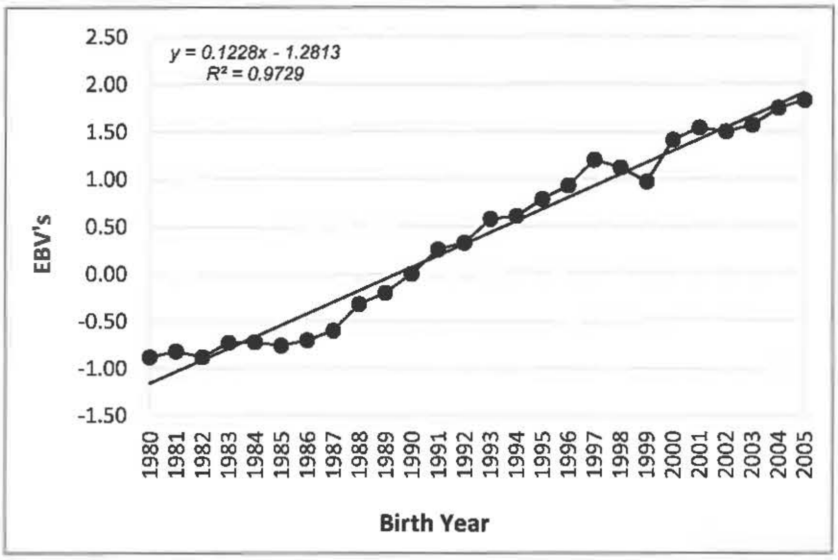

Figure 4.13: Genetic trend for age at first calving for the Bonsmara

4.3.6 Cow productivity

Cow productivity was measured in kilogram calf weaned per large stock unit (KgC/LSU). Cow weights and ICP were obtained from Table B7. The estimated KgC/LSU is also summarized in Table B7.

Unlike the Afrikaner, the Bonsmara showed a positive trend for KgC/LSU over the whole period with a decrease in inter-calving period despite an increase in cow weight (Table B7), which resulted in an increase in LSU (Table B7) over the period as illustrated in Figure 4.14.

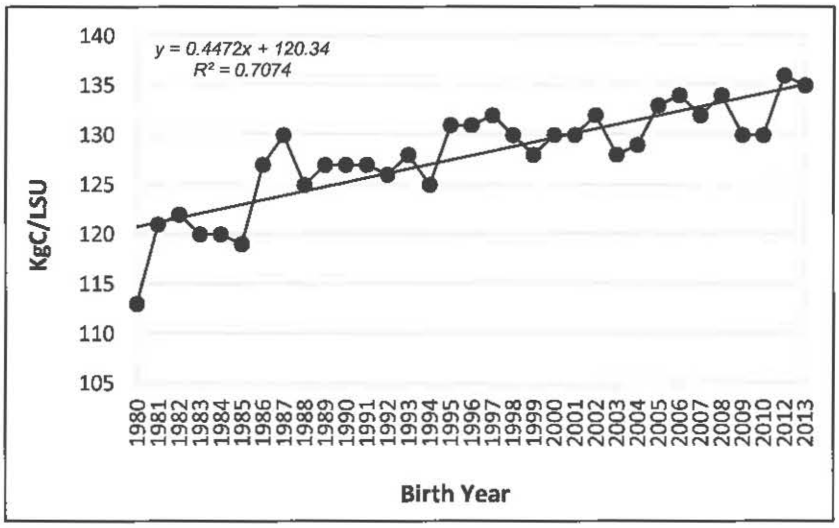

Figure 4.14: Kilogram Calf per LSU for the Bonsmara

4.3.7 Discussion

Trends

The phenotypic trend for birth weight in the Bonsmara shows no change. An overall phenotypic improvement in weaning weight was achieved over the period from 1985 to 2010, although for the period from 2000 to 2010 no improvement was observed. The net effect was +9.4kg over the whole period. Mature cow weight also increased by 17.4kg over the period. Fertility as measured by inter-calving period did improve phenotypically by 17 days, whereas age at first calving did not change.

Genetic change and/or genetic improvement for certain traits was observed in the Bonsmara breed. Birth weight increased by almost 1kg, whereas direct weaning weight increased by 11.7kg and maternal weaning weight by 3.5kg. The breeding strategy followed by the Bonsmara breeders managed to increase calf weaning weight genetically over the whole period. Unfortunately the mature cow weight also showed positive genetic trend of 15.9kg. There was no genetic trend for ICP whereas age at first calving showed a slight increase of 3 days.

The environmental trend for birth- and weaning weight decreased. The environmental trend for mature cow weight showed an initial increase until 1988, where after there was no change. This indicates that the increase in phenotype is not due to better feeding or management.

Cow productivity

Despite the genetic and phenotypic increase in mature cow weight, cow efficiency as measured in KgC/LSU (Table B7 and Figure 4.14), indicates an improvement in cow efficiency although the LSU for Bonsmara cows increased from 1.34 in 1980 to 1.45 in 2005. When selecting to increase growth the result will also be an increase in mature cow weight and an increase in maintenance requirements. The decrease in ICP was however more than enough to offset the higher maintenance requirements and the net effect was more efficient cows. It is also important to note that the maternal ability improved genetically, which contributed to the heavier weaning weights, albeit cow maintenance may have increased due to higher milk production. Selection should be used as a tool to increase total profitability, and not just revenues (Enns *et al.*, 2001).

Chapter 5

PHENOTYPIC, GENETIC AND ENVIRONMENTAL TRENDS IN THE DRAKENSBERGER BREED

5.1 HISTORY OF THE DRAKENSBERGER

The Drakensberger is a South African beef breed that has been developed and improved over many years. No documentary evidence is available on the earliest development or origin of the breed. Certain tribes of Hottentots already owned black cattle as far back as 1659. It is possible that eight bulls imported from Holland in the 1700's, probably of the Groningen breed, were the earliest sires and that the black cattle of the Hottentots were the original dams of the breed. The breed was initially known as "Uys cattle" for historical reasons. (Epstein, 1971; Bosman, 1994)

In November 1947 the Drakensberger Breeders' Society was formed and the name "Drakensberger" was officially given to the breed. In May 1969 the Society was recognized as an Associate Member and in 1972 as a Full Member of the SA Stud Book and Livestock Improvement Association. In 1980 the Society made performance recording compulsory. The Drakensberger was the first beef breed in South Africa for which a whole-breed BLUP analyses was done. (Bosman, 1994; Scholtz, 2010)

The Society claims that the modern Drakensberger is the culmination of a development process based on strict selection on scientific norms, and that in the selection programme emphasis is placed on economically important traits, such as fertility, adaptability, milk production, low mortality, growth, and feed conversion (Scholtz, 2010).

Drakensberger cattle are widely distributed throughout South Africa and in neighboring countries such as Namibia, Swaziland and Zimbabwe; and are even found further north in the humid climate of Equatorial Guinea. The Drakenberger has proved its ability to cross well with both *Bos indicus* and *Bos taurus* breeds, making it suitable as a dam line in crossbreeding systems (Scholtz, 2010).

In 1980 there were 222 registered Drakensberger herds of which 85 participated in Performance Testing. This number decreased to only 76 herds in 2010 and all participated in Performance Testing (Table C1).

5.2 MATERIALS AND METHODS

All tables are presented in Addendum C, starting with Table C1 and ending with Table C8.

The number of records available for this study and models used in the analysis for the different traits has already been described in Chapter 2.

The number of Drakensberger phenotypic, genetic and environmental records per year of birth for birth weight (BW), weaning weight (WW), mature cow weight (MW), inter-calving period 1-3 (ICP1, ICP2, ICP3) and age at first calving (AFC) were obtained from the edited data set used for the annual routine BLUP analyses (Table C1). The genetic and environmental trends were obtained from the output of the BLUP analyses using Pest (Groeneveld *et al.*, 1990) and averaged by year of birth.

The regression equations with the best fit were used to estimate the phenotypic, genetic and environmental trends for the different traits and the results are summarized in Table C8.

In the case of birth- and weaning weights for the period from 1985 until 2010 was used. For mature cow weight, ICP1-3 and age at first calving 1980 to 2005 was used.

5.3 RESULTS & DISCUSSION

5.3.1 Phenotypic records

The number of records for birth weight varied over time. The number of records for weaning weight increased until 1990, thereafter it decreased (Table C1).

5.3.2 Trends in birth weight

The number of records and the average phenotypic, genetic and environmental values per year of birth for birth weight are summarized in Table C2. The phenotypic, genetic and environmental trends in birth weight of the Drakensberger are graphically presented in Figures 5.1 to 5.3 below.

The phenotypic trend for birth weight in kg from 1985 to 2010 for the Drakensberger is presented in Figure 5.1. Until 1995 there seems to be a small increase in birth weight of 67g per year, where after a decreased again by 47g per year from 1996 to 2010.

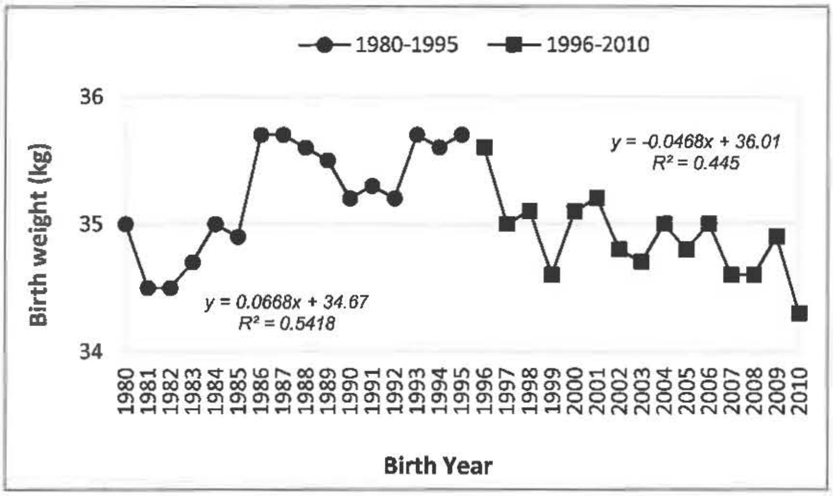

Figure 5.1: Phenotypic trend for birth weight for the Drakensberger

The genetic trend for birth weight (Figure 5.2) followed the same pattern as the phenotypic trend, but is so small that it can be ignored (less than 25g per year for both periods).

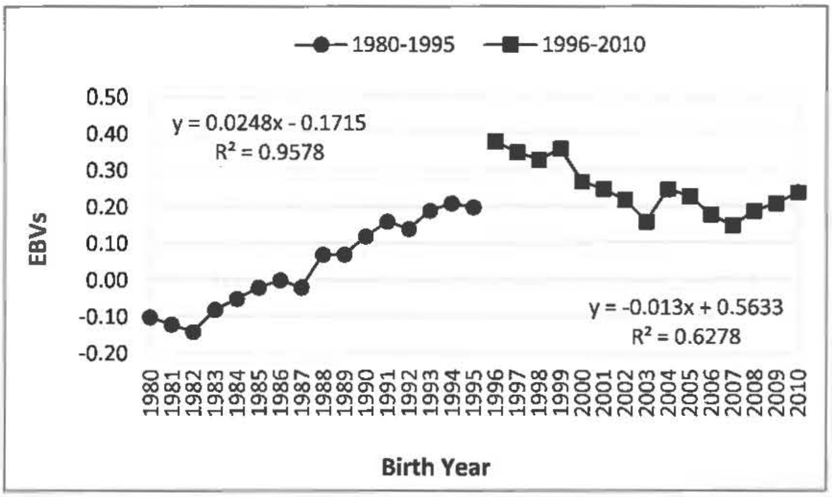

Figure 5.2: Genetic trend for birth weight for the Drakensberger

The environmental trend for birth weight show a gradual decrease over the period of 32g per year from 0.04 in 1985 to -0.75 in 2010 as illustrated in Figure 5.3, which is also small.

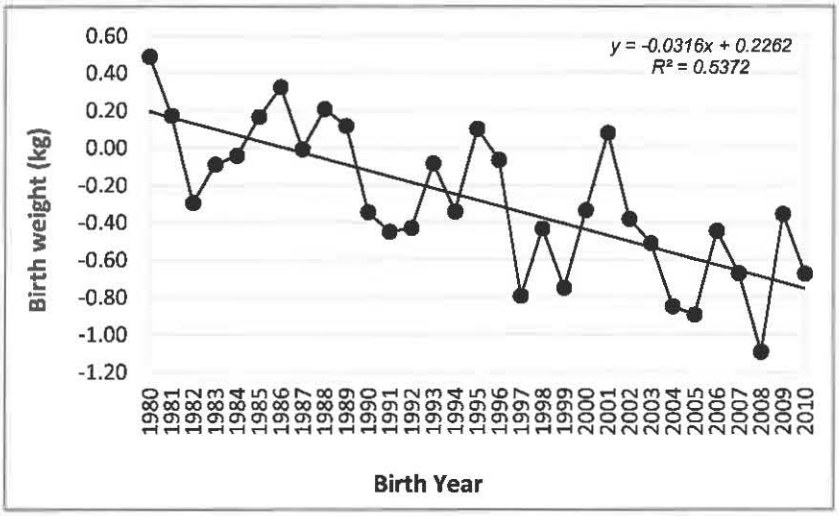

Figure 5.3: Environmental trend for birth weight for the Drakensberger

5.3.3 Trends in weaning weight

The number of records and the average phenotypic, genetic and environmental values per year of birth for weaning weight are summarized in Table C3.

The phenotypic weaning weight shows no trend ($R^2 = 0.024$) over the whole period from 1985 to 2010 as illustrated in Figure 5.4. Possible reasons for this will be discussed later.

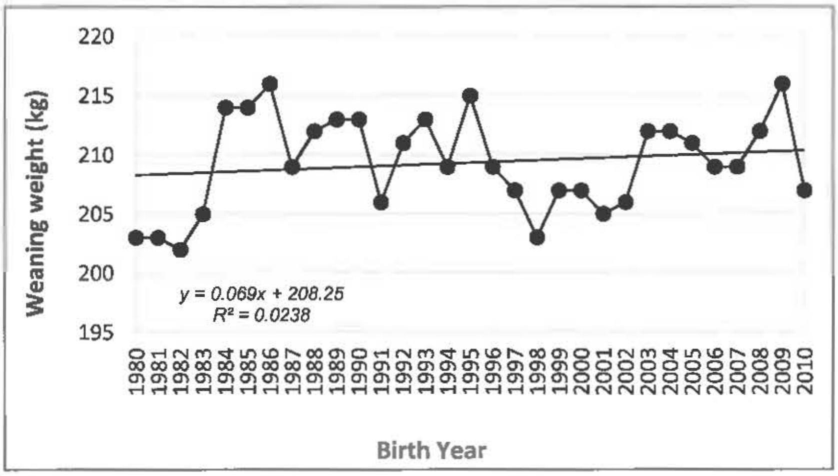

Figure 5.4: Phenotypic trend for weaning weight for Drakensberger

There is a positive linear genetic trend for direct weaning weight of 248g per year, from -0.13kg in 1985 to 6.1kg in 2010 as illustrated in Figure 5.5. This indicates that Drakensberger breeders did select for higher weaning weights and used breeding values as a selection tool to achieve their breeding objectives. In contrast to the positive trend in direct weaning weight there was no genetic trend for maternal weaning weight as illustrated in Figure 5.5 (R^2 = 0.01).

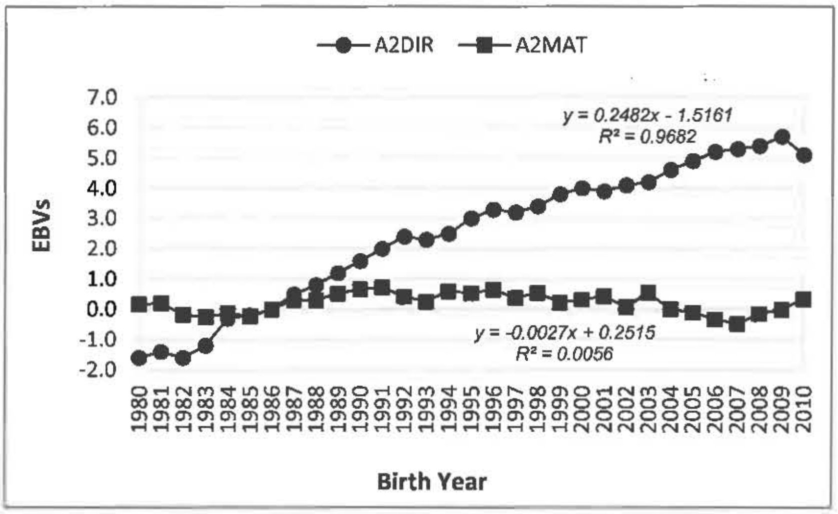

Figure 5.5: Genetic trend for weaning weight in kg for the Drakensberger

The environmental trend for the Drakensberger for weaning weight showed a decrease of 1.05kg per year (13.7kg) from 1985 until 1998, where after it increased by 725g per year (7.9kg) as illustrated in Figure 5.6.

