EVALUATION OF NON-GENETIC FACTORS AFFECTING BIRTH WEIGHT OF KALAHARI RED GOATS IN SOUTH AFRICA

by

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DEDICATION

This piece of work is dedicated to my parents; Phuti and Kgadi Ramoroka, my siblings; Kwena, Letladi, Noko and Manape who were always immersed in vision about my success.

DECLARATION

I declare that the mini-dissertation hereby submitted to the University of Limpopo, for the degree of Master of Science in Agriculture (Animal Production) has not previously been submitted by me for a degree at this or any other university; that it is my work in design and in execution, and that all material contained herein has been duly acknowledged.

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Ramoroka M.P (Mr) Date

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LIST OF ABBREVIATIONS

ADG	Average Daily Gain
ANOVA	Analysis of Variance
BW	Birth Weight
CI	Correlation Interval
DF	Degree Of Freedom
DNA	Deoxyribonucleic Acid
G*E	Genotype by Environment interaction
HSD	Honestly Significant Difference
LSM	Least Square Mean
MS	Mean Squares
MW	Mature Weight
N	Number
R	Region
SA	South Africa
SD	Standard Deviation
SE	Standard Error
SS	Sum of Squares
WW	Weaning Weight
YW	Yearly Weight

ABSTRACT

The objective of this study was to evaluate the effect of some non-genetic factors on birth weight of Kalahari Red goats. Data on pedigree, breeding and performance records (N=1902) of Kalahari Red goat kids born in the Northern, Southern and Eastern regions of South Africa during the period from 2008 to 2017 were used. Least squares analysis revealed that season of birth, sire age, dam age, sex of kid, breeder, year of birth and Litter size were significant ($p<0.05$) sources of variation for birth weight in Kalahari Red goats kids. The average birth weights (BW) were 2.45 ± 0.57 kg, 3.33 ± 0.15 kg and 3.14 ± 0.08 kg kg for Eastern, Northern and Southern regions, respectively. Kids born in the Northern region were heavier (3.33 ± 0.158 kg) than those born in the Eastern regions (2.45 ± 0.57 kg). However, region had no significant effect ($p>0.05$) on birth weight. Breeder effect was significant ($p<0.05$). Kidding interval was not significant (P>0.05). The average birth weight of male kids was higher than female kids (3.05 ± 0.21 kg: 2.89 ± 0.20 kg), and the difference was significant (P<0.05). The research found a significant effect ($p<0.05$) of Litter size with the average birth weight of single, twins, triples and quadruplets kids being 3.10 ± 0.19 kg, 2.9 ± 0.20 kg, 2.99 ± 0.20 kg and 2.87 ± 0.36 kg respectively. The kids that were born as single were heavier than those that were born as multiple (twins, triplets and quadruplets). There were four seasons of birth analysed in the study, which were found to be highly significant (P<0.05) on birth weight. Year of birth had significant effect ($p<0.05$) on birth weight. The kids born in the year 2015 were heavier in BW (3.39 ± 0.23 kg) than those born in the other years, while the kids born in 2016 had the lowest BW (1.91 ± 0.21 kg). Age of dam and sire had a significant effect ($p<0.05$) on birth weight. It was then concluded that season of birth, sire age, sex of kid, dam age, breeder, year of birth and Litter size significantly influence birth weight of Kalahari Red goat's kids and, therefore, need to be included in genetic evaluation models.

Keywords: *Adaptability, Growth potential, Parental effects, Reproduction potential.*

CHAPTER 1

1. INTRODUCTION

Goats are known to be potential genetic resources for meat, milk, skin, and fibre (Atoui *et al.* 2017). They also play an important role in the socio-economic lives of people as they feature prominently in socio-cultural functions like ceremonies and religious festivities. Goats are widely distributed in the tropics and subtropics as a result of their ability to adapt to a variety of environments (Mbayahaga *et al*. 1998). Growth traits of economic importance related to the cost of production are birth weight (BW), weaning weight (WW), average daily gain (ADG) and mature weight (MW). These traits are known in livestock species to be highly heritable, thus necessitating improvement strategies through performance selection (Dekkers *et al.,* 2002).

Growth performance is one of the most important selection criteria in almost any goat-breeding program. It can be determined in terms of body weight. In many goat breeds such as Boer, Kiko, Savannah, and Tennessee meat goat, continuous selection for increasing growth performance has led to a situation where a further increase in growth performance is contra-indicated. Growth performance should, therefore, be one of the most important criteria in the selection program of meat goats. Birth weight is an economically important trait in livestock production (Atoui *et al*. 2017), and it is a measure of prenatal growth which partially affects postnatal development (Barlow, 1978). According to Bailgy *et al.,* (1990), birth weight determines the future performance of the individual engaged in the prevailing environment. As body weight at all ages is positively genetically correlated (Safari *et al.,* 2005), selection for an increased birth weight will lead to an increase in mature body weight, which could have a desirable impact on overall profitability. Weight at birth is influenced by genetic and non-genetic factors.

Genetic improvement is an integral part of the utilisation of many goat genotypes in tropical climates, where breeding policies mostly aim to upgrade local goats by crossbreeding with, either temperate or tropical breeds (Larvaj & Gore, 1987). It can be achieved by selection, where the effect of non-genetic factors on productive traits should be considered first (Zinat *et al.,* 2013). Knowledge about environmental factors on economic traits is essential for the production of goats, which in turn may reduce kid's mortality to a reasonable extent and increasing overall production potential (Husain, 2004). Production traits are affected by various non-genetic factors like sex, season, year and type of birth (Kumar *et al.,* 2007). Birth weight is an economically important trait that is easy to measure and can be measured early in life. Kalahari Red goat has similarilites in appearance with the Boer goat. They are active and extremely hard animals and are ideally suited to the harsh and outstretched conditionds of large parts of South Africa. The Kalahari Red goats are resistant to diseases and parasites, and require less care and management than other goats. It can be used as a good crossbred for increasing hardiness and carcass size.

1.1. Problem statement

Performance traits of goats may be influenced by several genetic and non-genetic factors (Afzal *et al.,* 2004). The performance records of an animal should be corrected for identifiable non-genetic sources of variation, in order to obtain accurate estimates of genetic parameters and breeding values. This is a prerequisite to identifying animals with superior genetic merit for selective breeding and subsequent attainment of genetic improvement (Zinat *et al*., 2013). Knowledge of such factors also helps to improve the performance of animals by enabling planning for better management. Accurate selection of animals in a breeding programme requires that non-genetic factors influencing the accuracy of predicted breeding values be either controlled experimentally or eliminated statistically (Van Wyk *et al*., 1993). Identification of superior animals and subsequent selection decisions should be based on genetic merit rather than on differences due to environmental effects (Safari *et al.,* 2007). Therefore, performance records of animals need to be adjusted for the non-genetic sources of variation either before or during the process of estimation of breeding values. Adjustment of non-genetic factors is preferred for pragmatic and operational reasons applied in genetic evaluation systems (Notter *et al.,* 2005).

The influence of non-genetic factors such as the age of the animal, sex, Litter size (the type of birth) and the age of the dam of the animal on growth traits such as birth weight is well documented. However, there is limited information on the growth traits and non-genetic factors effecting the South African Kalahari Red goat breed. The prediction of an animal's worth in breeding requires knowledge of the co-variances among random and fixed effects for inclusion in a model for estimating breeding values. Incorrect covariance components could lead to biased breeding values, especially in multiple trait analysis of growth traits (Neser *et al.,* 2012). It could also lead to an incorrect measurement of the effectiveness of genetic selection. The current use of genetic parameters derived from other goat breeds in the models for estimating breeding values for Kalahari Red goats is a setback in the genetic improvement of the breed, since these parameters are specific a the population, breed, environment and period (Shelby *et al.,* 1963).

Growth is influenced by several factors including environmental variables such as feeding level, forage quality, housing and climate, direct genetic effects and maternal environment provided by the dam (Dube, 2015). It is influenced by the additive genetic and permanent environmental effects of the dam (Dube, 2015). Several studies in South Africa have been carried out on various goat breeds to analyse traits like milk yield; however there is limited research on growth traits. Studies on growth traits have been conducted for various breeds elsewhere, but not in South Africa. Despite the fact that the Kalahari Red is an indigenous goat breed, there is paucity of information on it in the literature. It is imperative to develop information required to estimate breeding values for the breed, in order to improve it genetically. Studies carried out on non-genetic factors affecting birth weight for various goat breeds, need to be redefined and updated.

1.2. Background information and rationale

Animals under tropical conditions are subjected to an extremely severe environment (cyclical food stress, irregular watering, high disease risks, excessive temperature, and humidity) which are very variable in time and space. Correction of these environmental effects such as annual effects, regional effects and herd effects is very difficult (Pagot, 1992). Moreover, the variance of environmental factors, which is very high indirectly, reduces the contribution of genetic effects and thus the heritability of the characteristics (Pagot, 1992).

Kosum *et al*. (2004) reported that weight is an important selection objective in meat animals; thus knowledge of the phenotypic and genetic parameters of growth traits is of utmost importance. It is, therefore, important that knowledge of environmental influences and the magnitude of their effects on growth traits are developed in genetic improvement programmes for meat production. The size of offspring at birth is controlled by factors other than nutrition during pregnancy. These factors include sex (Goodwin, 1971; Hassan, 1987 and Osinowo *et al*., 1990), breed type (Goodwin, 1971), parity of dam (Hassan, 1987), type of birth (Goodwin, 1971; Osinow *et al*., 1990, 1993) and season of birth (Hassan, 1987; Osinowo *et al.,* 1992).

Genetic contribution determines the maximum potential of an animal's performance. Genetic parameters affect response to selection in a breeding programme. There is a dearth of information on genetic parameters of body weight and growth traits of goats in general (Bosso *et al.,* 2007). Previous studies of genetic parameters in goats under conventional production systems in South Africa did not include the Kalahari Red breed, mainly because the breed did not have a sound performance recording system. Growth performance is one of the most important traits in the selection program for Kalahari Red goats. As body weight at all ages is positively genetically correlated (Safari *et al.,* 2005), selection for an increased body weight at any age will lead to an increase in mature body weight, which could have a desirable impact on overall profitability. However, few of the studies paid attention to genetic parameters of milk production, fleece weight and diameter, and body weight of other goat breeds. Significant genetic improvement has been achieved in Boer, Kiko, Savannah, and Tennessee meat goat breeds through selection.

Pribyl *et al*. (2000) found that environmental factors, especially management practices, are responsible for the large variability in growth traits. These factors include season, year of birth, type of birth, sex of kid. Knowledge of such effects helps to improve the performance of animals by planning for better management. (Montaldo *et al.,* 1987). According to Lewis and Beatson (1999), the variation in performance due to non-genetic factors can be identified and isolated by appropriate statistical methods and further used for planning accurate breeding programs. Development of effective genetic evaluation and improvement programs requires knowledge of the genetic parameters and environmental effects that need to be adjusted in economically important traits. These parameters need to be estimated from relevant populations as parameters and fixed effects may vary among breeds and different populations (Safari *et al.,* 2007). Although many studies have been conducted on models for the genetic evaluation of growth traits for different goat breeds, there is no published information on the models for the genetic evaluation of growth traits for Kalahari Red goats. Growth traits have been studied in Naeini, Khari and Sirohi breeds. Growth traits in Naeini goats were affected by environmental effects of sex, birth year, and birth type and dam age at kidding. Consideration of the factors included in the models used for the estimation of genetic parameters and genetic evaluation is necessary to avoid biased genetic parameter estimates and estimated breeding values. Along with the direct effects of the animal, maternal permanent environmental effects also need to be considered for genetic evaluation (Gowane *et al.,* 2011). This makes the study effective given that the Southern Africa region is increasingly growing in Kalahari Red goat flock sizes.