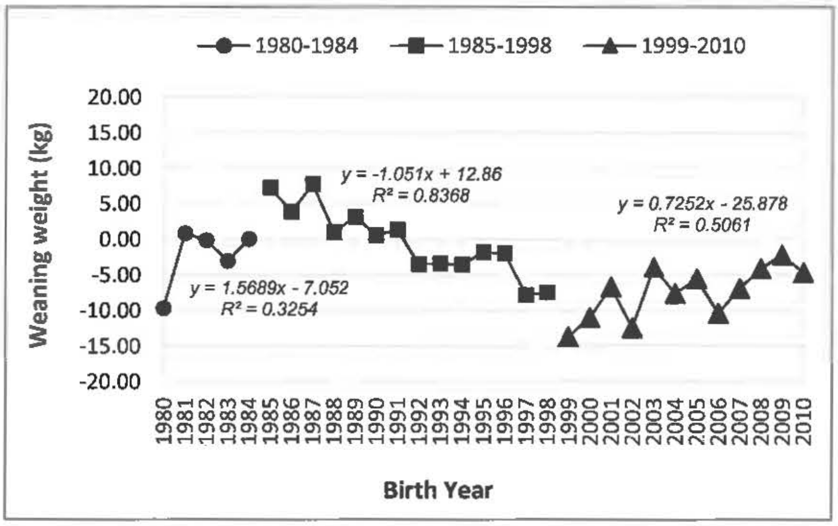

Figure 5.6: Environmental trend for weaning weight for the Drakensberger

The trends in weaning weight is not what is to be expected in practice. Although there was a positive genetic trend, there was no phenotypic trend and the environmental trend was variable. This could be an indication of variable and harsh environments (e.g. cold spells in certain years) over the period of the study.

5.3.4 Trends in mature cow weight

The number of records and the average phenotypic, genetic and environmental values per year of birth for mature cow weight are summarized in Table C4. The number of mature cow weights for the Drakensberger is much less than the number of weaning weight records as indicated in Table C3, and is usually the case with all field data.

The phenotypic mature cow weight over the 25 year period as illustrated in Figure 5.7 showed no significant change (R^2 = 0.07).

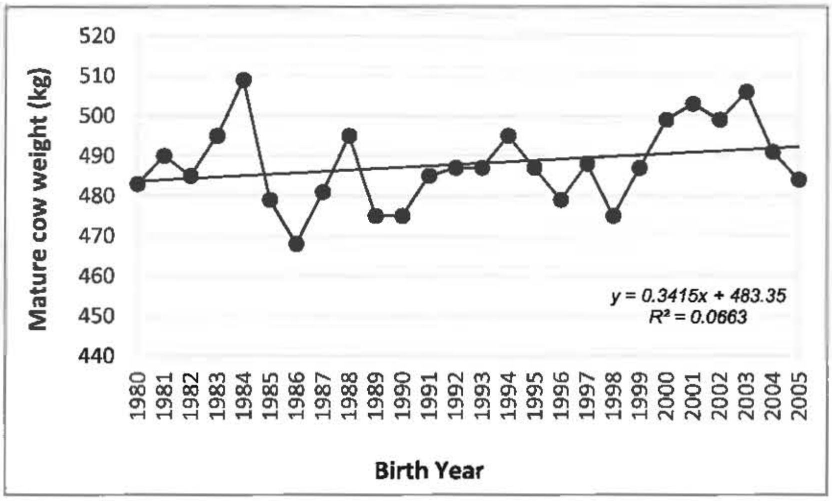

Figure 5.7: Phenotypic trend for mature cow weight

In contrast to the phenotypic trend, the Drakensberger has a positive genetic trend for mature cow weight of 603g per year (+15kg) from 1980 to 2005 as illustrated in Figure 5.8. This genetic increase in mature cow weight can be due to selection on other growth traits such as weaning weight and could cause the increase in mature cow weight because of highly correlated growth traits (Chapter 2: Table 2.1).

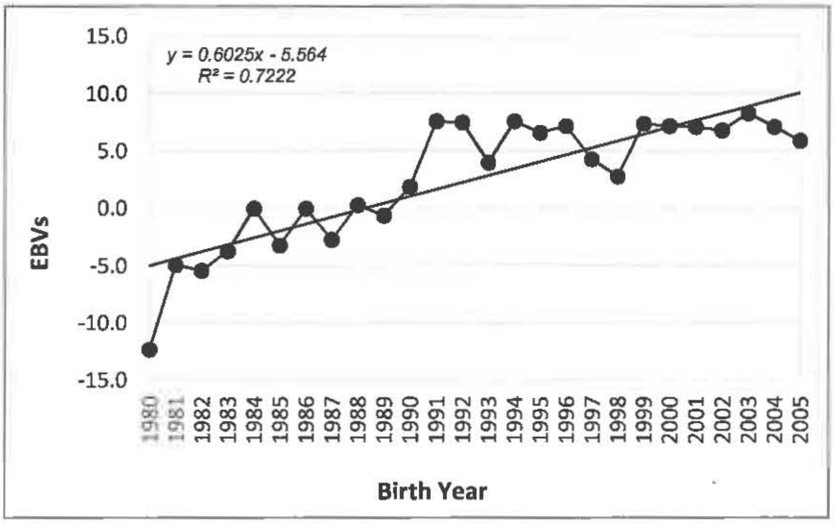

Figure 5.8: Genetic trend for mature cow weight for the Drakensberger

The environmental trend for mature cow weight show a decrease of 1.76kg per year (23kg) from 405kg in 1980 to 381kg in 1994 but the R^2 is very low (0.15) indicating the large variability in the trend. Since 1995 it increased with 2.68kg (27kg) from 360kg in 1995 to 387kg in 2005 with a R^2 of 0.68 as illustrated in Figure 5.9. This supports the argument in paragraph 5.3.3 of variable and harsh environments (e.g. cold spells) over the period of the study. The trend lines in Figure 5.6 (weaning weight) and Figure 5.9 (mature cow weight) are also very similar, supporting the argument of variable environments.

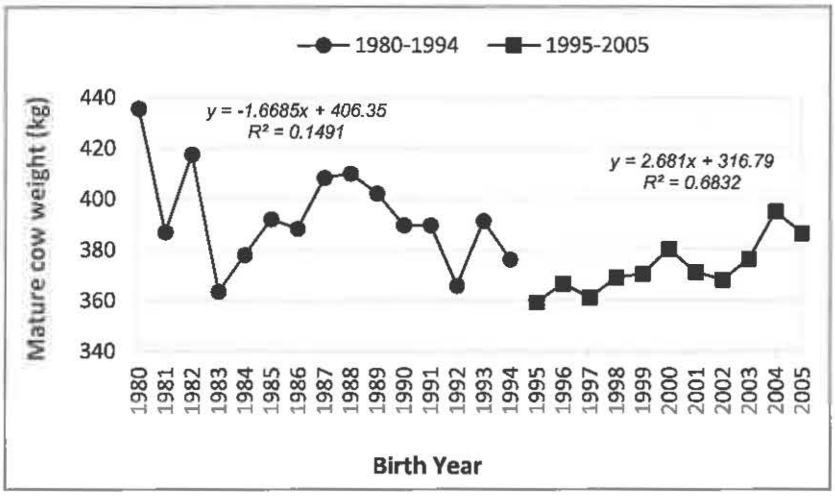

Figure 5.9: Environmental trend for mature cow weight for the Drakensberger

5.3.5 Trends for the first three inter-calving periods and age at first calving

The number of records and the average phenotypic, genetic and environmental values per year of birth for inter-calving period 1-3 (ICP1, ICP2, ICP3) are summarized in Table C5.

The phenotypic ICP1-3 decreased from 1980 to 2005 which indicates an improvement in fertility for the 25 year period for the first ICP1-3 cows, which can be the result of an improvement in management or selection by culling the cows that did not calf in a season, however the actual reason is unknown and cannot be determined from the phenotypic trend. The decrease in phenotype for ICP1-3 is 1.36 days per year (34 days) from 473 days in 1980 to 439 days in 2005 as illustrated in Figure 5.10.

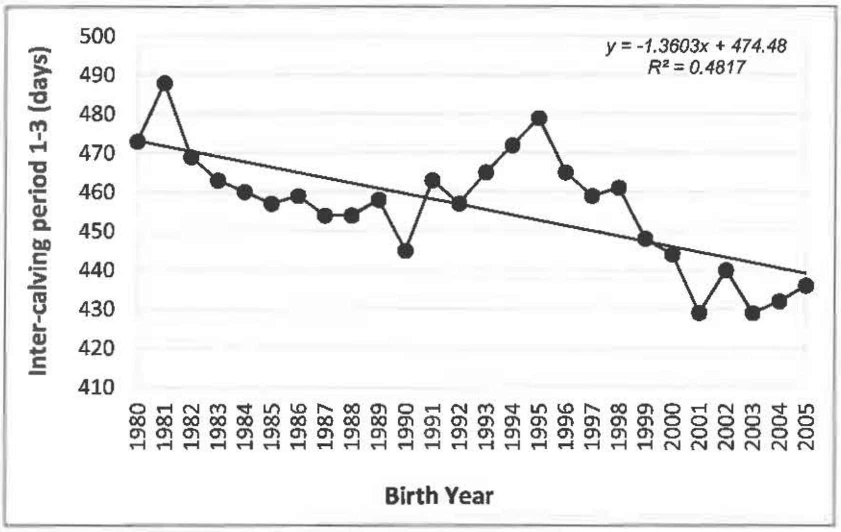

Figure 5.10: Phenotypic trend for ICP1-3 in days for the Drakensberger

The genetic trend for ICP1-3 indicates a decrease over the 25 year period of 0.07 days per year from 0.47 in 1980 to -1.34 in 2005 as illustrated in Figure 5.11. This indicates an improvement in fertility for Drakensberger cows with 1.81 days less for ICP1-3.

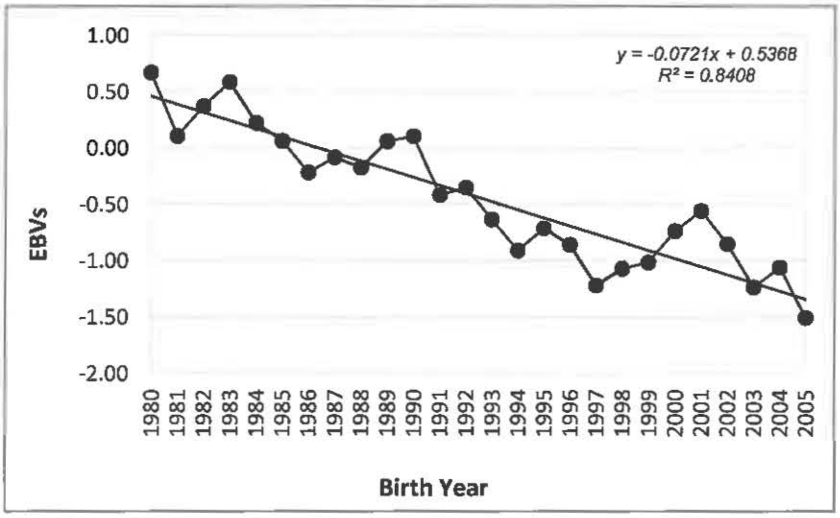

Figure 5.11: Genetic trend for ICP1-3 for the Drakensberger

The number of records and the average phenotypic, genetic and environmental values per year of birth for age at first calving are summarized in Table C6. There is no indication of a phenotypic trend (R^2 = 0.01) over the 25 year period from 1980 to 2005, for age at first calving as illustrated in Figure 5.12.

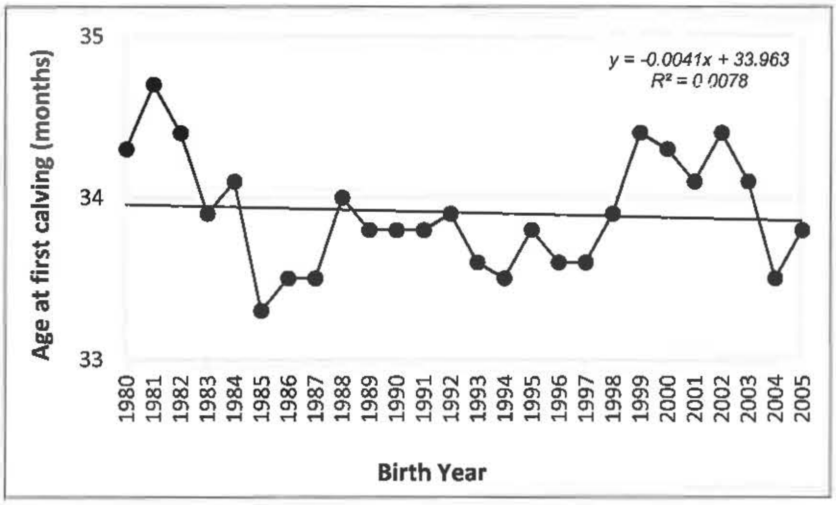

Figure 5.12: Phenotypic trend for age at first calving in months for the Drakensberger

There was a small increase of 0.09 days per year in the genotype for age at first calving from 0.25 in 1980 to 2.54 in 2005 as illustrated in Figure 5.13.

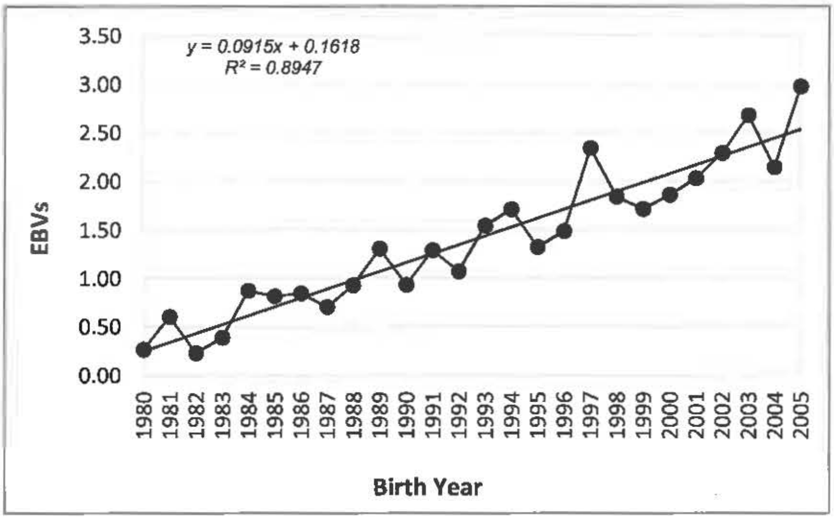

Figure 5.13: Genetic trend for age at first calving for the Drakensberger

5.3.6 Cow productivity

Cow productivity was measured in kilogram calf weaned per large stock unit (KgC/LSU) per cow calved (estimated from ICP). Cow weights and ICP were obtained from Table A7. The estimated KgC/LSU is also summarized in Table C7. The Drakensberger showed a positive trend of 1.51kg per year for KgC/LSU from 1980 to1994, there after a negative trend of 6.4kg per year from 1995 to 1999; and then a positive trend of 1.48kg per year from 2000 to 2013 (Figure 5.14).

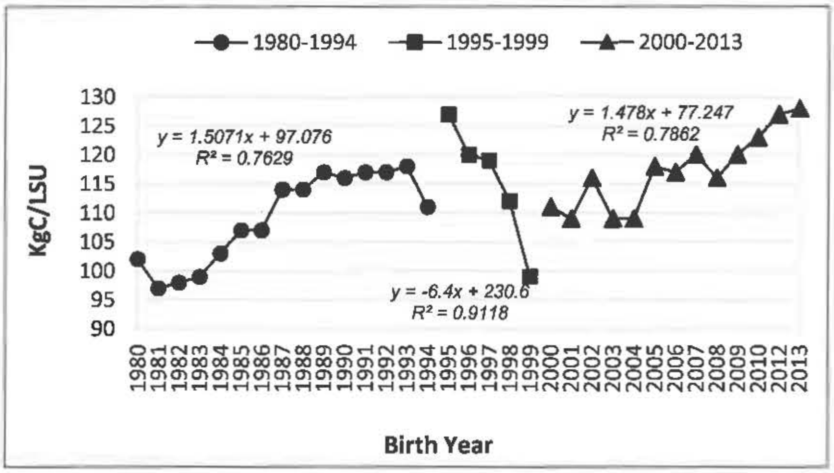

Figure 5.14: Kilogram Calf per LSU for the Drakensberger

5.3.7 Discussion

Trends

The phenotypic trend for birth weight initially showed an increase but decreased since 1996, within no trend in weaning- and mature cow weight. Inter-calving period decreased by 1.36 days per year, with no trend in age at first calving.

There was no genetic change in birth weight, indicating that breeders managed to maintain calf weight at birth, whereas there was a genetic improvement in direct weaning weight and no change in maternal weaning weight. Mature cow weight also increased genetically, although no genetic change is obvious from 1996. Inter-calving period decreased slightly by 1.81 days with a small increase in age at first calving of 2.25 days over the whole period.

The environmental trend for birth weight is negative whereas that for weaning- and mature cow weight is variable, but also negative. This supports the arguments in paragraph 5.3 of variable and harsh environments (e.g. cold spells) over the period of the study.

Cow productivity

Despite the genetic and small phenotypic increase in mature cow weight, cow productivity as measured in KgC/LSU indicates an improvement in cow efficiency. This occurred despite of the fact that the LSU for Drakensberger cows increased slightly from 1.39 in 1980 to 1.41 in 2010; the reason being the decrease in ICP of 35 days (higher estimated fertility). The net result is a remarkable increase of 27kg in cow efficiency.

Chapter 6

PHENOTYPIC, GENETIC AND ENVIRONMENTAL TRENDS IN THE NGUNI BREED

6.1 HISTORY OF THE NGUNI

Domesticated livestock form an integral part of the history of indigenous people of South Africa and archaeological findings indicate a stone-age society known as the San, resided in the eastern parts of South Africa ranging from the current Eastern Cape to KwaZulu-Natal. Another stone-age society entered the region between 800 and 1200 AD with domesticated livestock. These societies became more complex and by 1500 AD cultural patterns developed that became associated with the Nguni speaking people. By the 17th century cattle from the Nguni speaking people were present in large numbers along the south-east African coast and the immediate interior. Shipwrecked mariners described "Natal ", the current KwaZulu-Natal, as "full of cattle" and it is likely that these are the ancestors of present day Nguni cattle. (Curson & Thornton, 1936; Duminy & Guest, 1989)

During the period of colonialization these cattle and many other indigenous breeds of Africa was regarded as inferior. Another reason for this early ignorance of the qualities of the Nguni, stemmed from its variety of colours and colour patterns, giving the impression of a mixture of breeds. This variety in colours and colour patterns were in sharp contrast to the general trend in the seed stock breeding industry to emphasize uniformity. (Scholtz, 1988; Scholtz & Ramsay, 2007). A report by Bonsma *et al.* (1951) led to the establishment of a few government Nguni herds. The potential of the Nguni was only demonstrated with the introduction of a beef recording scheme in 1959 and the publication of research results of Nguni in the early 1980's (Scholtz & Ramsay, 2007).

Some seed stock and commercial breeders became interested in Nguni cattle in the 1970's when the only source of Ngunis were remote tribal areas where the influence of exotic breeds were less prevalent (Hobbs, 2006). In the 1980's the interest in the breed from the commercial sector accelerated and in August 1983 the breed was recognized as a developing breed under the Livestock Improvement Act (1977) of South Africa, and a Breed Society was established in 1987. It is currently numerically the second largest seed stock beef breed in South Africa.

The Nguni's survival after exposure to infectious diseases for many centuries, is indicative of an acquired tolerance to these conditions. It is a small framed animal. Different ecotypes developed in the different agro-ecological regions and this diversity is maintained within the breed. Although there is no such thing as a universal breed, the Nguni has found its way to almost every livestock production region in South Africa over the past few years. (Scholtz, 2010)

According to the Society's breeding objectives the breed is selected on functional efficiency and breed characteristics, while maintaining its inherent traits. The Society argues that it is "difficult to improve a breed that survived over centuries without the interference of man and that has adapted to harsh environments" as found in Southern Africa. The aim of the Society is therefore to develop rather than improve the breed in regions where it is adapted, without changing any of its inherent characteristics. This implies that the Society does not have any science based breeding objectives to change the breed and as the modern custodians of the breed they would "like to keep it as it is". (South African Livestock Breeding, 2004; Scholtz, 2010). Through accurate recording of births, cows that do not meet the minimum requirements for reproduction are stringently culled. The Nguni is also the breed with the shortest inter calving period of the three breeds in this study.

Prior to 1988 there were very few Nguni herds. In 1988 there were 80 registered Nguni herds of which 25 participated in Performance Testing, whereas by 2010 there were 408 Nguni herds of which 87 participated in Performance Testing (Table D1).

6.2 MATERIALS AND METHODS

All tables are presented in Addendum D, starting with Table D1 and ending with Table D8.

The number of records available for this study and models used in the analysis for the different traits has already been described in Chapter 2.

The average Nguni phenotypic, genetic and environmental measurements per year of birth for birth weight (BW), weaning weight (WW), mature weight (MW), inter-calving period 1-3 (ICP1, ICP2, ICP3) and age at first calving (AFC) were obtained from the edited data set used for the annual routine BLUP analyses (Table D1). The genetic and environmental trends were obtained from the output of the BLUP analyses using Pest (Groeneveld *et al.*, 1990) and averaged by year of birth.

The regression equations were used to estimate the phenotypic, genetic and environmental trends for the different traits and the results are summarized in Table D8.

In the case of the Nguni information from 1988 and onwards were used in this study, in contrast to the other breeds where information from 1995 was used. Records prior to this date was mainly from a few government farms and varied between 6 and 16 herds in Performance Testing (Table D1). In 1988 it was for example the first time that almost 2 000 weaning weights were recorded.

6.3 RESULTS & DISCUSSION

6.3.1 Phenotypic records

The average Nguni phenotypic records per year of birth for birth weight (BW), weaning weight (WW), mature cow weight (MW), inter-calving period 1-3 (ICP1, ICP2, ICP3) and age at first calving (AFC) were obtained from the INTERGIS which were collected by breeders and technicians in the service of the ARC. Performance data for these traits are presented in Table D1.

The number of records for both birth- and weaning weights indicates an increase over time. In the case of weaning weight the number fluctuated more than in the case of birth weight. The number of mature cow weights is much less in comparison with the weaning weights and that is an indication that very few Nguni breeders measure cow weight at weaning on a regular basis.

6.3.2 Trends in birth weight

The number of records and the average phenotypic, genetic and environmental values per year of birth for birth weight are summarized in Table D2. The phenotypic, genetic and environmental trends in birth weight of the Nguni are graphically presented in figures below.

The phenotypic trend for birth weight declined by 115g per year (2.53kg) from 1988 to 2010 as illustrated in Figure 6.1, indicating a tendency for phenotypic birth weight to decrease.

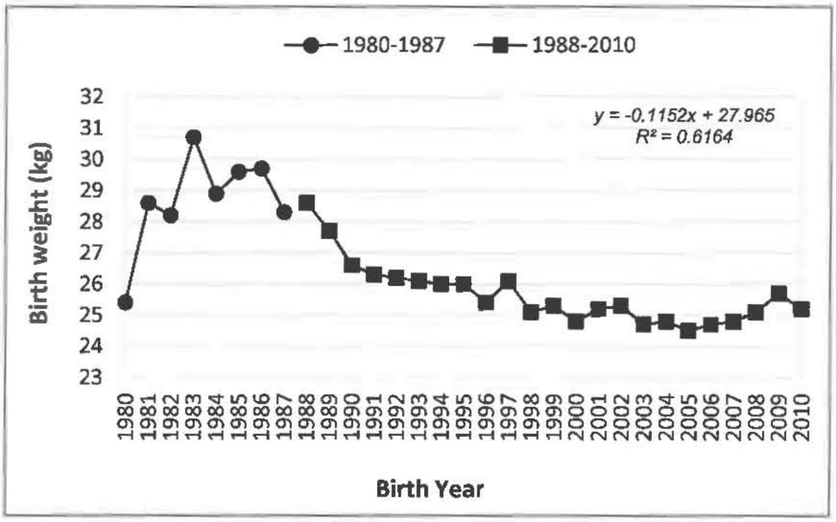

Figure 6.1: Phenotypic trend for birth weight for the Nguni

The genetic trend for birth weight decreased by 11g per year which is negligible as illustrated in Figure 6.2. Although this is a small decrease, the Nguni is one of only a few breeds internationally experiencing such a decrease.

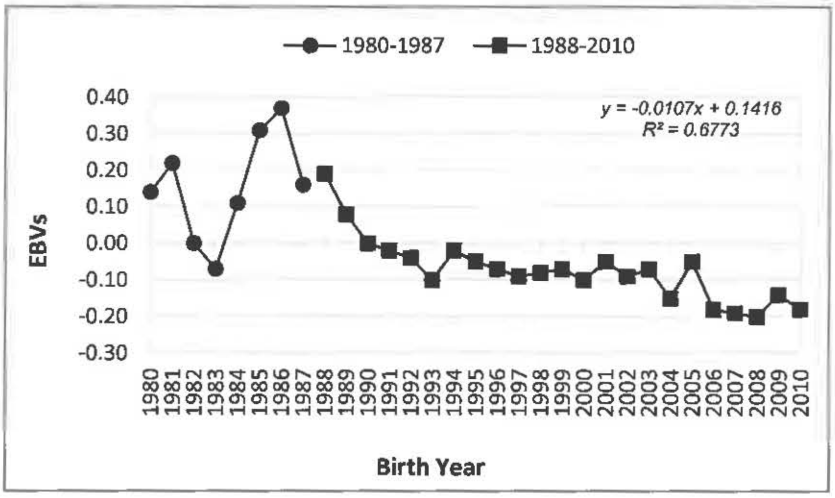

Figure 6.2: Genetic trend for birth weight for the Nguni

Similarly the environmental trend for birth weight (Figure 6.3) shows a slight decrease of 7g per year from 1988 to 2010.

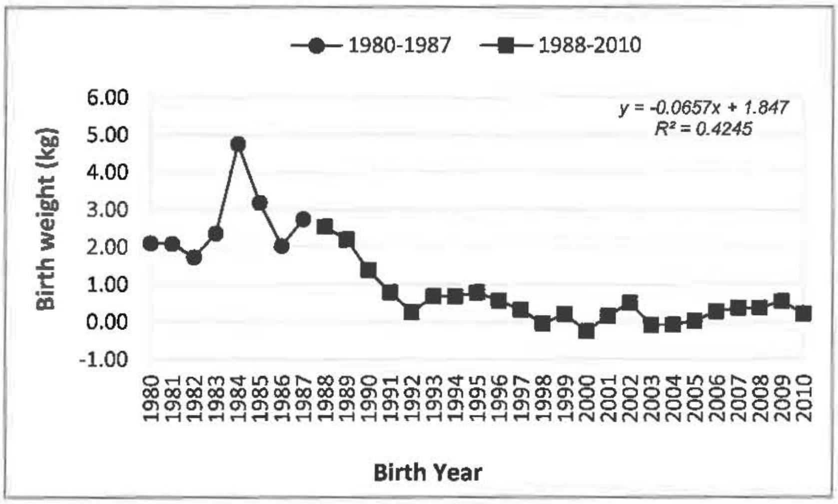

Figure 6.3: Environmental trend for birth weight for the Nguni

6.3.3 Trends in weaning weight

The number of records and the average phenotypic, genetic and environmental values per year of birth for weaning weight are summarized in Table D3. The regression equation fitted to determine the trend for phenotypic weaning weight ($R^2 = 0.01$) indicated no phenotypic trend in weaning weight for the Nguni (Figure 6.4). A phenotypic trend line is a combination of genetic and environmental influences and it therefore important to understand the relative contributions.

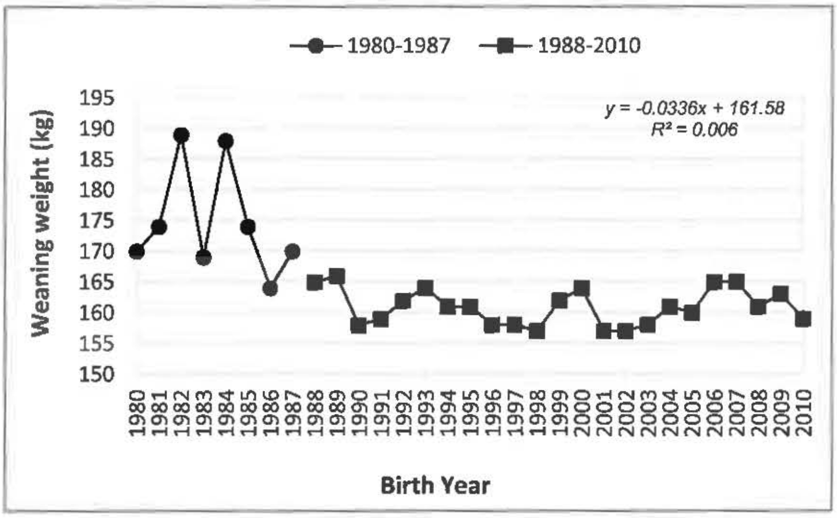

Figure 6.4: Phenotypic trend for weaning weight for the Nguni

There is an indication of a small positive genetic trend for direct weaning weight of 0.58g per year as illustrated in Figure 6.5. This indicates for all practical reasons no genetic improvement for the breed and the result of not selecting breeding stock based on growth performance that is genetically superior to the parent stock. The genetic trend for weaning maternal decreased by 12g per year from 1988 to 2010 which indicates a genetic change of -0.3kg over the 22 year period.

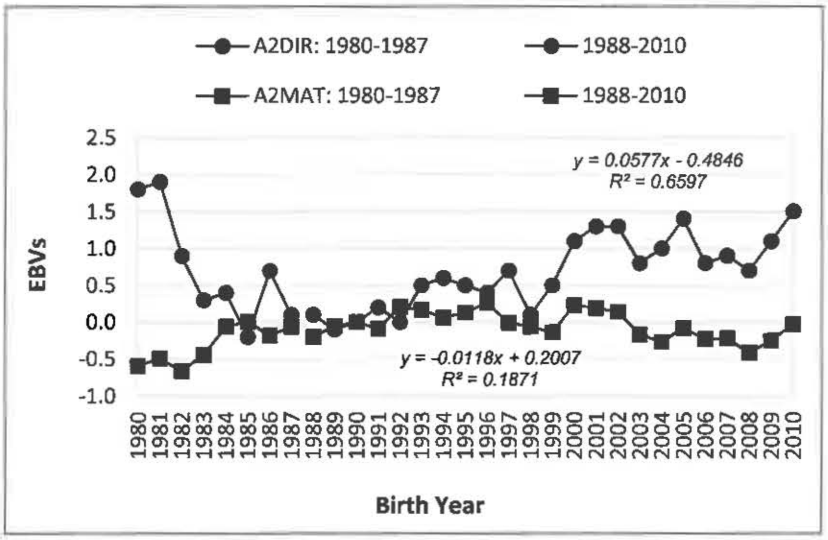

Figure 6.5: Genetic trend for weaning weight for the Nguni

The decrease in the environmental trend for weaning weight is 165g per year as illustrated in Figure 6.6. The negative trend may be an indication that no improvement of management systems and environment over time for weaning weight has occurred. However, this statement is only speculation.