The aim of this study was to evaluate non-genetic factors affecting birth weight of Kalahari Red goat kids in three regions of South Africa. Knowledge of such factors will help to achieve improved flock performance through more accurate selective breeding and better informed management decisions.

1.3. Objectives

I. To determine environmental factors affecting birth weight (BW) of stud Kalahari Red goats of South Africa.
II. To determine reproductive factors affecting birth weight (BW) of stud Kalahari Red goats of South Africa.

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1.4. Hypothesis

i. H_O: Environmental factors do not affect birth weight of stud Kalahari Red goats of South Africa.

ii. H_O: Reproductive factors do not affect birth weight of stud Kalahari Red goats of South Africa.

CHAPTER 2

2. LITERATURE REVIEW

2.1. Introduction

In South African rural areas, goats are the most common ruminant animals. They are very important as a source of meat, and for religious purposes, as well as savings. However, goats are not a priority enterprise for financial investment or innovation. South African, like most developing countries, is characterized by poverty, malnutrition and a growing human population with an unequal distribution of wealth (Greyling *et al.,* 2004). The demand for livestock is increasing significantly as a result of a fast-growing world population, changes in lifestyle and food preferences (Delgado *et al*., 1999). Goat breeds in rural areas are primarily of the indigenous type and possess characteristics such as hardiness, disease resistance, and drought tolerance. Preston and Murgueitio (1992) revealed that indigenous goat breeds are better able to utilize low quality feeds and can walk for longer distances, in search of water and feed, than imported breeds. According to Webb and Mamabolo (2004), indigenous goat breeds can tolerate local diseases such as pulpy kidney, tick-borne diseases and gastrointestinal parasite infestation (Baker *et al.,* 1998). Indigenous breeds raised under range conditions outperform imported breeds (Mpofu, 2002). In contrast, Peackock (1996) reported that performance of indigenous goat breeds is generally low, partly as a result of high disease and parasite challenge and a low plane of nutrition. Meissner *et al* (2013), reckon that South Africa has approximately 1 million goats, with the Eastern Cape boasting the highest concentration of goats in the country. The emerging and communal sectors own 67% of the goats in South Africa (Meissner *et al*., 2013).

The genetically diverse group of goat population breeds in South Africa consists of Angora goats kept for meat, and Saanen, British, Alpine, and Toggenburg kept for milk, as well as unimproved indigenous goats. These indigenous goats are kept mostly for meat and ceremonial slaughter purposes by the emerging and communal sectors (Braun, 1998). Only 36% of the total number of goats in South Africa is farmed on a commercial basis (Coetzee, 1998). Goats are important for both commercial and subsistent farming systems in South Africa. Indigenous breeds such as Boer and Nguni goats have several advantages over the exotic breeds, due to their good mothering ability, adaptability, hardiness, and resistance to diseases under the harsh South African farming conditions (Casey & Van Niekerk, 1988). Among the indigenous breeds in South Africa, the Boer goat has numerous productive advantages over the rest and this has led to its popularity and demand worldwide. The adaptability of the breed, the quality of meat produced and their ability to perform well under extensive semi-arid climatic conditions, ranging from hot dry seasons to the extremely low temperatures of snow-clad mountainous regions, are among the advantages (Casey & Van Niekerk, 1988).

The Kalahari Red is regarded as an indigenous goat breed of Southern Africa. Records indicate that the goats have been selected from lop-eared animals that migrated with tribes to the southern part of Africa more than 2000 years ago (Epstein, 1971). The Kalahari Red was recognized as a landrace breed in 1998 with the establishment of a breeder's organization. Today this goat breed is an important meat-producing breed in South Africa, with characteristics such as adaptation to arid and semi-arid savannah, good foraging abilities and excellent mothering abilities. It is regarded as a "minimum care / maximum profit" breed (Ramsay *et al.,* 2001). The South African goat production system plays a major role in the reproductive and adaptive performance of different goat breeds. Non-genetics factors (environmental and reproductive factors) affect the growth traits of animals.

2.2. Goat production systems in South Africa

Goats are among the earliest animals to be domesticated and rank among important livestock species used for meat production around the world (Galal, 2005). Although they are found worldwide, this small ruminant species has been neglected in the livestock sector (Dubeuf *et al.,* 2004). In order to put interactions between livestock and the environment in a system, livestock production systems must be defined, described and put in a geographic context (FAO, 1995). Different authors have classified livestock/small ruminant production systems using different criteria. Identification of livestock production systems contributes to the total household revenue (income and food), types of livestock species kept, mobility and duration of movement (Solomon *et al.,* 2010).

2.2.1. Extensive (free ranging) Production System

This system consists of no mating control; therefore, community goats are interbred as a single flock (Kosgey *et al.,* 2008; Manyema *et al.,* 2008). This is common during the dry season when crops have been harvested and the rangeland feed quality is of low nutritive value (Dziba, 2000; Chikwanda, 2004). Under this system, goats are allowed to browse (free range) freely. This system is suited for areas where browsing fields are not a problem. The goats are released early in the morning to forage freely without any restrictions (Dube, 2015), and they are more prone to predators in this system since they would travel on their own for long distances in search of feed (Kusina, 2000).

2.2.2. Intensive (Herding) System

In most communal areas, herding is conducted by women and school children (Kusina, 2000; Chikwanda, 2004; Rumosa-Gwaze, 2009) or employed shepherds (Wason and Hall, 2002). Herded goats have access to freely select a variety of plants and pods unlike the tethered goats (Chikwanda, 2004). Goat movement is, however, controlled by the attendant through guiding them into preferred grazing areas (Gizaw *et al.,* 2010). This system is generally popular during the cropping season when goats are prevented from straying into cropping fields or vegetable gardens (Kusina, 2000; Rumosa-Gwaze, 2009). As a result of the commitment of labour to other activities such as school and cropping, goats are often penned for longer periods awaiting availability of labour (Kusina, 2000; Chikwanda, 2004; Rumosa-Gwaze, 2009). This situation leads to reduced foraging time that translates into poor body condition (Chikura, 1999).

2.2.3. Smallholder goat production

Smallholder farming systems are characterized by minimal resources in terms of land and capital, low income, poor food security, diversified agriculture and informal labour arrangements derived from family members (de Sherbinin *et al.,* 2008). The household economy of smallholder farmers is often multi-sectorial, with income arising from non-agricultural activities such as handicrafts, trade, wage labour, remittances or pensions (Bayer *et al*., 2001). Smallholder farming systems are also characteristic of poor access to conventional knowledge and information, and little or no mechanization (Boyazoglu *et al.,* 2005). In the low rainfall communal areas of Southern Africa, for example, goats represent the principal economic output, contributing a large proportion of the income of the resource-poor farmers (Ben Salem *et al.,* 2008). Regardless of such contributions, communal goats are neglected by researchers, veterinarians, extension workers, sources of credit and various other stakeholders (de Vries, 2008), leading to lack of improvement in productivity of these invaluable genetic resources.

Smallholder goat production systems consist of sedentary resource-poor farmers, each with a small piece of land on which they practice mixed farming (Kosgey *et al.,* 2006). The integration of goats with other enterprises indicates a way of diversification so as to improve food security (Mashatise *et al.,* 2005). Efforts to improve agricultural output in these areas have often been biased towards crop and cattle production enterprises, with little attention being paid to other livestock species, particularly goat production (Iniguez, 2004; Lebbie, 2004). This flawed approach ignores the fact that crop and goat production interact at the farm level (Chianu *et al*., 2007). The neglect of the goat enterprise is due to various reasons. Most goat products flow through the informal markets (Lebbie, 2004) where they are not taxed, thus leading to non-recognition of their contribution to the national economy. In addition, goat-keepers are often poorly resourced and are economically and politically marginalized (Peacock *et al.,* 2005). Bayer *et al.* (2001) and Kosgey (2004) argue that some agricultural extension practitioners, policy makers and scientists, in Southern Africa perceive communal goat farming as primitive. It entails, therefore, that much effort is required to change the way goats are perceived. In addition, it is also pertinent to describe the goat production systems and breeds used.

2.2.4. Communal goat production systems

Goat rearing is an integral part of the extensive farming system in most countries (Banda *et al.,* 1993; Loforte, 1999; Wason and Hall, 2002), with herding and tethering as the main feeding systems. Most goats are herded during the day and corralled at night. In cases where there is limited grazing land, all the goats from the entire village may be considered as a single interbreeding flock with no attempts of controlling mating (Manyema *et al.,* 2008). In most communal areas, school children are responsible for herding goats, implying that grazing depends on the school timetable (Loforte, 1999), whereas in some countries men can be employed as shepherds (Wason and Hall, 2002). Tethered goats are secured with a rope and tied to a peg to prevent them from destroying crops and to enable farmers to conduct other farming activities. Tethering can also be practiced in areas where goats are herded (Mbuh *et al.,* 2008). In some cases, however, goats are tethered in the morning hours and then herded in the afternoon when school children are back from school (Wilson *et al.*, 1989). Since tethering restricts a goat to a specific area, the animal will have little choice of feed, resulting in poor body condition, inferior weight gains and higher predisposition of the goat to heavy helminth burdens (Caldeira *et al*., 2007) indicating how a production system can impact on productivity levels of the goats.

2.3. History of Kalahari Red goats

The Kalahari Red is regarded as an indigenous goat breed originating from southern Africa (Kotze *et al.,* 2004). The Kalahari Red is believed to have originated from two lines consisting of a line of red-head Boer Goats and another from "unimproved" local goats in South Africa (Campbell, 2003). Records indicate that the goats have been selected from lop-eared animals that migrated with tribes to the southern part of Africa more than 2000 years ago (Epstein, 1971). When they reach maturity, the unique properties of the red lambs were discovered. The collection process of red goats went to Namibia where red goats were found (Snyman, 2014). Breeders from the Northern Cape Province in South Africa and the southern part of Namibia, specifically the Kalahari Desert area, selected animals slightly smaller than the red and white improved Boer goat, but with uniform red pigmentation. The Kalahari Red was recognized as a landrace breed in 1998 with the establishment of a breeder's organization (Snyman, 2014). Today this goat breed is an important meat-producing breed in South Africa with characteristics such as adaptation to arid and semi-arid savannah, good foraging abilities and excellent mothering abilities. It is regarded as a "minimum care / maximum profit" breed (Ramsay *et al.,* 2001). The breeding goal was to have a hardy, very adaptable meat goat that could survive the harsh conditions of the African landscape while still maintaining high birth rate, high survival rate, and a profitable meat carcass. Emphasis was also put on mothering traits and adaptability. The so-called Kalahari Reds were named after the colour of the sand in the Kalahari Desert (Snyman, 2014).

2.4. Growth performance of Kalahari Red goats

Snyman (2014) reported that the weaning age for male Kalahari Red kids is 3 – 3½ months and for female kids is 3½ - 4½ months. It has been found by Pienaar (2017) that the age at first breeding of Kalahari Red goats is 6 months, weaning weight for buck kids is 25 kg and weaning weight for doe kids is 21 kg. The mature weight of Kalahari Red goat does is 75 kg, which is lower than for Boer goats (Kotze *et al.,* 2004). The breed is also easy to handle and can give maximum profit to the farmers (Ramsay *et al.,* 2001). Karakus *et al.* (2008) and Topal *et al.* (2004) reported a higher value of regression (98.9 %) on Boer goat body weight compared to Kalahari Red body weight regression (97.7%). Correlation coefficients among body weight, body length and height at withers for Kalahari Red female goats were positive as shown in Table 2. Hassen *et al.* (2012) found that indigenous goats also have a positive relationship among measure of size (body weight, heart girth and body length). Hifzan *et al.* (2015) found that Kalahari Red goat body weight was highly correlated to height at withers compared to body length (0.96 vs. 0.92). The results disclose the correlation between body weight and body length, which indicates that there is a moderate positive relationship between variables.