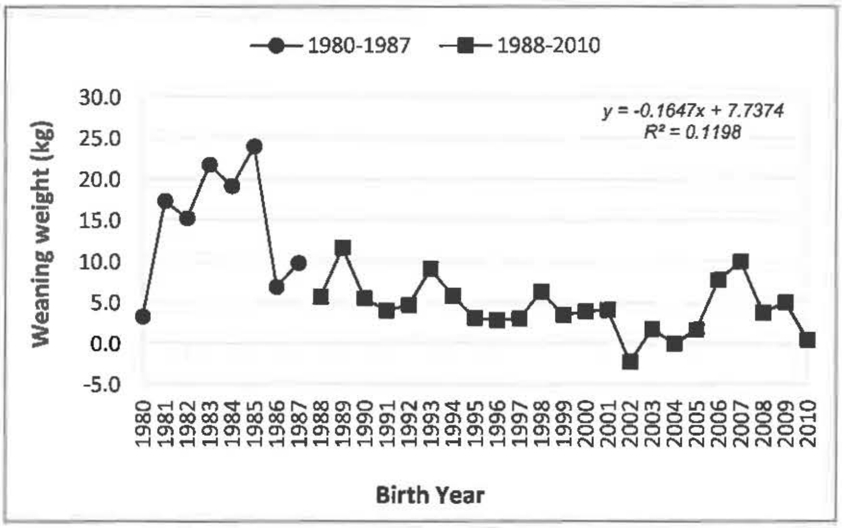

Figure 6.6: Environmental trend for weaning weight for the Nguni

6.3.4 Trends in mature cow weight

The number of records and the average phenotypic, genetic and environmental values per year of birth for mature cow weight are summarized in Table D4. The number of mature cow weights for the Nguni is much less than the number of weaning weight measurements as indicated in Table D3 which illustrates the practise of breeders not weighing the cows as well while weighing calves at weaning. The phenotypic trend in mature cow weight decreased by a massive 1.02kg per year or 22.3kg over the period, as illustrated in Figure 6.7. This decrease is probably the largest for all breeds in Southern Africa.

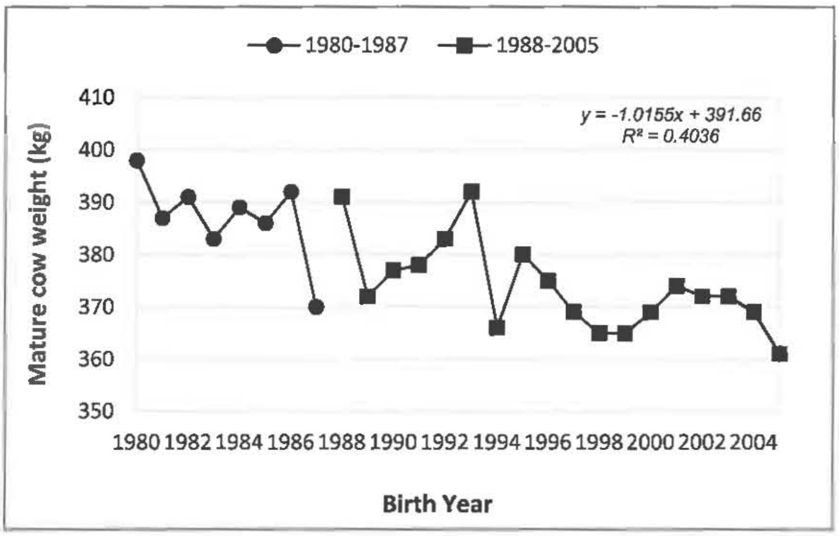

Figure 6.7: Phenotypic trend for mature cow weight for period 1980–2005

The Nguni show no definite genetic trend for mature cow weight as illustrated in Figure 6.8.

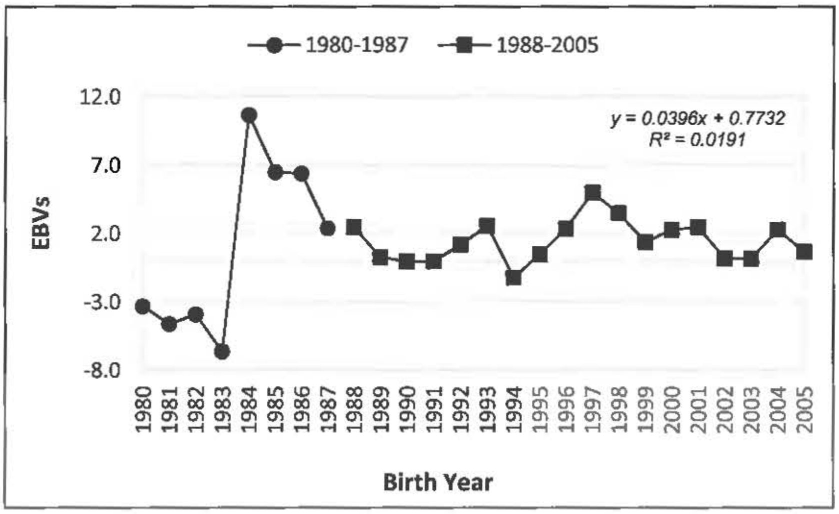

Figure 6.8: Genetic trend for mature cow weight for the Nguni

The environmental trend for mature cow weight is very variable and difficult to interpret as illustrated in Figure 6.9 and is probably due to the small sample size (Table D1). These limited numbers may contribute to the variable trends observed.

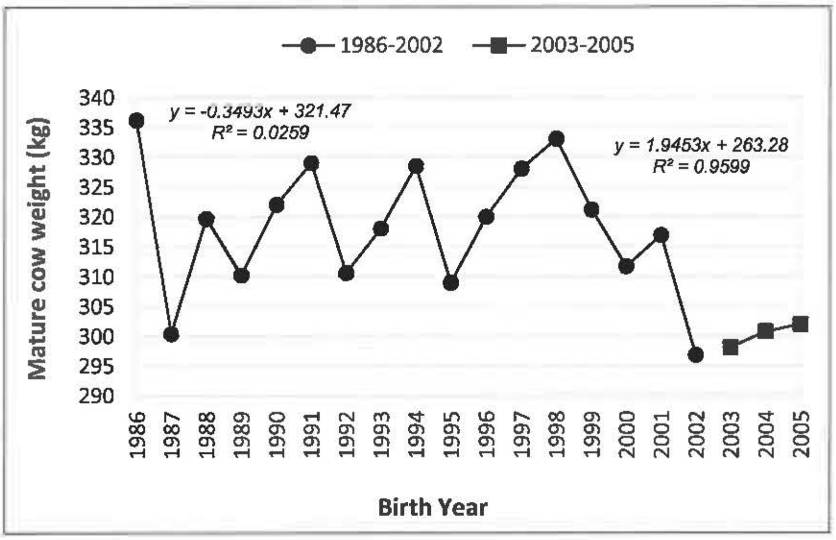

Figure 6.9: Environmental trend for mature cow weight for the Nguni

6.3.5 Trends in the first three inter-calving periods and age at first calving

The number of records and the average phenotypic, genetic and environmental values per year of birth for inter-calving period 1-3 (ICP1, ICP2, ICP3) are summarized in Table D5.

The phenotypic trend for ICP1-3 decreased by 1.08 days per year, or 24 days (426 to 402 days) which shows an improvement in fertility for the period from 1988 to 2005 (Figure 6.10). This can be the result of the stringent application of breed standards in respect of fertility and/or the culling of cows that did not calf in a season but the reason is unknown and cannot be determined from the phenotypic trend.

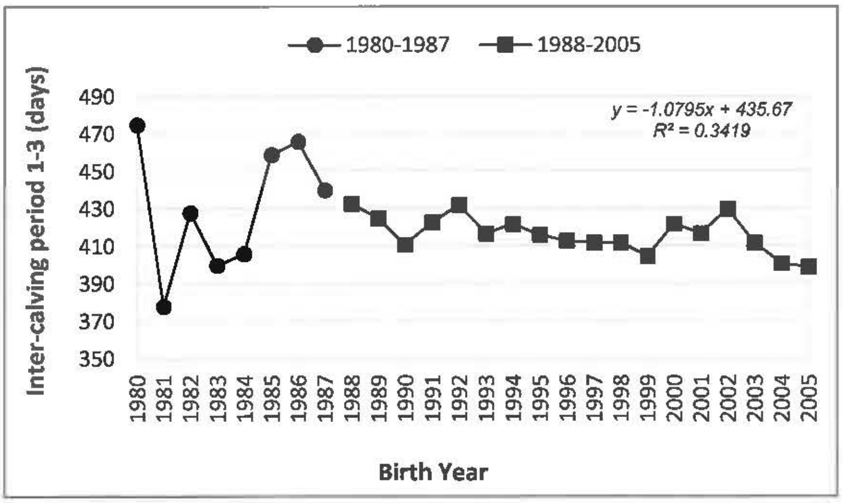

Figure 6.10: Phenotypic trend for ICP1-3 in days for the Nguni

There is a slight decrease in the genetic trend for ICP1-3 but is not significant (R^2 = 0.18) as illustrated Figure 6.11.

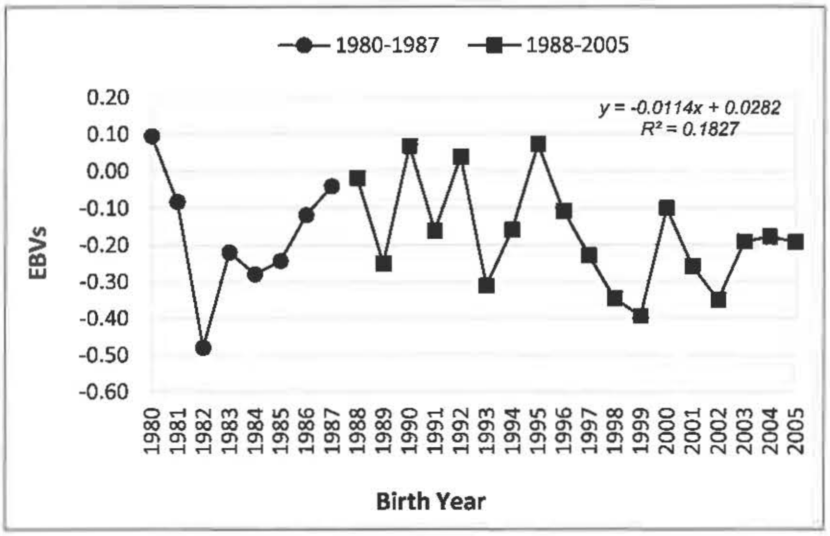

Figure 6.11: Genetic trend for ICP1-3 in days for the Nguni

The age at first calving shows a very small decrease in the phenotypic trend of 0.08 days per year. Age at first calving can easily be manipulated by breeders by mating heifers at an earlier age, or a change or improvement in the feeding of heifers. Management may therefore have an important influence on age at first calving for the Nguni, as demonstrated in Figure 6.12.

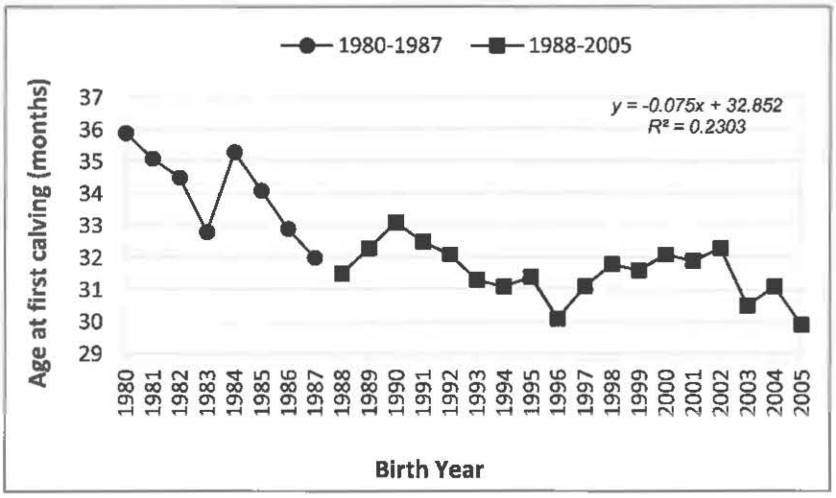

Figure 6.12: Phenotypic trend for age at first calving in months for the Nguni

There was no genetic trend for age at first calving as illustrated in Figure 6.13.

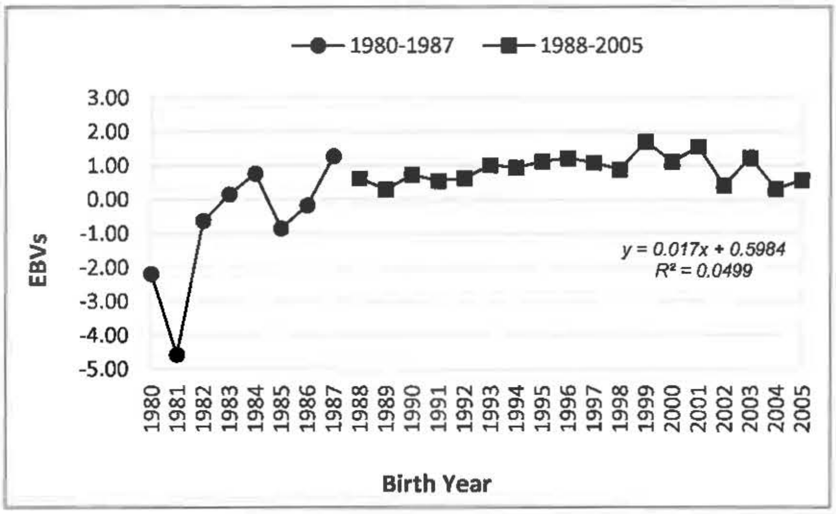

Figure 6.13: Genetic trend for age at first calving for the Nguni

6.3.6 Cow productivity

Cow productivity was measured in kilogram calf per large stock unit (KgC/LSU) per cow calved (estimated from ICP). Cow weights and ICP were obtained from Table D7. The estimated KgC/LSU is also summarized in Table D7.

The Nguni showed an increase of 0.49kg per year or 11.71kg in KgC/LSU from 1988 to 2013, as illustrated in Figure 6.14, although during the period from 1988 to 1998 no obvious trend is clear.

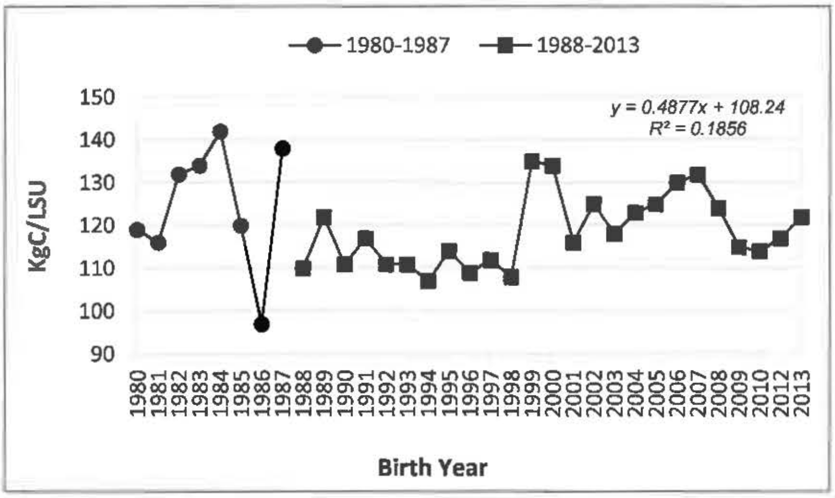

Figure 6.14: Kilogram Calf per LSU for the Nguni

6.3.7 Discussion

Knowledge of the data used for the trends may allow a breeder to interpret a trend line, but it is more likely that a breeder will not be able to distinguish between the contributions of genetic and environmental influences (Wilson & Willham, 1986). In the case of the Nguni there is no evidence of a clear breeding strategy with breeding objectives, followed by the Nguni breeders. Essentially the trend lines indicate that the status quo was maintained.

Trends

All the phenotypic changes in the Nguni were negative, except for weaning weight that did not change and KgC/LSU that increased. The reason for the large decrease in mature cow weight is not clear, and it can only be speculated that it may be the result of poorer management, farming practices and environmental conditions.

The genetic changes in birth weight and maternal weaning weight decreased. The direct weaning weight showed a slight increase whereas that for mature cow weight, ICP and age at first calving did not change. Kars *et al.* (1994) also reported an increase in direct weaning weight and a decrease in maternal weaning weight. It is important to note that the data used in his study only included the Bartlow Combine Nguni Cattle Stud from 1960 to1991.

It is also important to note that the number of breeders increased from 80 in 1988 to 408 in 2010. However, the participation in Performance Testing increased only from 25 to 87 breeders. The net result of this is that Performance Testing decreased from 31% to 21% participation. No genetic changes can be expected in a breed with such a low participation in Performance Testing and with no clear breeding objectives.

The environmental changes in birth-, weaning- and mature cow weight were all negative. Kars *et al.* (1994) also reported a decrease for weaning weight over the period from 1980 to 1990.

Cow productivity

Cow productivity increased phenotypically by 0.49kg per year or 11.71kg in KgC/LSU from 1988 to 2013, although during the period from 2000 to 2013 no obvious trend is clear. The improvement in cow productivity (KgC/LSU) was possible due to the improvement in calving percentage, estimated using ICP.