Table 2.1: Correlation coefficients between body weights, height at wither and body length in Kalahari red goats (Hifzan *et al.,* 2015).

Parameters	Body weight	Height at wither	Body length
Body weight	1.00		
Height at wither	0.96	1.00	

Body length	0.92	0.88	1.00

2.5. Reproductive and adaptive performance of Kalahari Red goat

The limited differences among populations of goats may be suggested for local selection adaptation, and the presence of possible ecotypes in distinct environments should be further investigated (Tunon *et al.,* 1989; Saitbekova *et al.,* 1999; Yang *et al.,* 1999; Watts *et al*., 2001). Possible ecotypes should not be forfeited but should be used to their full potential to benefit livestock production in their respective areas (Kotze *et al*., 2004). The Kalahari Red today, have a distinct red colour and is often used in crossbreeding to result in goats with a uniform, solid, red colour. They are fully pigmented and are able to endure heat and strong sunshine. Their dark coats and long ears provide good heat resistance (Snyman, 2004). The breed has the excellent walking ability and good mothering ability and they will kid three times in two years. Kalahari Reds are less susceptible to diseases and require fewer vaccinations compared to other goat breeds (Snyman, 2014). The semi-arid climate has contributed to Kalahari's overall hardiness. Although guided by selective breeding, natural selection played a major role in the development of this breed. These are particularly sun, parasite, and disease resistant livestock (Snyman, 2014).

Their skin is fully pigmented, allowing them to forage and increase gains through the heat of the day. Their parasite and disease resistance allows for less vaccination inoculation than the average goat breed. Does are known to be great in maternal instincts, usually with no assistance needed for parturition (Campbell, 2003). The most distinct visual characteristic of Kalahari Red goats is their red coat color. White or light shades of red are not desirable, as they do not provide as much camouflage from predators in their native pastures (Snyman, 2014). They can enhance the tenderness of the meat, the hardiness of the animal and the camouflage and hence the survival of their kids (Snyman, 2014).

2.6. Factors affecting growth traits in goats

2.6.1. Non-genetic factors

Non-genetic factors like sex of calf, season, year and parity may affect production traits of goats. Knowledge of these factors and their influence on animal performance are important in the formulation of management and selection decisions (Goyache *et al*., 2003). These factors can be included in analytical models as main effects or in two- and/or three-way interactions with other effects to account for environmental sources of variation in animals' performance (Wasike, 2006). These factors affect the growth and reproductive performance of the individual (Almaz Bekele, 2012) which in turn affects farm productivity. Sex, year of birth, season of birth, kidding interval, Litter size and dam age have been reported to have a large in influence on the growth rate of goats (Guha *et al*., 1968). Siddiqui *et al.* (1982) found that sex and type of birth had a significant effect on monthly weights up to 10 months of age in Osmanabadi goat kids. They also reported that season significantly affects body weights at 1,2,3,6 and 9 months of age.

2.6.1.1. Sex

It is generally recognized that the gender of an animal in most species of domestic animals has a definite influence on the different growth stages (Smith, 2010). Melka (2001) found that gender accounted for 4.3% and 3.8% of the variation in birth weight (BW) and weaning weight (WW) respectively. It is well documented that males of most species of domestic animals grow more rapidly and reach a higher mature weight than females (Koger & Knox, 1945; Gregory *et al*., 1950; Koch & Clark, 1955; Ahunu *et al*., 1997). In a more recent study, Villalba *et al*. (2000) found male calves to be 6.4% heavier at birth than females. This phenomenon is mainly due to the physiological effect of male endocrinology (Sushma *et al.,* 2006). It has been found that testosterone exerts a direct anabolic effect on protein synthesis in many non-reproductive organs and body tissues. This accounts mainly for the increased muscle mass associated with male calves and thus heavier body weights (Raff *et al.*, 2004).

2.6.1.2. Year of birth

Year of birth has been found to significantly influence growth traits (Sushma *et al.,* 2006). It is particularly evident in extensive grazing conditions. The contribution of year of birth can be extremely variable due to differences in climatic conditions, feeding, and management as well as the genetic composition of the herd (Smith, 2010). It was found by Holloway *et al.* (1985) that dams that were allowed to have access to high-quality nutrients showed a 23% increase in fatness and a 0.90 kg/day increase in milk production. Year of birth has also been reported to significantly influence other important traits like average daily gain (ADG), feed efficiency, shrinkage, slaughter grade, dressing percentage, carcass grade, the colour of eye muscle, the area of eye muscle and fat thickness (Webb and Casey, 2010).

2.6.1.3. Season of birth

The plane of maternal nutrition, in general, reflects the effect of month of birth on birth weight (Plasse *et al.,* 1995; Sushma *et al.,* 2006; Raphaka, 2008). This is due to the fact that kids born from dams that were in a better body condition score during their late pregnancy phase, on good grazing, gave birth to heavier calves (Smith, 2010). The dams on restricted planes of nutrition prior to calving produced lighter kids due to decreased fatal growth rate (Villalba *et al*., 2000).

2.6.1.4. Breeder

Sushma *et al.,* (2006) found that young animals bred by different breeders differed significantly from each other due to environmental conditions as well as human choice variation. The decisions made by the breeder mostly relating to management practices, selection objectives as well as the choice of breeding animal's accounts for the majority of the variation associated with growth traits (Krupa *et al*., 2005).