Chapter 7

GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

7.1 INTRODUCTION

From the results in this study it is clear that each of the Landrace breeds considered has its own breeding strategy, breed standards and breeding objectives. This resulted in different selection and management processes which undoubtedly influenced production and genetic response in each breed. It is therefore important to evaluate the changes that occurred in the four breeds, while not directly comparing the different breeds.

The data used in this study (excluding age at first calving and inter calving period) are based only on those herds participating in the NBIS. Performance recording of most traits are optional. This means that the breed averages only reflect those herds recording that particular trait. The implication is that for those breeds with a low percentage participation in performance recording, the reported breed averages are not necessarily be a true reflection of the breed's overall performance. Any comparison of phenotypic performance across breeds and years, should be done with extreme caution, as information reflects both genetic merit and environmental influences. The different breeds may be kept in different geographical areas to some extent, resulting in different environmental conditions within the same year. Furthermore, the management and production systems may differ between breeds.

7.2 GENERAL DISCUSSION ON THE CHANGES OBSERVED FOR THE BREEDS

The three traits that influence cow productivity as defined in this study are: (1) weaning weight of the calf, (2) feed requirement to produce the calf and for this purpose the cow LSU units were estimated since it is linked to daily feed intake; and (3) the frequency at which a calf is produced, where ICP was used to estimate calving percentage. In Table 7.1 the phenotypic and genetic trends/changes for the three basic traits for all the breeds are summarized as well as the resultant effect on cow productivity (205 day weaning weight of calf/cow LSU unit x calving percentage). Although the changes are summarized in the table it should not be used for direct breed comparison.

Table 7.1: Summarized phenotypic and genetic trends/changes for the three basic traits (in kg) and cow productivity (% increase) for the four Landrace breeds

	Type of trend	Weaning weight	Mature cow weight	Inter-calving period	Cow productivity
Afrikaner	Phenotypic	+20.4	-8.3	-19.7	18.3%
	Genetic	+7.0	+3.8	+1.0	
Bonsmara	Phenotypic	+9.1	+17.5	-16.9	10.0%
	Genetic	+11.7	+15.9	-0.2	
Drakensberger	Phenotypic	+1.7	+8.5	-34.0	14.2%
	Genetic	+6.2	+15.1	-1.80	
Nguni	Phenotypic	-0.7	-17.3	-19.4	10.4%
	Genetic	+1.2	+0.7	-0.3	

From Table 7.1 it can be seen that the phenotypic trends for both weaning and mature cow weights were positive for all breeds, except for weaning weight in the Nguni and mature cow weight in Afrikaner and Nguni. Interestingly, the genetic trends in weaning and mature cow weights were positive in all breeds, albeit small in the case of the Nguni. There was no genetic trend for inter-calving period in any of the breeds. Some scientists may argue that the EBV's for a trait such as inter-calving period are not valid and that days to calving is a feasible alternative (Johnston & Bunter, 1996). However, the phenotypic trend for inter-calving period decreased drastically by between 16.9 and 34 days. The net effect is that cow productivity increased by between 10.0% and 18.3%.

The breeding strategy followed by the Afrikaner breeders managed to increase calf weaning weight genetically by +7.0kg, while the increase in mature cow weight was only +3.8kg. The phenotype for weaning weight increased by +20.4kg, whereas that for mature cow weight decreased by -8.3kg. This increase in calf weaning weight with a concomitant decrease in mature cow weight and ICP (which was used to estimate calving percentage) resulted in an increase of 18.3% in cow productivity. This is the highest percentage increase for all the breeds studied.

In the case of the Bonsmara, where performance testing is compulsory and the use of BLUP breeding values is common amongst breeders, genetic change is to be expected. However, selection for weight and/or growth traits can also influence the production efficiency of animals if the mature weight increases simultaneously. Maintenance requirements for larger framed cows will increase and the environment may not always be sufficient if nutritional requirements are increasing over time, although animals may have the genetic potential. In this respect the genetic trend in weaning weight (+11.7kg) is higher than the phenotypic trend (+9.1kg), which is the opposite in the Afrikaner. The trends in mature cow weight is also high. Fortunately, ICP decreased by 16.9 days and this decrease to some extent offsets the higher maintenance requirements associated with the heavier cows and cow productivity still improved by 10%. The breed is cautioned about the increase in mature cow weight.

The Drakensberger results are similar to the trends in the Bonsmara where the mature cow weight increased simultaneously with the increase in weaning weight, albeit at a lower level. The fact that the phenotype of mature cow weight increased by +8.5kg and that for weaning weight by only +1.7kg resulted in a decrease in cow productivity. Fortunately, the ICP decreased drastically by 34 days and the net result is an increase in cow productivity of 14.2%. The Society claims that in the Drakensberger the selection programme emphasizes economically important traits, such as fertility and this result support their claim.

It is common knowledge that the Nguni breed does not have a uniform breeding strategy that is followed by most of the breeders. The breeding values are not fully utilized as a selection tool by the majority of the breeders. This could partially explain the fact that no genetic change were observed in respect of the Nguni. Another explanation for the lack of genetic change may be inconsistent breeding objectives within the breed or divergent selection criteria between bulls and heifers in the breed. The latter was reported by Matjuda *et al.* (2014). Phenotypically weaning weight (-0.7kg) and mature cow weight (-17.3kg) decreased over time, but the improvement in reproduction measured by calving percentage led to an increase in cow productivity of 10.4%, which is similar to the increase in the cow productivity of the Bonsmara.

Not all the breeds showed similar genetic and phenotypic changes or improvement in cow productivity. Possible reasons for the differences between breeds are, (1) changes in the production environment, production region and production system, e.g. Nguni cattle are currently farmed with in areas that were traditionally regarded as unsuitable for cattle farming, (2) relative emphasis on pre-weaning and post weaning traits and (3) effects of climate change on the availability of nutritional needs. It seems that some breeds will have to reconsider their breeding strategies.

An issue of concern is that there was no detectable genetic change for inter-calving period in all the breeds. It is therefore important that attention is given to this trait. The decrease in the phenotype for inter-calving period observed in this study could be a result of many factors including but not limited to: better record keeping both on the farm and by Society, management decisions such as culling cows that do not reconceive regularly or within a specified period of time, stringent application of breed standards in respect of fertility, etc.. However, the specific reason(s) for what is observed here is not clear and cannot be determined from these results.

7.3 CONCLUSION

This study demonstrates what happened genetically in South African Landrace breeds over the past years and what the current levels of productivity are in these breeds. It also demonstrated that cow productivity improved in all the breeds and this will reduce the carbon footprint of beef production from these breeds. However this improvement in cow productivity was the result of phenotypic changes and not genetic changes. The knowledge generated from this study can assist breeders and societies to understand the implications of management and selection decisions on the long term performance of their respective breeds.

The study also demonstrates the challenges associated with single trait selection, which may not necessarily translate into improved production efficiency. With single trait selection certain unfavorable changes can occur in correlated traits, which may have a negative effect on production efficiency. Dairy cattle breeding is a good example of what can happen if it is assumed that an increase in individual production will automatically be followed by a rise in productivity or economic return per animal, since maintenance requirements will decline as proportion of the total. However there are evidence that breeding for e.g. milk production will have negative effects on a range of other traits. (Pryce *et al.,* 2004; de Jong, 2007; McManus *et al.,* 2013).There is a real danger that this may also happen to beef cattle if single traits linked to weights, growth rates and feed efficiency are over emphasized.

In the case of beef cattle, a selection index with traits of genetic and economic importance, with respective emphasis on each trait, can be combined into one value, usually a monetary value. The American Angus Association, for example, use a $value to express the selection index (Northcutt, 2014). Similarly Breedplan developed selection indexes for beef cattle. It is also possible to develop customized indexes for individual producers using herd-specific production information and marketing goals through Breedplan (Breedplan Users Manual, 2006).

7.4 RECOMMENDATIONS

As pointed out by Capper (2011) improving productivity is the key to reducing the environmental impact of beef production and to provide sufficient animal protein to satisfy the growing demand. It is therefore important to improve the cow productivity of the Landrace beef breeds of South Africa in the era of climate change. The recommendations made below is an attempt to give some guidance on the research and development required to achieve this.

This study clearly demonstrated the effect of calving percentage on cow productivity. Cow productivity in the South African beef sector can drastically be improved if the relatively low calving percentage of 62% in the commercial sector (Scholtz & Bester, 2010) can be improved on. This study indicated no genetic improvement in calving percentage as estimated from inter-calving period and this aspect needs urgent attention. Selection for days to calving was proposed as an effective way to improve selection for fertility in beef cattle (Johnston & Bunter, 1996). However, its application is still limited in South Africa since the required data is not recorder by farmers. It is recommended that the genetic improvement of fertility in beef cattle in South Africa be investigated properly and that the appropriate breeding technology to handle fertility be developed or refined.

It is foreseen that Landrace breeds may become more important in South Africa as a consequence of climate change that will result in more challenging environments. It is therefore recommended that economic selection indices that indicates cow productivity are developed for South Africa's Landrace breeds.

It is further recommended that studies similar to this one is carried out for all the major beef breeds in South Africa. This will give an indication of the genetic changes that occurred in the different breeds and breed types in South Africa and how this affects cow productivity. This is of particular interest in the case of breeds where genetic material is imported regularly.

Until now measurements to improve post weaning efficiency of beef cattle in South Africa is limited to weight for age, growth rate and feed conversion ratio. However, all these traits are positively correlated to mature weight and may increase mature cow weight to varying degrees that will increase maintenance requirements. It is therefore recommended that alternative traits such as Residual Feed Intake or Residual Daily Gain are investigated for implementation in South Africa. An alternative may also be to apply weights for Average Daily Gain and Daily Feed Intake directly. The latter will be straightforward and more transparent to farmers (MacNeil *et al.*, 2013).

Mokolobate (2015) studied novelty traits to improve cow-calf efficiency in climate smart beef production systems. The recommendation from this study is to include calf weaning weight as trait of the dam and cow maintenance requirements (LSU units of the cow) in a selection index.

GENETIC AND ENVIRONMENTAL TRENDS IN LANDRACE BEEF BREEDS AND THE EFFECT ON COW PRODUCTIVITY

by

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ABSTRACT

Since the implementation of breeding values in South Africa during 1994 it is still unknown how many breeders actually utilize breeding values in selection decisions; and whether the breeds that promote the use of breeding values have actually made any genetic improvement or if this observed improvement was due to better management and/or more favorable environments.

Climate change will have a negative effect on livestock production environments and matching the genotype with the production environment will become important. The selection of animals and genotypes that are better adapted to the anticipated environment, will ensure sustainable production. In South Africa the indigenous Sanga and Sanga derived breeds can form the basis for increased productivity and product quality. It is also anticipated that these breed types will increasingly be used as dam lines, as they mostly have smaller frames with lower feed requirements, good maternal abilities, low birth weights and mortalities.

The data available on the INTERGIS (Integrated Registration and Genetic Information System) was used to do a genetic evaluation for the Landrace beef breeds in South Africa. These breeds are the Afrikaner, Bonsmara, Drakensberger and Nguni (regulations of the

Animal Improvement Act, Act 62 of 1998) and are all Sanga or Sanga derived breeds.

A complete pedigree and data set was extracted from the INTERGIS for each of the breeds and data validation procedures were carried out as part of the routine editing procedures prior to the BLUP genetic evaluation analyses. The genetic models developed by the ARC for the routine genetic evaluation of beef breeds in 2010, were used in this study. The phenotypic-, genetic- and environmental trends were calculated for the four breeds. The total number of weaning weights and mature cow weights (the first weight after 4 years of age) are summarized below.

Weights	Afrikaner	Bonsmara	Drakensberger	Nguni
Weaning	74 753	948 225	110 935	55 021
Mature cow	2 323	69 446	4 428	2 684

Genetic, phenotypic and environmental trends for a 25 year period from 1980 to 2005 for mature cow weight, first three inter-calving periods and age at first calving was estimated; and birth- and weaning weight trends from 1985 to 2010 for the Afrikaner, Bonsmara and Drakensberger breeds. In the case of the Nguni the period started in 1988, due to limited data from only a few state owned herds prior to 1988. The reason for this apparent discrepancy is to ensure that the same "year of birth groups" is compared due to the time lag that exist between the measurements of the different traits.

Cow efficiency was defined as kg calf weaned per large stock unit (KgC/LSU) mated, and estimated and averaged per year of birth. Frames size specific equations were used to calculate the LSU for different weights of lactating cows. The predicted calving percentage was calculated from inter-calving period using an equation from the literature. This trait did not form part of the genetic analyses. Trends in this trait were estimated using data recorded between 1980 and 2013. The phenotypic, genetic and environmental trends for weaning weight, mature cow weight and inter calving period are discussed here, where applicable, since these are the traits that contribute to the estimation of cow efficiency.

In the case of the Afrikaner, the phenotypic, direct genetic and maternal trends for weaning weight were +818g, +277g and +84g per year respectively. There was also a total improvement of 12kg in the environmental trend, indicating a possible improvement in management. For mature cow weight the phenotypic trend first decreased by 3.5kg per year between 1980 and 1988, thereafter it increased by 4.3kg per year between 1989 and 1995, and then stabilized. No definite changes were observed in the genetic and environmental trends for mature cow weight. It seems that the breeding strategy followed by the Afrikaner breeders managed to increase calf weaning weight genetically by +7.0kg, while limiting the increase in mature cow weight. With inter-calving period there was a phenotypic decrease of 0.79 days per year. The genetic trend was so small that it can be ignored for all practical purposes. Initially cow efficiency (KgC/LSU) decreased, but since 1987 it has increased. The phenotype for weaning weight has increased by +20.4kg, whereas that for mature cow weight has decreased by -8.3kg. This increase in calf weaning weight with a concomitant decrease in mature cow weight and inter calving period (which was used to estimate calving percentage) resulted in an increase of 18.3% in cow productivity. This is the highest percentage increase for all the breeds studied.

In the case of the Bonsmara, the phenotypic trend for weaning weight initially increased by 671g per year until 1999 where after it decreased by 182g per year until 2010. The direct genetic, maternal and environmental trends for weaning weight were +467g, +142g and -346g per year respectively. There may be many reasons for the latter trend, including poorer adaptation due to the diminishing influence of Afrikaner genes in the Bonsmara, or the decrease in number of breeders from 510 to 353 resulting in different environments. In respect of mature cow weight both the phenotypic and genetic trends increased by 700g and 638g per year respectively. From 1989 until 2000 there was no change in the environmental trend. The phenotypic trend for inter calving period decreased by 0.68 days per year with no clear genetic change. Despite the genetic and phenotypic increase in mature cow weight, cow efficiency improved although the LSU for cows increased from 1.34 in 1980 to 1.45 in 2013. The reason for this is that inter calving period decreased by 16.9 days and this decrease offset the higher maintenance requirements associated with the heavier cows and cow productivity still improved by 10%. The breed is cautioned about the increase in mature cow weight.

In the case of the Drakensberger the phenotypic and maternal genetic trends for weaning weight do not show any change, whereas there is an increase of 248g per year in the direct genetic trend. The environmental trend for weaning weight first decreased (-1.05kg/year) and then increased (+0.725g/year) from 2000. The trends in weaning weight are antagonistic and variable. This could be an indication of the variable and harsh environments (e.g. cold spells) in which the breeds was kept over the period of the study. There was no phenotypic change in mature cow weight. In contrast to no phenotypic trend, there was a positive genetic trend for mature cow weight of 603g per year and a negative environmental trend for mature cow weigh of 1.76kg per year from 1980 to 1994, thereafter it increased with 2.68kg per year until 2005. For inter-calving period there was a phenotypic decrease of 1.36 days per year. The genetic trend showed a small decrease of 0.07 days per year. Cow efficiency increased over time although there was a slight decrease from 1996 to 2004. This was due to a decrease in weaning weights and a lower calving percentage (longer inter-calving period) during the same period. Inter calving period decreased drastically by 34 days over the period of study and the net result is an increase in cow productivity of 14.2%.

All the phenotypic changes in the Nguni were non-significant or negative (in the case of inter-calving period this is favourable), except for cow efficiency. The phenotype for mature cow weight decreased by 1.02kg per year. All the genetic changes were negligible. It is common knowledge that the Nguni breed does not have uniform breeding strategies that is followed by most of the breeders. It is therefore not surprising that no genetic change was observed in respect of the Nguni. The improvement in cow efficiency was possible due to an improvement in inter-calving period of 1.08 days per year or 19.4 days over the period. The improvement in estimated calving percentage managed to increase cow efficiency by 10.4%, which is similar to the increase in the cow efficiency of the Bonsmara.

Possible reasons for the differences in the phenotypic and genetic changes between breeds are, (1) changes in the production environment, production region and production system, e.g. Nguni cattle are currently farmed with in areas that were traditionally regarded as unsuitable for cattle farming, (2) relative emphasis on pre-weaning and post weaning traits and (3) effects of climate change on the availability of nutritional needs. From this study it would appear that some breeds will have to reconsider their breeding strategies.

An issue of concern is that there were no detectable genetic change for inter-calving period in all the breeds. It is therefore recommended that the genetic improvement of fertility in beef cattle in South Africa be researched properly and that the appropriate breeding technology to handle fertility be developed or refined. The decrease in the phenotype for inter-calving period observed in this study can be a result of many factors including but not limited to; better record keeping both on the farm and by the Society, management decisions such as culling cows that do not reconceive regularly or within a specified period of time and stringent application of breed standards in respect of fertility.

This study demonstrated what happened genetically in South Africa's Landrace breeds over the past years and what the current levels of productivity are in these breeds. It also demonstrated that cow productivity improved in all the breeds. Improving productivity is the key to reducing the environmental impact of beef production and to provide sufficient animal protein to satisfy the growing demand. It is foreseen that Landrace breeds may become more important in South Africa as a consequence of climate change that will result in more challenging environments. It is therefore recommended that economic selection indices be developed that includes both post weaning growth traits and cow productivity for South Africa's Landrace breeds.

It is recommended that studies similar to this one is carried out for all the major beef breeds in South Africa. This will give an indication of the genetic changes that occurred in the different breeds and breed types in South Africa and how this affected cow productivity. This is of particular interest in the case of breeds where genetic material is imported regularly.

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ADDENDUM A: AFRIKANER

Table A1: Number of records (n) and means ($\bar{x}$) for birth- (BW), weaning- (WW), mature cow weight (MW), inter-calving period 1-3 (ICP1-3) and age at first calving (AFC)

Year	R	S	BW (kg)		WW (kg)		MW		ICP1-3		AFC	
	n	n	n	$\bar{x}$	n	$\bar{x}$	N	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$
1980	355	65	295	33.7	501	175	35	472	125	480	164	35.0
1981	335	72	1264	33.7	1516	171	41	475	116	452	192	35.3
1982	340	70	1280	34.0	1878	177	50	466	140	478	210	35.3
1983	326	102	1121	33.8	2272	176	54	464	159	462	226	34.6
1984	297	87	685	33.4	2716	183	58	456	190	461	282	34.7
1985	270	100	304	32.6	2285	187	82	451	144	465	212	34.7
1986	250	111	145	33.0	3260	183	77	451	302	475	391	33.7
1987	234	119	276	34.1	3295	185	86	453	280	485	421	34.0
1988	253	124	672	33.0	2860	183	50	447	309	472	447	34.5
1989	238	112	729	31.9	3139	185	34	450	321	469	485	35.2
1990	229	103	821	32.4	3355	184	64	459	313	471	452	35.4
1991	233	81	1213	33.2	3067	180	73	458	268	459	394	35.1
1992	205	76	1457	32.7	3163	182	104	473	299	455	482	35.0
1993	176	82	1079	32.4	2515	189	101	477	233	459	362	35.2
1994	147	83	934	32.5	2927	189	84	454	281	466	421	35.0
1995	133	75	912	31.8	2687	190	60	487	205	459	348	34.8
1996	122	64	897	32.0	2652	188	87	482	249	469	395	35.0
1997	108	57	961	32.4	2773	192	87	466	233	466	356	35.4
1998	108	58	994	32.8	2427	189	97	474	241	462	351	35.2
1999	108	58	932	32.0	2696	188	134	478	290	466	452	34.4
2000	103	60	740	32.7	2296	191	198	475	272	452	423	34.6
2001	104	65	792	32.8	2282	192	159	469	198	446	316	35.1
2002	86	59	960	32.4	2468	196	115	466	215	453	346	35.4
2003	74	54	1104	32.5	2270	201	119	464	203	459	342	34.8
2004	-	-	961	32.2	2323	200	80	476	214	439	394	34.5
2005	75	54	900	32.2	2225	196	62	472	178	459	382	34.5
2006	68	49	1066	32.3	1978	199						
2007	72	51	1229	31.8	1873	201						
2008	69	50	1229	31.5	1541	198						
2009	64	48	879	32.4	1391	194						
2010	66	43	702	31.7	561	199						

n – number of animals

R – Herds registered, S – Herds participating in Performance Scheme

Table A2: Number of measurements and average values per year of birth for birth weight

Year	n	Cg	Phenotypic	Genetic	Environmental
1980	295	42	33.70	0.10	1.74
1981	1264	73	33.70	0.03	1.87
1982	1280	84	34.00	0.11	1.68
1983	1121	65	33.80	0.20	1.14
1984	685	56	33.40	0.13	1.01
1985	304	21	32.60	-0.04	0.05
1986	145	12	33.00	0.00	-0.31
1987	276	16	34.10	0.32	0.23
1988	672	34	33.00	0.14	-0.46
1989	729	40	31.90	0.02	-1.00
1990	821	43	32.40	0.27	0.30
1991	1213	64	33.20	0.38	0.49
1992	1457	67	32.70	0.24	0.07
1993	1079	70	32.40	0.24	-0.09
1994	934	64	32.50	0.24	0.66
1995	912	68	31.80	0.28	-0.53
1996	897	55	32.00	0.32	-0.57
1997	961	52	32.40	0.41	-0.57
1998	994	65	32.80	0.43	-0.72
1999	932	60	32.00	0.34	-1.15
2000	740	59	32.70	0.38	-0.94
2001	792	57	32.80	0.38	-0.27
2002	960	62	32.40	0.32	-0.57
2003	1104	63	32.50	0.45	-0.18
2004	961	68	32.20	0.37	-0.64
2005	900	71	32.20	0.52	-0.28
2006	1066	98	32.30	0.54	-1.19
2007	1229	96	31.80	0.52	-1.05
2008	1229	84	31.50	0.54	-1.38
2009	879	67	32.40	0.63	-0.91
2010	702	43	31.70	0.61	-0.63

n – number of animals

Cg – the number contemporary groups

Table A3: Number of measurements and average values per year of birth for weaning weight

Year	n	Cg	Phenotypic	Genetic	Environmental
1980	501	81	175	-0.6	-1.3
1981	1516	83	171	-0.3	-9.6
1982	1878	106	177	0.0	-11.1
1983	2272	164	176	-0.3	-9.9
1984	2716	210	183	-0.4	-8.6
1985	2285	254	187	-0.4	-0.5
1986	3260	251	183	0.0	0.6
1987	3295	299	185	0.3	-0.8
1988	2860	274	183	0.2	0.6
1989	3139	249	185	0.4	-2.6
1990	3355	250	184	1.1	0.0
1991	3067	299	180	1.3	-6.2
1992	3163	243	182	1.5	-4.4
1993	2515	213	189	2.0	-3.6
1994	2927	216	189	2.2	0.3
1995	2687	228	190	2.6	-2.6
1996	2652	228	188	3.3	0.7
1997	2773	200	192	3.8	1.4
1998	2427	208	189	4.1	-1.3
1999	2696	197	188	3.9	1.0
2000	2296	230	191	4.5	2.7
2001	2282	179	192	4.8	4.5
2002	2468	237	196	5.4	2.8
2003	2270	225	201	5.4	6.1
2004	2323	145	200	5.8	10.8
2005	2225	126	196	6.0	4.2
2006	1978	148	199	6.3	9.4
2007	1873	119	201	6.0	1.6
2008	1541	112	198	6.1	2.8
2009	1391	89	194	6.6	4.8
2010	561	81	199	6.3	8.4

n – number of animals

Cg – the number contemporary groups

Table A4: Number of measurements and average values per year of birth for mature cow weight

Year	n	Cg	Phenotypic	Genetic	Environmental
1980	35	2	472	1.8	383
1981	41	4	475	-3.2	348
1982	50	6	466	5.4	394
1983	54	6	464	-0.3	416
1984	58	4	456	0.1	417
1985	82	4	451	1.7	392
1986	77	9	451	0.0	398
1987	86	17	453	0.0	385
1988	50	21	447	-3.2	398
1989	34	14	450	-5.0	370
1990	64	10	459	5.1	365
1991	73	23	458	4.1	372
1992	104	28	473	1.3	381
1993	101	14	477	-0.5	379
1994	84	11	454	-0.8	380
1995	60	19	487	-1.5	371
1996	87	17	482	-0.2	382
1997	87	23	466	0.1	395
1998	97	19	474	1.7	407
1999	134	18	478	2.2	368
2000	198	18	475	1.3	395
2001	159	19	469	-0.8	403
2002	115	15	466	0.5	394
2003	119	34	464	4.1	380
2004	80	41	476	4.7	407
2005	62	43	472	2.2	395

n – number of animals

Cg – the number contemporary groups

Table A5: Trends for inter-calving period 1-3 for the Afrikaner

Year	N	Phenotypic	Genetic
1980	125	480	0.61
1981	116	452	0.43
1982	140	478	0.66
1983	159	462	-0.02
1984	190	461	0.04
1985	144	465	0.67
1986	302	475	1.00
1987	280	485	0.40
1988	309	472	0.37
1989	321	469	-0.12
1990	313	471	-0.15
1991	268	459	0.52
1992	299	455	0.47
1993	233	459	-0.16
1994	281	466	-0.39
1995	205	459	-1.30
1996	249	469	-0.10
1997	233	466	-0.60
1998	241	462	0.45
1999	290	466	0.39
2000	272	452	0.22
2001	198	446	0.29
2002	215	453	0.15
2003	203	459	0.59
2004	214	439	0.96
2005	178	459	0.75

n – number of animals

Table A6: Trends for age at first calving for the Afrikaner

Year	N	Phenotypic	Genetic
1980	164	35.0	1.08
1981	192	35.3	1.07
1982	210	35.3	0.21
1983	226	34.6	0.93
1984	282	34.7	0.15
1985	212	34.7	0.61
1986	391	33.7	0.52
1987	421	34.0	0.84
1988	447	34.5	0.43
1989	485	35.2	0.72
1990	452	35.4	0.61
1991	394	35.1	1.03
1992	482	35.0	0.50
1993	362	35.2	0.72
1994	421	35.0	0.31
1995	348	34.8	1.08
1996	395	35.0	0.75
1997	356	35.4	1.15
1998	351	35.2	1.26
1999	452	34.4	0.71
2000	423	34.6	0.56
2001	316	35.1	0.54
2002	346	35.4	1.20
2003	342	34.8	0.64
2004	394	34.5	0.77
2005	382	34.5	0.86

n – number of animals

Table A7: The input information used to estimate KgC/LSU and the estimated KgC/LSU

Year	WW	CW	ICP	LSU	Calf %	KgC/LSU
1980	176	459	472	1.34	71	93
1981	174	447	477	1.31	69	91
1982	171	456	462	1.33	73	94
1983	174	454	495	1.33	64	84
1984	172	478	496	1.38	64	80
1985	180	477	485	1.38	67	88
1986	184	472	520	1.37	58	78
1987	182	467	490	1.36	66	89
1988	183	478	476	1.38	70	93
1989	180	442	474	1.30	70	97
1990	183	452	463	1.32	73	101
1991	182	448	474	1.32	70	97
1992	175	447	470	1.31	71	95
1993	182	444	458	1.31	75	104
1994	184	463	459	1.35	74	101
1995	187	460	446	1.34	78	109
1996	186	447	453	1.31	76	108
1997	186	470	445	1.36	78	107
1998	187	471	441	1.36	79	108
1999	185	469	438	1.36	80	109
2000	184	463	450	1.35	77	105
2001	190	474	451	1.37	76	105
2002	186	473	439	1.37	80	109
2003	194	473	467	1.37	72	102
2004	196	479	457	1.38	75	107
2005	196	476	445	1.37	78	111
2006	195	487	446	1.40	78	109
2007	193	472	443	1.37	79	112
2008	195	478	433	1.38	81	115
2009	195	470	453	1.36	76	109
2010	189	481	452	1.38	76	104
2012	192	470	475	1.36	70	100
2013	176	468	452	1.36	76	107

WW – Weaning Weight, CW - Cow Weight, ICP - Inter-calving Period,
LSU - Large Stock Unit, KgC/LSU - Kg calf per large stock unit

Table A8: Phenotypic, genetic and environmental changes in the Afrikaner over the 25 year period (with the accuracy of fit indicated by R^2)

Trait	**Change**		
	Phenotypic	Genetic	Environmental
Birth weight	-1.43 $R^2 = 0.57$	+0.45 $R^2 = 0.80$	-0.44 / -0.97 $R^2 = 0.91 / 0.49$
Weaning weight *Direct*	+20.4 $R^2 = 0.85$	+7.0 $R^2 = 0.97$	+11.9 $R^2 = 0.6$
Weaning weight *Maternal*		*2.1* $R^2 = 0.7$	
Mature cow weight	-27.9 / +25.7 / -6.1 $R^2 = 0.89 / 0.49 / 0.12$	-0.3 / +4.1 $R^2 = 0.02 / 0.48$	+6.5 $R^2 = 0.01$
Inter-calving period 1-3	-19.7 $R^2 = 0.33$	-0.58 / +1.58 $R^2 = 0.24 / 0.67$	
Age at first calving	+0.04 $R^2 = 0.00$	+0.18 $R^2 = 0.03$	
KgC/LSU	-5.0/ +14.07 $R^2 = 0.63 / 0.44$		

ADDENDUM B: BONSMARA

Table B1: Number of records (n) and means ($\bar{x}$) for birth- (BW), weaning- (WW), mature cow weight (MW), inter-calving period 1-3 (ICP1-3) and age at first calving (AFC)

Year	R	S	BW (kg)		WW (kg)		MW		ICP1-3		AFC	
	n	n	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$
1980	315	315	1831	34.6	7394	207	458	480	1490	454	1822	32.4
1981	325	325	6725	34.6	9459	207	1301	493	1796	448	2216	32.6
1982	338	338	13783	34.8	11773	208	1981	498	2120	445	2714	32.5
1983	371	371	16485	34.6	15375	205	2285	502	2666	446	3353	31.9
1984	438	438	21741	34.7	17839	215	2522	501	3247	444	3987	31.9
1985	510	510	23541	34.5	18386	214	2598	502	2707	450	3401	32.0
1986	522	522	25631	35.0	28012	214	2935	494	4839	443	6433	31.6
1987	516	516	36106	35.7	34698	217	2696	495	5463	445	7366	31.2
1988	523	523	40943	35.7	37389	219	2848	504	5328	444	7329	32.0
1989	513	513	47516	35.4	42296	215	2900	498	5488	440	7963	32.4
1990	605	522	45927	35.4	40158	214	2726	504	5063	437	7167	32.1
1991	606	531	43855	35.7	37817	211	2815	505	4774	439	6507	32.4
1992	568	520	42352	35.3	37906	215	3197	500	5304	440	7112	32.0
1993	524	484	37113	35.6	34610	219	2761	502	4774	444	6477	32.0
1994	459	445	37744	35.4	36462	218	2726	497	4774	441	6684	31.8
1995	436	398	35719	36.0	34577	222	2482	511	4455	437	6551	31.9
1996	401	369	38805	35.8	35520	218	2570	508	4442	439	6447	31.7
1997	390	358	38867	35.8	34466	222	2528	498	4321	439	5893	32.1
1998	356	337	38767	35.5	34256	216	2483	502	4357	441	6030	32.2
1999	356	337	35925	35.4	31185	220	2517	508	4154	442	5858	31.7
2000	330	321	34190	35.5	29668	224	2592	509	4073	436	5519	31.9
2001	311	301	35004	35.8	28959	221	2818	510	4163	429	5673	32.5
2002	291	272	33353	35.3	29107	222	2659	514	4330	433	5751	32.1
2003	307	291	33326	35.1	29042	226	2918	509	4473	434	5925	31.6
2004	-	-	34190	35.4	29933	225	3084	511	5007	430	6560	31.6
2005	320	303	35543	35.3	31466	222	3121	505	5341	433	7065	31.4
2006	300	293	37503	35.5	32470	222						
2007	303	293	39832	35.3	35885	226						
2008	324	317	42050	35.2	37095	222						
2009	345	334	44743	35.5	38225	223						
2010	353	350	44826	35.1	30687	219						

n – number of animals
R – Herds registered, S – Herds participating in Performance Scheme