2.6.1.5. Dam age

It was reported by many works of literature that growth traits increased along with increasing age of dam until the age of 5-7 years. Lower birth weight (BW), weaning weight (WW), and yearling weight (YW) were obtained for dams younger than two years old as well as dams older than 8 years (Krupa *et al*., 2005). Burfening (1981) found that younger dams had a higher percentage of kidding difficulties than older dams.

2.6.1.6. Kidding interval

Kidding interval refers to the number of days between successive kidding (Steele, 1996). Kidding interval contributes largely to the productive efficiency and it has been reported to be affected by nutrition, suckling, parity (number of times kidded) and breed (Banerjee *et al.,* 2000). Under normal circumstances (no drought), tropical goats should be kidding at least three times in 2 years. For this to be realized, the kidding interval should not exceed 8 months (245 days). A kidding interval of 268 ± 100 days has also been reported for indigenous goats under traditional management (Lebbie and Manzini, 1989). According to these authors, intervals between first and second births (256 days) were apparently shorter than those at higher parities (275 days). It has been reported that the average kidding interval for indigenous goats of South Africa in Mootse was 258 days (Mamabolo and Webb, 2005). Delay in puberty ultimately delays the age at which first kidding occurs (Jainudeen and Hafeez, 1993; Madibela *et al.,* 2002). Chikura (1999) found that in the dry season goats had longer kidding intervals of 382±90 days as compared to 265±48 days in the wet season. However, there is limited literature available on evaluation of non-genetic factor (kidding interval) in goat population, this may be due to the recent studies focusing mainly on improvement of kidding interval as a trait, such studies by (Harikrishna *et al.,* 2013; Kumar *et al.,* 2010).

2.6.2. Environmental factors

2.6.2.1. Diseases and parasites

Diseases and parasites are major constraints to goat production and are pervasive in many regions of Southern Africa (Githiori *et al.,* 2006). Loforte (1999) ranked diseases and parasites as the major constraint to goat production in Mozambique. The impact of diseases and parasites may be through high morbidity, mortalities, abortions or subclinical effects manifested as weight loss or reduced gains and the financial implications involved in controlling or overcoming the effects of the disease (Mahusoon *et al.,* 2004). Goats are also susceptible to *Haemonchus contortus*, a gastrointestinal helminth causing anaemia and economic losses in goats in the tropics (Van Wyk et al., 2006). Disease may cause the animal to lose appetite and a reduction of feed consumption during pregnancy, leading to loss of weight to the unborn animal. Some of the diseases are hereditary; they will affect the dam and also the embryo.

2.6.2.2. Climatic conditions

Heat regulation in livestock is of great economic significance because mammals attempt to maintain a constant optimal body temperature (Lawrie and Ledward, 2006). Low temperatures tend to prolong animal development and high temperatures tend to retard it. Animal genes react differently to climatic conditions depending on their size, body shape and insulation through tissue and fur, some animals have a relatively narrow zone of temperature tolerance and also the adaptability. The stress that an animal is subjected to affects growth of the unborn animal, and that can negatively affect body gain. It will also cause the animal to eat less during pregnancy.

2.6.2.3. Nutritional Factors

Acker and Cunningham (1991) reported that the quality and quantity of usable meat depends on the animal's plane of nutrition, whether it is over or underfed. Nutrition is one of the most important factors affecting growth performance of goats. Underfed does take long to attain the critical body weight (two-thirds of mature weight) at which puberty occurs (Rhind, 1992) and this may also affect the foetus's weight. Does that are on a low plane of nutrition have suppressed early occurrence of first estrus, hence reducing their ability to conceive (Madibela *et al.,* 2002). Nutritional stress limits the reproductive performance of female goats (Dube, 2015). Reduced doe body weight has a negative impact on the birth weight of the unborn animal. Birth weight is affected by the nutrition the dam received during the pregnancy term (Atoui *et al.,* 2017). Maternal nutrition during this period plays an important role in the regulation of foetal and placental development. The possible reason for this observation is that there is competition for nutrients between the growing dam and the developing foetus in the maiden dam. In young dams that are not physically or biologically mature enough, the consumed nutrients are not only used for maintenance, lactation, and gestation, but also towards their own growth (Rumph & Van Vleck, 2004).

2.6.3. Management factors

High kid mortality is caused by factors such as failure of kids to consume colostrum, poor nutrition of the doe leading to low milk production, lack of hygiene allowing the build-up of infective agents and contaminated water (Peacock, 1996).

2.6.3.1. Housing

Dube (2015), explained that poor housing negatively impacts on goat productivity as goats will be exposed to extreme weather conditions. Lack of controlled breeding results in inbreeding and poor growth rates (Saico and Abul, 2007). In most communal areas there are no structured breeding systems and appropriate infrastructure such as paddocks and, therefore, does and bucks run together all year round (Tefera *et al.,* 2004). Conventional management practices such as planned breeding, replacement culling, pasture management and records keeping are not practiced.

2.6.3.2. Forage availability

Poor management of rangelands, inappropriate grazing management, rangeland fires, and droughts limit the availability of fodder in the communal areas (Gutierrez-A, 1985). The productivity of goats and other ruminants in the tropical areas is hindered by a shortage of good quality feed, especially in the long dry season characteristic of such areas (Raghuvansi *et al*., 2007; Ben Salem and Smith, 2008). Veld quality and availability are highly variable in the tropics with crude protein dropping below 8% in dry mature tropical grasses (Bakshi and Wadhwa, 2007; Kalundi *et al*., 2007).

2.6.3.3. Poor breeding practices

The Kalahari Red goat's natural breeding cycle is late summer and autumn. Young ewes have a shorter season of receptivity than the older ewes. According to Zelda (2008), for this reason, two breeding seasons are used and the season for mature ewes is from October to November when ewes are run with a mature ram. Young ewes selected for stud breeding are put with the rams when the ewes are at 40kg. Most ewes lamb every eight to nine months but poor management could lead to a decrease in birth weight. It also causes stress to pregnant animals, that will affect the birth weight of the unborn kid.

2.6.4. Animal and Genetic factors

According to Lawrie (1991), several economically important traits in meat animals are heritable to some degree and can thus be improved through selective breeding. In goats, certain growth features are controlled by recessive genes which have not so far been controlled, complicating breeding. One such trait is dwarfism; another is the double muscling condition, which causes muscle hypertrophy and thereby increases the animal's commercial value (Lawrie *et al.,* 2006). Genetic analysis continues to reveal the genetic mechanisms that control numerous aspects of the endocrine system and, through it, meat growth and quality as concluded by Lawrie and Ledward (2006). Genetic engineering techniques can shorten breeding programmes significantly because they allow for the identification and isolation of genes coding for desired traits, and for the reincorporation of these genes into the animal genome as reported by (Lawrie *et al*., 2006).

2.7. Improvement of goat production through Research

The accuracy of selecting superior parents for the next generation is the basis on which genetic improvement is dependent (Van Wyk *et al*., 1993). Inadequate description, classification, and evaluation of goats have resulted in a poor understanding of the potential of most tropical breeds (Kosgey *et al*., 2006; Simela and Merkel 2008; Tixier-Boichard *et al*., 2008). Breed differences can be established through molecular taxonomic characterization, which can, in turn, serve as a guide on decisions relating to conservation

(Lehloenya *et al*., 2005; Toro *et al*., 2008) and improvement of these breeds. Attributes of each breed will have to be identified and evaluated, to develop appropriate and sustainable breeding programmes. In South Africa, microsatellites have been used to evaluate the genetic diversity among goats and identify those strains under threat (Visser *et al*., 2004). More similar studies should be conducted, on a large scale. To achieve efficient animal improvement, it is important to provide comprehensive and consistent information – for fair comparisons of indigenous versus exotic germplasm as well as long-term genetic improvement (DAFF, 2003).

To effectively design sustainable genetic improvement programmes, correct matching of genotypes with the prevailing and projected socio-economic and cultural environments should be considered (Philipsson *et al*., 2006). Programmes that encourage farmers to keep records should be developed. Regarding within-breed selection, realistic performance and pedigree recording, with active farmer participation need to be adopted. There are situations in which the ideal producing animal could be the intermediate between a tropical adapted and an improved temperate breed. One way of achieving this is by crossing the two different breed types. Crossbreeding has been applied in Southern Africa to exploit goat breed complementarity and heterosis (Peacock, 1996). Imported breeds have been crossed with indigenous breeds to combine the high productivity of the former with adaptive attributes of the latter. Safari *et al*., (2005) concluded that exotic breeds with higher growth potential can be used to upgrade the performance of the indigenous goats. Most crossbreeding programmes, however, have lacked long-term strategies on how to maintain a suitable level of upgrading (Safari *et al*., 2005).

The required DNA tests has being conducted to determine whether there was sufficient genetic separation between the Boer goats, Savannahs, and Kalahari Reds (Snyman, 2014). Establishing the profile of the Kalahari Red breed through a survey, monitoring population status and descriptive qualities is the essential first step in better understanding, developing and utilizing this animal genetic resource (Kotze *et al.,* 2004). The genetic relationships between the different populations within the Kalahari Red breed were measured by determining the genetic distance between populations (Nei, 1978).

Correction of environmental factors such as age of dam, month of birth and year of birth is used to reduce variation in traits (Cundiff *et al.,* 1996).

2.8. Conclusion

Indigenous goats are vital in the livelihoods of the South African commercial and communal farmers. The literature review highlights the different investigations that have been carried out under mainly South African conditions with regards to indigenous goats mainly Kalahari Red goats, in the capacity of improving the productivity of the breed. The evaluation of factors that affect growth traits in different goat breeds has given background information to the current study. With the South African scenario, very little research has been conducted on the estimation of non-genetic factors, hence the current study was conducted in order to rectify the situation and to improve genetic evaluation models for indigenous goat breeds, since they contribute to household food security and also assist in seasonal food variability and availability.

CHAPTER 3

3. METHODOLOGY AND ANALYTICAL PROCEDURES

3.1. Study site

The study was carried out in three regions of South Africa (Eastern, Northern and Southern region) using 11 commercial farms of registered stud goats.

3.1.1. Northern Region (Gauteng, Mpumalanga, North West and Limpopo)

The Northern Region is the link between South Africa and countries further afield in sub-Saharan Africa. It consists of the South African provinces: Limpopo, Mpumalanga, Gauteng, and North West. Limpopo contains much of the Waterberg Biosphere, a massif of approximately 15,000 km^2 which is the first region in the northern part of South Africa. The massif was shaped by hundreds of millions of years of riverine erosion yielding diverse bluff and butte landforms (Michael *et al., 2006*). The Waterberg ecosystem can be characterized as a dry deciduous forest or Bushveld. Temperatures range from 17° to 31 °C (62° to 88 °F) in summer and from 3° to 21 °C (37° to 70 °F) in winter. Annual rainfall totals about 360 mm (about 14 in), with almost all of it falling during the summer months, between October and April (accessed from Wikipedia on the 19th September 2018).

3.1.2. Eastern Region (Kwa Zulu Natal and Eastern part of Eastern Cape)

The Eastern Region has three different geographic areas. The province contains rich areas of biodiversity of a range of flora and fauna. Some part of the region is wetlands, which is of international importance for migratory species, and are designated as Ramsar sites. The north westerly line of equal latitude and longitude traverses the province from the coast at Hibberdene (30°34′35″S 30°34′35″E) to northeast Lesotho. KwaZulu-Natal has a varied yet verdant climate thanks to diverse, complex topography. Generally, the coast is subtropical with inland regions becoming progressively colder. On the south coast it has an annual rainfall of 1009 mm, with daytime maxima peaking from January to March at 28 °C (82 °F) with a minimum of 21 °C (70 °F), dropping to daytime highs from June to August of 23 °C (73 °F) with a minimum of 11 °C (52 °F) (accessed from Wikipedia on the 19th September 2018).