Table B2: Number of measurements and average values per year of birth for birth weight

Year	n	Cg	Phenotypic	Genetic	Environmental
1980	1831	339	34.60	-0.66	11.52
1981	6725	541	34.60	-0.72	11.28
1982	13783	926	34.80	-0.66	11.27
1983	16485	1161	34.60	-0.60	11.00
1984	21741	1373	34.70	-0.57	11.12
1985	23541	1463	34.50	-0.50	10.64
1986	25631	1474	35.00	-0.37	10.81
1987	36106	1550	35.70	-0.31	10.81
1988	40943	1687	35.70	-0.16	11.05
1989	47516	1838	35.40	-0.10	10.75
1990	45927	1790	35.40	0.0	10.56
1991	43855	1708	35.70	0.12	10.52
1992	42352	1548	35.30	0.17	10.23
1993	37113	1371	35.60	0.22	10.15
1994	37744	1354	35.40	0.24	9.99
1995	35719	1275	36.00	0.32	10.24
1996	38805	1315	35.80	0.33	10.25
1997	38867	1310	35.80	0.32	10.20
1998	38767	1277	35.50	0.33	9.89
1999	35925	1179	35.40	0.31	9.75
2000	34190	1142	35.50	0.31	9.79
2001	35004	1167	35.80	0.37	10.25
2002	33353	1182	35.30	0.34	9.71
2003	33326	1157	35.10	0.32	9.56
2004	34190	1166	35.40	0.34	9.75
2005	35543	1199	35.30	0.35	9.65
2006	37503	1255	35.50	0.36	9.83
2007	39832	1292	35.30	0.34	9.84
2008	42050	1388	35.20	0.38	9.60
2009	44743	1473	35.50	0.42	9.77
2010	44826	1436	35.10	0.45	9.70

n – number of animals

Cg – the number contemporary groups

Table B3: Number of measurements and average values per year of birth for weaning weight

Year	n	Cg	Phenotypic	Genetic	Environmental
1980	7394	621	207	-5.1	6.6
1981	9459	735	207	-4.6	4.7
1982	11773	903	208	-4.2	6.6
1983	15375	1186	205	-3.8	4.4
1984	17839	1400	215	-3.7	5.0
1985	18386	1637	214	-3.0	10.6
1986	28012	1742	214	-2.7	9.0
1987	34698	1901	217	-2.1	8.1
1988	37389	1986	219	-1.3	11.6
1989	42296	2162	215	-0.8	9.6
1990	40158	2218	214	0.0	4.8
1991	37817	2210	211	0.8	3.8
1992	37906	2168	215	1.2	0.7
1993	34610	1957	219	1.9	5.2
1994	36462	1905	218	2.3	3.6
1995	34577	1826	222	3.1	6.7
1996	35520	1792	218	3.6	8.0
1997	34466	1816	222	3.9	3.5
1998	34256	1679	216	4.1	6.7
1999	31185	1587	220	4.5	0.6
2000	29668	1545	224	5.0	3.7
2001	28959	1534	221	5.5	3.3
2002	29107	1660	222	5.6	0.1
2003	29042	2092	226	6.0	4.2
2004	29933	1421	225	6.4	0.7
2005	31466	1600	222	6.5	-0.7
2006	32470	1765	222	7.1	-1.4
2007	35885	2038	226	7.0	0.6
2008	37095	2281	222	7.4	-3.0
2009	38225	2404	223	7.9	-1.9
2010	30687	1890	219	8.6	-5.5

n – number of animals

Cg – the number contemporary groups

Table B4: Number of measurements and average values per year of birth for mature cow weight

Year	n	Cg	Phenotypic	Genetic	Environmental
1980	458	62	480	-12.0	394
1981	1301	90	493	-10.0	382
1982	1981	116	498	-9.2	383
1983	2285	140	502	-7.9	373
1984	2522	138	501	-6.9	383
1985	2598	147	502	-6.1	390
1986	2935	242	494	-5.9	389
1987	2696	352	495	-3.4	390
1988	2848	467	504	-2.3	401
1989	2900	520	498	-1.8	403
1990	2726	524	504	0.0	397
1991	2815	589	505	2.4	394
1992	3197	556	500	2.4	383
1993	2761	522	502	2.2	398
1994	2726	509	497	2.3	397
1995	2482	502	511	4.4	394
1996	2570	508	508	2.6	399
1997	2528	529	498	3.0	390
1998	2483	474	502	3.3	398
1999	2517	501	508	3.7	388
2000	2592	472	509	3.5	394
2001	2818	452	510	2.9	404
2002	2659	481	514	4.7	388
2003	2918	650	509	3.3	400
2004	3084	419	511	4.7	395
2005	3121	489	505	4.7	399

n – number of animals

Cg – the number contemporary groups

Table B5: Trends for inter-calving period 1-3 for the Bonsmara

Year	n	Phenotypic	Genetic
1980	1490	454	1.81
1981	1796	448	0.47
1982	2120	445	0.42
1983	2666	446	0.26
1984	3247	444	0.33
1985	2707	450	0.24
1986	4839	443	0.09
1987	5463	445	0.05
1988	5328	444	-0.10
1989	5488	440	-0.11
1990	5063	437	-0.25
1991	4774	439	-0.43
1992	5304	440	-0.46
1993	4774	444	-0.47
1994	4774	441	-0.27
1995	4455	437	0.16
1996	4442	439	-0.35
1997	4321	439	-0.33
1998	4357	441	-0.45
1999	4154	442	-0.34
2000	4073	436	-0.10
2001	4163	429	0.21
2002	4330	433	0.14
2003	4473	434	0.42
2004	5007	430	0.70
2005	5341	433	0.75

n – number of animals

Table B6: Trends for age at first calving for the Bonsmara

Year	n	Phenotypic	Genetic
1980	1822	32.4	-0.88
1981	2216	32.6	-0.82
1982	2714	32.5	-0.88
1983	3353	31.9	-0.73
1984	3987	31.9	-0.72
1985	3401	32.0	-0.76
1986	6433	31.6	-0.70
1987	7366	31.2	-0.60
1988	7329	32.0	-0.32
1989	7963	32.4	-0.20
1990	7167	32.1	0.00
1991	6507	32.4	0.26
1992	7112	32.0	0.33
1993	6477	32.0	0.58
1994	6684	31.8	0.61
1995	6551	31.9	0.79
1996	6447	31.7	0.93
1997	5893	32.1	1.20
1998	6030	32.2	1.12
1999	5858	31.7	0.97
2000	5519	31.9	1.41
2001	5673	32.5	1.54
2002	5751	32.1	1.50
2003	5925	31.6	1.57
2004	6560	31.6	1.75
2005	7065	31.4	1.83

n – number of animals

Table B7: The input information used to estimate KgC/LSU and the estimated KgC/LSU

Year	WW	CW	ICP	LSU	Calf %	KgC/LSU
1980	199	459	451	1.34	76	113
1981	197	457	432	1.33	82	121
1982	199	459	431	1.34	82	122
1983	197	456	436	1.33	81	120
1984	199	462	433	1.34	81	120
1985	206	472	442	1.36	79	119
1986	207	468	427	1.35	83	127
1987	208	477	416	1.37	86	130
1988	212	486	431	1.40	82	125
1989	211	487	425	1.40	84	127
1990	208	483	419	1.39	85	127
1991	209	488	421	1.40	85	127
1992	205	480	420	1.38	85	126
1993	211	490	420	1.40	85	128
1994	211	496	425	1.42	84	125
1995	216	501	414	1.43	87	131
1996	216	503	414	1.44	87	131
1997	213	497	407	1.42	88	132
1998	216	505	413	1.44	87	130
1999	211	494	416	1.41	86	128
2000	215	503	412	1.44	87	130
2001	220	508	417	1.45	86	130
2002	213	498	410	1.42	88	132
2003	217	489	428	1.40	83	128
2004	221	509	421	1.45	85	129
2005	220	509	409	1.45	88	133
2006	217	499	410	1.43	88	134
2007	216	502	409	1.44	88	132
2008	218	508	405	1.45	89	134
2009	217	508	413	1.45	87	130
2010	215	504	414	1.44	87	130
2012	217	476	417	1.37	86	136
2013	219	501	410	1.43	88	135

WW – Weaning Weight, CW - Cow Weight, ICP - Inter-calving Period,
LSU - Large Stock Unit, KgC/LSU - Kg calf per large stock unit

Table B8: Phenotypic, genetic and environmental changes in the Bonsmara over the 25 year period (with the accuracy of fit indicated by R^2)

Trait	**Change**		
	Phenotypic	Genetic	Environmental
Birth weight	*0.55* *R^2 = 0.17 / 0.24*	+0.70 / +0.10 *R^2 = 0.97 / 0.61*	-1.31 *R^2 = 0.87*
Weaning weight *Direct*	+10.1 / -1.6 *R^2 = 0.63 / 0.08*	+11.7 *R^2 = 0.98*	-6.1 *R^2 = 0.57*
Weaning weight *Maternal*		*3.6* *R^2 = 0.98*	
Mature cow weight	+17.5 *R^2 = 0.54*	+15.9 *R^2 = 0.98*	*4.1 / 0.6* *R^2 = 0.21 / 0.001*
Inter-calving period 1-3	-16.93 *R^2 = 0.75*	*-1.23 / 2.99* *R^2 = 0.58 / 0.95*	
Age at first calving	-0.42 *R^2 = 0.13*	+3.07 *R^2 = 0.97*	
KgC/LSU	+12.08 *R^2 = 0.71*		

ADDENDUM C: DRAKENSBERGER

Table C1: Number of records (n) and means ($\bar{x}$) for birth- (BW), weaning- (WW), mature cow weight (MW), inter-calving period 1-3 (ICP1-3) and age at first calving (AFC)

Year	R	S	BW (kg)		WW (kg)		MW		ICP1-3		AFC	
	n	n	N	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$
1980	222	85	357	35.0	543	203	33	483	121	473	144	34.3
1981	198	96	1180	34.5	1055	203	70	490	196	488	240	34.7
1982	208	100	1608	34.5	1234	202	123	485	237	469	293	34.4
1983	205	124	1902	34.7	1695	205	117	495	342	463	429	33.9
1984	220	130	2787	35.0	2577	214	173	509	532	460	670	34.1
1985	219	149	3524	34.9	2774	214	169	479	520	457	612	33.3
1986	218	157	4713	35.7	4461	216	167	468	663	459	863	33.5
1987	219	152	5641	35.7	5451	209	169	481	699	454	1000	33.5
1988	206	143	6014	35.6	5648	212	163	495	598	454	821	34.0
1989	193	148	6587	35.5	5655	213	222	475	612	458	863	33.8
1990	179	131	6607	35.2	5525	213	239	475	617	445	844	33.8
1991	168	138	6176	35.3	4922	206	204	485	606	463	786	33.8
1992	141	138	5356	35.2	4688	211	228	487	596	457	854	33.9
1993	138	133	4805	35.7	4316	213	195	487	497	465	720	33.6
1994	114	104	4660	35.6	4570	209	192	495	584	472	798	33.5
1995	115	102	4632	35.7	4425	215	183	487	505	479	740	33.8
1996	116	98	4386	35.6	4357	209	136	479	427	465	682	33.6
1997	115	98	4412	35.0	4429	207	124	488	405	459	649	33.6
1998	108	96	5011	35.1	4731	203	182	475	401	461	565	33.9
1999	108	96	4831	34.6	4156	207	201	487	443	448	596	34.4
2000	104	95	3890	35.1	3440	207	232	499	436	444	571	34.3
2001	89	79	3503	35.2	3124	205	162	503	382	429	503	34.1
2002	78	70	3400	34.8	2995	206	151	499	467	440	583	34.4
2003	73	68	3386	34.7	3150	212	228	506	500	429	641	34.1
2004	-	-	3347	35.0	3211	212	197	491	493	432	688	33.5
2005	79	73	3696	34.8	3149	211	120	484	446	436	628	33.8
2006	73	69	4193	35.0	3598	209						
2007	79	72	4092	34.6	3316	209						
2008	75	71	3705	34.6	3190	212						
2009	71	70	3719	34.9	3182	216						
2010	76	76	3099	34.3	253	207						

n – number of animals

R – Herds registered, S – Herds participating in Performance Scheme

Table C2: Number of measurements and average values per year of birth for birth weight

Year	n	Cg	Phenotypic	Genetic	Environmental
1980	357	64	35.00	-0.10	0.49
1981	1180	142	34.50	-0.12	0.17
1982	1608	186	34.50	-0.14	-0.30
1983	1902	230	34.70	-0.08	-0.09
1984	2787	265	35.00	-0.05	-0.04
1985	3524	320	34.90	-0.02	0.16
1986	4713	357	35.70	0.00	0.32
1987	5641	356	35.70	-0.02	-0.01
1988	6014	371	35.60	0.07	0.21
1989	6587	424	35.50	0.07	0.12
1990	6607	389	35.20	0.12	-0.34
1991	6176	361	35.30	0.16	-0.45
1992	5356	318	35.20	0.14	-0.43
1993	4805	258	35.70	0.19	-0.08
1994	4660	274	35.60	0.21	-0.34
1995	4632	256	35.70	0.20	0.10
1996	4386	258	35.60	0.38	-0.06
1997	4412	263	35.00	0.35	-0.79
1998	5011	275	35.10	0.33	-0.43
1999	4831	260	34.60	0.36	-0.75
2000	3890	227	35.10	0.27	-0.33
2001	3503	218	35.20	0.25	0.08
2002	3400	182	34.80	0.22	-0.38
2003	3386	190	34.70	0.16	-0.51
2004	3347	185	35.00	0.25	-0.85
2005	3696	192	34.80	0.23	-0.89
2006	4193	208	35.00	0.18	-0.44
2007	4092	208	34.60	0.15	-0.67
2008	3705	185	34.60	0.19	-1.09
2009	3719	195	34.90	0.21	-0.35
2010	3099	163	34.30	0.24	-0.67

n – number of animals

Cg – the number contemporary groups

Table C3: Number of measurements and average values per year of birth for weaning weight

Year	n	Cg	Phenotypic	Genetic	Environmental
1980	543	68	203	-1.59	-9.6
1981	1055	96	203	-1.43	0.8
1982	1234	129	202	-1.55	-0.0
1983	1695	145	205	-1.22	-2.9
1984	2577	201	214	-0.31	0.1
1985	2774	254	214	-0.19	7.3
1986	4461	308	216	0.00	3.9
1987	5451	388	209	0.48	7.7
1988	5648	382	212	0.75	1.0
1989	5655	413	213	1.15	3.2
1990	5525	386	213	1.63	0.6
1991	4922	390	206	2.01	1.3
1992	4688	324	211	2.36	-3.4
1993	4316	254	213	2.28	-3.3
1994	4570	325	209	2.54	-3.5
1995	4425	306	215	2.99	-1.7
1996	4357	353	209	3.26	-1.9
1997	4429	337	207	3.18	-7.7
1998	4731	327	203	3.42	-7.4
1999	4156	295	207	3.76	-13.6
2000	3440	244	207	3.99	-10.9
2001	3124	255	205	3.94	-6.6
2002	2995	277	206	4.05	-12.4
2003	3150	313	212	4.16	-3.8
2004	3211	205	212	4.64	-7.5
2005	3149	190	211	4.90	-5.5
2006	3598	222	209	5.23	-10.3
2007	3316	228	209	5.25	-6.8
2008	3190	226	212	5.44	-4.0
2009	3182	232	216	5.67	-2.1
2010	253	52	207	5.08	-4.6

n – number of animals

Cg – the number contemporary groups

Table C4: Number of measurements and average values per year of birth for mature cow weight

Year	n	Cg	Phenotypic	Genetic	Environmental
1980	33	3	483	-12.3	436
1981	70	1	490	-4.9	387
1982	123	1	485	-5.4	418
1983	117	2	495	-3.7	364
1984	173	6	509	0.0	378
1985	169	5	479	-3.2	392
1986	167	15	468	0.0	388
1987	169	33	481	-2.7	408
1988	163	37	495	0.3	410
1989	222	37	475	-0.6	402
1990	239	37	475	1.9	390
1991	204	61	485	7.6	390
1992	228	45	487	7.5	366
1993	195	37	487	4.0	391
1994	192	47	495	7.6	376
1995	183	51	487	6.6	359
1996	136	53	479	7.2	367
1997	124	42	488	4.3	361
1998	182	43	475	2.8	369
1999	201	57	487	7.4	370
2000	232	48	499	7.2	380
2001	162	41	503	7.1	371
2002	151	51	499	6.8	368
2003	228	59	506	8.3	376
2004	197	48	491	7.1	395
2005	120	55	484	5.9	387

n – number of animals

Cg – the number contemporary groups

Table C5: Trends for inter-calving period 1-3 for the Drakensberger

Year	n	Phenotypic	Genetic
1980	121	473	0.67
1981	196	488	0.11
1982	237	469	0.38
1983	342	463	0.59
1984	532	460	0.23
1985	520	457	0.07
1986	663	459	-0.21
1987	699	454	-0.08
1988	598	454	-0.17
1989	612	458	0.06
1990	617	445	0.11
1991	606	463	-0.41
1992	596	457	-0.35
1993	497	465	-0.63
1994	584	472	-0.91
1995	505	479	-0.71
1996	427	465	-0.86
1997	405	459	-1.22
1998	401	461	-1.07
1999	443	448	-1.01
2000	436	444	-0.73
2001	382	429	-0.55
2002	467	440	-0.85
2003	500	429	-1.23
2004	493	432	-1.06
2005	446	436	-1.50

n – number of animals

Table C6: Trends for age at first calving for the Drakensberger

Year	n	Phenotypic	Genetic
1980	144	34.3	0.27
1981	240	34.7	0.60
1982	293	34.4	0.23
1983	429	33.9	0.39
1984	670	34.1	0.88
1985	612	33.3	0.82
1986	863	33.5	0.85
1987	1000	33.5	0.71
1988	821	34.0	0.93
1989	863	33.8	1.31
1990	844	33.8	0.94
1991	786	33.8	1.30
1992	854	33.9	1.08
1993	720	33.6	1.55
1994	798	33.5	1.71
1995	740	33.8	1.33
1996	682	33.6	1.49
1997	649	33.6	2.35
1998	565	33.9	1.84
1999	596	34.4	1.72
2000	571	34.3	1.86
2001	503	34.1	2.04
2002	583	34.4	2.30
2003	641	34.1	2.69
2004	688	33.5	2.15
2005	628	33.8	2.98

n – number of animals

Table C7: The input information used to estimate KgC/LSU and the estimated KgC/LSU

Year	WW	CW	ICP	LSU	Calf %	KgC/LSU
1980	195	484	465	1.39	73	102
1981	198	481	482	1.38	68	97
1982	198	479	482	1.38	68	98
1983	198	482	478	1.39	69	99
1984	200	481	471	1.38	71	103
1985	209	488	466	1.40	72	107
1986	205	489	464	1.40	73	107
1987	212	495	451	1.42	76	114
1988	203	482	447	1.39	78	114
1989	207	487	442	1.40	79	117
1990	206	484	446	1.39	78	116
1991	207	494	437	1.41	80	117
1992	200	455	445	1.33	78	117
1993	207	496	436	1.42	81	118
1994	205	489	452	1.40	76	111
1995	208	470	427	1.36	83	127
1996	210	487	438	1.40	80	120
1997	203	486	431	1.40	82	119
1998	200	492	441	1.41	79	112
1999	196	488	470	1.40	71	99
2000	204	501	445	1.43	78	111
2001	202	493	453	1.41	76	109
2002	199	491	431	1.41	82	116
2003	199	484	451	1.39	76	109
2004	198	496	447	1.42	78	109
2005	206	508	426	1.45	83	118
2006	207	513	427	1.47	83	117
2007	203	504	418	1.44	85	120
2008	204	499	436	1.43	81	116
2009	208	498	432	1.42	82	120
2010	211	491	432	1.41	82	123
2012	213	477	430	1.37	82	127
2013	214	497	419	1.42	85	128

WW – Weaning Weight, CW - Cow Weight, ICP - Inter-calving Period,
LSU - Large Stock Unit, KgC/LSU - Kg calf per large stock unit

Table C8: Phenotypic, genetic and environmental changes in the Drakensberger over the 25 year period (with the accuracy of fit indicated by R^2)

Trait	**Change**		
	Phenotypic	Genetic	Environmental
Birth weight	+0.67 / -0.65 *R^2 = 0.54 / 0.45*	+0.25 / -0.18 *R^2 = 0.96 / 0.63*	-0.41 *R^2 = 0.54*
Weaning weight *Direct*	+1.7 *R^2 = 0.02*	+6.2 *R^2 = 0.9*	-13.7 / 7.9 *R^2 = 0.8 / 0.5*
Weaning weight *Maternal*		*-0.06* *R^2 = 0.0*	
Mature cow weight	+8.5 *R^2 = 0.07*	+15.06 *R^2 = 0.7*	*-23 / +27* *R^2 = 0.15 / 0.68*
Inter-calving period 1-3	-34.01 *R^2 = 0.48*	-1.81 *R^2 = 0.84*	
Age at first calving	-0.11 *R^2 = 0.01*	+2.29 *R^2 = 0.89*	
KgC/LSU	*+21.1 / -25.6 / +17.7* *R^2 = 0.76 / 0.91 / 0.79*		

ADDENDUM D: NGUNI

Table D1: Number of records (n) and means ($\bar{x}$) for birth- (BW), weaning- (WW), mature cow weight (MW), inter-calving period 1-3 (ICP1-3) and age at first calving (AFC)

Year	R	S	BW (kg)		WW (kg)		MW		ICP1-3		AFC	
	n	n	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$
1980	6	6	282	25.4	10	170	1	398	2	475	2	35.9
1981	6	6	297	28.6	14	174	11	387	4	378	4	35.1
1982	8	8	253	28.2	15	189	13	391	11	428	11	34.5
1983	6	6	182	30.7	17	169	16	383	13	400	14	32.8
1984	6	6	310	28.9	58	188	30	389	17	406	19	35.3
1985	13	13	571	29.6	234	174	76	386	9	459	9	34.1
1986	37	15	514	29.7	825	164	124	392	109	466	148	32.9
1987	51	16	579	28.3	1236	170	115	370	164	440	236	32.0
1988	80	25	948	28.6	1976	165	91	391	244	433	436	31.5
1989	84	40	1317	27.7	2095	166	102	372	247	425	414	32.3
1990	99	53	2118	26.6	2441	158	122	377	308	411	493	33.1
1991	107	64	2489	26.3	2572	159	96	378	294	423	472	32.5
1992	110	76	2644	26.2	2135	162	88	383	238	432	398	32.1
1993	103	82	2215	26.1	1577	164	140	392	242	417	400	31.3
1994	104	68	2531	26.0	1948	161	100	366	273	422	394	31.1
1995	103	66	2457	26.0	1272	161	93	380	197	416	316	31.4
1996	123	78	2542	25.4	1244	158	122	375	208	413	327	30.1
1997	131	83	2602	26.1	1661	158	105	369	172	412	309	31.1
1998	139	70	3229	25.1	1541	157	124	365	192	412	292	31.8
1999	139	70	3238	25.3	1209	162	112	365	181	405	266	31.6
2000	150	69	2636	24.8	1410	164	114	369	205	422	323	32.1
2001	178	69	2699	25.2	1069	157	101	374	151	417	217	31.9
2002	151	62	3059	25.3	1162	157	151	372	187	430	241	32.3
2003	153	55	2865	24.7	1058	158	161	372	171	412	218	30.5
2004	-	-	2543	24.8	1624	161	220	369	299	401	368	31.1
2005	225	56	2705	24.5	2121	160	187	361	301	399	489	29.9
2006	251	64	3138	24.7	2387	165						
2007	342	91	3533	24.8	2827	165						
2008	412	92	4154	25.1	3467	161						
2009	423	89	4115	25.7	2898	163						
2010	408	87	3446	25.2	2353	159						

n – number of animals
R – Herds registered, S – Herds participating in Performance Scheme

Table D2: Number of measurements and average values per year of birth for birth weight

Year	n	Cg	Phenotypic	Genetic	Environmental
1980	282	3	25.40	0.14	2.10
1981	297	4	28.60	0.22	2.09
1982	253	7	28.20	0.00	1.72
1983	182	7	30.70	-0.07	2.36
1984	310	12	28.90	0.11	4.75
1985	571	18	29.60	0.31	3.18
1986	514	28	29.70	0.37	2.03
1987	579	54	28.30	0.16	2.74
1988	948	92	28.60	0.19	2.54
1989	1317	133	27.70	0.08	2.20
1990	2118	184	26.60	0.00	1.38
1991	2489	202	26.30	-0.02	0.78
1992	2644	227	26.20	-0.04	0.26
1993	2215	210	26.10	-0.10	0.67
1994	2531	228	26.00	-0.02	0.67
1995	2457	223	26.00	-0.05	0.78
1996	2542	223	25.40	-0.07	0.55
1997	2602	240	26.10	-0.09	0.31
1998	3229	264	25.10	-0.08	-0.05
1999	3238	236	25.30	-0.07	0.20
2000	2636	209	24.80	-0.10	-0.26
2001	2699	212	25.20	-0.05	0.15
2002	3059	221	25.30	-0.09	0.50
2003	2865	211	24.70	-0.07	-0.09
2004	2543	218	24.80	-0.15	-0.09
2005	2705	216	24.50	-0.05	0.01
2006	3138	228	24.70	-0.18	0.27
2007	3533	277	24.80	-0.19	0.36
2008	4154	279	25.10	-0.20	0.37
2009	4115	275	25.70	-0.14	0.54
2010	3446	253	25.20	-0.18	0.21

n – number of animals

Cg – the number contemporary groups

Table D3: Number of measurements and average values per year of birth for weaning weight

Year	n	Cg	Phenotypic	Genetic	Environmental
1980	10	5	170	1.8	3.3
1981	14	6	174	1.9	17.4
1982	15	10	189	0.9	15.3
1983	17	18	169	0.3	21.8
1984	58	6	188	0.3	19.2
1985	234	14	174	-0.2	24.0
1986	825	23	164	0.7	6.9
1987	1236	55	170	0.1	9.8
1988	1976	120	165	0.1	5.7
1989	2095	170	166	-0.0	11.7
1990	2441	253	158	0.0	5.5
1991	2572	268	159	0.2	4.0
1992	2135	266	162	-0.0	4.7
1993	1577	231	164	0.5	9.0
1994	1948	195	161	0.5	5.8
1995	1272	182	161	0.5	3.1
1996	1244	131	158	0.4	2.9
1997	1661	138	158	0.6	3.0
1998	1541	139	157	0.0	6.3
1999	1209	111	162	0.4	3.5
2000	1410	96	164	1.1	3.9
2001	1069	127	157	1.2	4.1
2002	1162	106	157	1.2	-2.2
2003	1058	110	158	0.8	1.8
2004	1624	110	161	0.9	-0.0
2005	2121	148	160	1.3	1.7
2006	2387	164	165	0.8	7.7
2007	2827	210	165	0.9	10.0
2008	3467	218	161	0.6	3.7
2009	2898	175	163	1.0	5.0
2010	2353	161	159	1.5	0.4

n – number of animals

Cg – the number contemporary groups

Table D4: Number of measurements and average values per year of birth for mature cow weight

Year	n	Cg	Phenotypic	Genetic	Environmental
1980	1	-	398	-3.3	-
1981	11	-	387	-4.6	-
1982	13	-	391	-3.9	-
1983	16	-	383	-6.6	-
1984	30	-	389	10.7	-
1985	76	-	386	6.5	-
1986	124	2	392	6.4	336
1987	115	2	370	2.4	300
1988	91	4	391	2.5	320
1989	102	4	372	0.3	310
1990	122	11	377	0.0	322
1991	96	12	378	0.0	329
1992	88	30	383	1.2	311
1993	140	34	392	2.6	318
1994	100	31	366	-1.2	329
1995	93	39	380	0.5	309
1996	122	30	375	2.4	320
1997	105	28	369	5.0	328
1998	124	32	365	3.5	333
1999	112	37	365	1.4	321
2000	114	20	369	2.3	311
2001	101	32	374	2.5	317
2002	151	31	372	0.2	297
2003	161	40	372	0.2	298
2004	220	35	369	2.3	301
2005	187	33	361	0.7	302

n – number of animals

Cg – the number contemporary groups

Table D5: Trends for inter-calving period 1-3 for the Nguni

Year	n	Phenotypic	Genetic
1980	2	475	0.09
1981	4	378	-0.08
1982	11	428	-0.48
1983	13	400	-0.22
1984	17	406	-0.28
1985	9	459	-0.24
1986	109	466	-0.12
1987	164	440	-0.04
1988	244	433	-0.02
1989	247	425	-0.25
1990	308	411	0.07
1991	294	423	-0.16
1992	238	432	0.04
1993	242	417	-0.31
1994	273	422	-0.16
1995	197	416	0.07
1996	208	413	-0.11
1997	172	412	-0.23
1998	192	412	-0.35
1999	181	405	-0.39
2000	205	422	-0.10
2001	151	417	-0.26
2002	187	430	-0.35
2003	171	412	-0.19
2004	299	401	-0.18
2005	301	399	-0.19

n – number of animals

Table D6: Trends for age at first calving for the Nguni

Year	n	Phenotypic	Genetic
1980	2	35.9	-2.18
1981	4	35.1	-4.56
1982	11	34.5	-0.62
1983	14	32.8	0.16
1984	19	35.3	0.77
1985	9	34.1	-0.84
1986	148	32.9	-0.16
1987	236	32.0	1.28
1988	436	31.5	0.63
1989	414	32.3	0.31
1990	493	33.1	0.74
1991	472	32.5	0.55
1992	398	32.1	0.63
1993	400	31.3	1.02
1994	394	31.1	0.95
1995	316	31.4	1.14
1996	327	30.1	1.23
1997	309	31.1	1.09
1998	292	31.8	0.89
1999	266	31.6	1.72
2000	323	32.1	1.11
2001	217	31.9	1.57
2002	241	32.3	0.42
2003	218	30.5	1.23
2004	368	31.1	0.32
2005	489	29.9	0.58

n – number of animals

Table D7: The input information used to estimate KgC/LSU and the estimated KgC/LSU

Year	WW	CW	ICP	LSU	Calf %	KgC/LSU
1980	170	398	418	1.21	85	119
1981	174	387	442	1.19	79	116
1982	189	391	423	1.20	84	132
1983	169	383	388	1.18	94	134
1984	188	389	403	1.19	90	142
1985	174	386	430	1.19	82	120
1986	164	392	470	1.20	71	97
1987	170	370	387	1.15	94	138
1988	165	391	439	1.20	80	110
1989	166	372	420	1.16	85	122
1990	158	377	429	1.17	82	111
1991	159	378	417	1.17	86	117
1992	162	383	436	1.18	81	111
1993	164	392	436	1.20	81	111
1994	161	366	452	1.15	76	107
1995	161	380	427	1.18	83	114
1996	158	375	438	1.16	80	109
1997	158	369	431	1.15	82	112
1998	157	365	441	1.14	79	108
1999	162	364	383	1.14	95	135
2000	164	374	383	1.16	95	134
2001	157	382	413	1.18	87	116
2002	157	370	393	1.15	92	125
2003	158	362	421	1.14	85	118
2004	161	369	408	1.15	88	123
2005	160	365	404	1.14	89	125
2006	165	364	401	1.14	90	130
2007	165	362	399	1.14	91	132
2008	161	366	407	1.15	88	124
2009	156	364	423	1.14	84	115
2010	158	374	423	1.16	84	114
2012	155	351	423	1.11	84	117
2013	153	398	400	1.13	90	122

WW – Weaning Weight, CW - Cow Weight, ICP - Inter-calving Period,
LSU - Large Stock Unit, KgC/LSU - Kg calf per large stock unit

Table D8: Phenotypic, genetic and environmental changes in the Nguni over the 25 year period (with the accuracy of fit indicated by R^2)

Trait	**Change**		
	Phenotypic	Genetic	Environmental
Birth weight	-2.53 $R^2 = 0.62$	-0.24 $R^2 = 0.68$	-0.19 $R^2 = 0.43$
Weaning weight *Direct*	-0.7 $R^2 = 0.01$	+1.7 $R^2 = 0.6$	-3.6 $R^2 = 0.12$
Weaning weight *Maternal*		-0.2 $R^2 = 0.2$	
Mature cow weight	-22.3 $R^2 = 0.4$	0.8 $R^2 = 0.02$	-30.5 $R^2 = 0.57$
Inter-calving period 1-3	-23.75 $R^2 = 0.34$	-0.25 $R^2 = 0.18$	
Age at first calving	-1.65 $R^2 = 0.23$	+0.37 $R^2 = 0.05$	
KgC/LSU	+11.71 $R^2 = 0.19$		