3.1.3. Southern Region (Eastern Cape and eastern parts of Western Cape)

The Southern Region gets progressively wetter from west to east. The west is mostly semiarid Karoo, except in the far south, which is temperate rainforest in the Tsitsikamma region. The west is dry with sparse rain during winter or summer, with frosty winters and hot summers. Further east, rainfall becomes more plentiful and humidity increases, becoming more subtropical along the coast with summer rainfall. The interior can become very cold in winter, with heavy snowfalls occasionally occurring in the mountainous regions between Molteno and Rhodes. The temperature in Port Elizabeth: Jan Max: 25 °C, Min: 18 °C; Jul Max: 20 °C, Min: 9 °C and Molteno & Barkly East: Jan Max 28 °C, Min 11 °C; Jul Max: 14 °C, Min: -7 °C (accessed from Wikipedia on the 19th September 2018).

3.2. Study animals

Data on Kalahari Red goat breed kids and their parents were used in this study. Their birth weight was measured and recorded.

Figure 3.1: A mature buck of Stud Kalahari Red goats (Snyman, 2014)

3.3. Animal management

The Kalahari Red goats were conventionally raised following standard husbandry practices. Animals were kept extensively or intensively. Some were kept in zero-grazing conditions with all their forage brought to them.

3.3.1. Feed management

Majority of the diet was composed of forage (grass, forbs, browsers and hay). Supplement was required to meet nutritional requirements not met by forage (late gestation, lactation, growth and poor quality forage).

3.3.2. Breeding Management

First breeding of does started at 6 months of age and the buck ran with the does all year around.

3.3.3. Housing management

Goat housing was generally characterized by open or roofed kraals made of locally available resources and offered good drainage during the rainy season.

3.3.4. Health Management

Parasitic infection in goat houses is further exacerbated by unhygienic conditions. Most parasites may be harboured in the animal dung; hence failure to remove the dung as well as maintain good hygiene may lead to the transfer of parasitic pathogens (Dube, 2015). Routine for health management was followed by vaccinations, parasite control, hoof care and biosecurity in order to reduce diseases such as internal parasites, respiratory, digestive, foot rot and scald.

3.4. Data collection

The SA Studbook availed a total of 26204 performance records for the Kalahari Red breed. The records ranged from the year 1977 to 2018 and kids were born all year round in different parts of South Africa (Northern, Eastern and Southern). The information contained in the data set included pedigree information, birth date, season of birth, birth weight, breeder, sex, age of sire/dam at kidding and the region. Only 1902 goats had BW records.

The growth performance trait analysed was birth weight, and was measured using a weighing scale. Some of the data used was calculated as follow:

i. Birth weight was recorded at birth.

ii. Age of Dam and Sire at kidding was calculated as Kid birth date – birth date of Sire/dam.

iii. Kidding interval was calculated as Age of the dam (last kidding) – Age of the dam (previous kidding)

Figure 3.2: A Kalahari Red Stud goat just after giving birth to twins (Snyman, 2014)

3.5. Data editing and analysis

Edits consisted of checks for sex, litter size, season of birth, year of birth, sire ID, breeder, region, kidding interval, sire age, and dam age. All animals without birth weight were excluded from the analyses. Data for a period of 10 years (2008 to 2017) was used because years prior to 2007 had a very low number of records, missing information on litter size, sire and the dam. Only sires with more than 15 progeny were retained. Breeders with less than 15 records were discarded. Only Eastern, Northern and Southern regions were used. Kidding interval ranged from 170 to 390 days, and anything outside this range was discarded as they indicate errors in data capturing. Only 1902 kids were used after data editing. The structure of the edited data that was subsequently used in the analyses of non-genetic factors affecting BW of Kalahari Red goats are shown in Table 3.1.

Table 3.1: Structure of edited data that were used in the analyses of non-genetic factors affecting BW of Kalahari Red goats.

	Records of kids used.
Number of animals	1902
Number of Males	978
Number of Females	929
Kidding interval range (days)	170 to 390

Litter size	single (142), twins (330), triples (66) and quadruplets (4)
Breeders	134091563, 480156152, 484770884, 503407721, 509512900, 541020517, 542190721, 610190480, 614783869, 698383515, 782691341
Period (year)	2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017

The significance of fixed effects (sex, litter size, season of birth, year of birth, breeder and region) and random effects (dam age, sire age and kidding interval) was tested by conducting least-squares analyses of variance (ANOVA) using the General Linear Lodel (GLM) procedure of the Minitab 18.1 (2017) Statistical software. The model, in matrix notationis as follows:

$$y = Xb + Zu + e$$

where:

y = vector of observation (BW)

b = vector of fixed effects (sex, region, year of birth, season of birth, breeder, litter size)

u = vector of covariates (animal effects : dam age, sire age, kidding interval)

e = vector of random residual effects

X and Z are incidence matrices relating records to the fixed and animal effects, respectively.

N.B: Information on factors (sex, litter size, season of birth, year of birth and region) used to test for non-genetic factors affecting birth weight of Kalahari Red goats is shown in Appendix 6.5.

Different rearing strategies were followed in the different stud farms from birth. The Kalahari Red in South Africa is bred in different ecological regions of the country, under very different management levels. Tukey's Honestly Significant Difference (HSD) procedure was used for mean separation at the 5% level of significance.

CHAPTER 4

4. RESULTS AND DISCUSSION

The study determined non-genetic factors that influence birth weight of Stud Kalahari Red goat kids on different flocks from three regions (Eastern, Northern, and Southern) in South Africa. All the results are presented in Tables 4.1 to 4.7 below. A summary of the Analysis of Variance (ANOVA) of BW is shown in Appendix 6.2.

4.1. Environmental factors affecting birth weight (BW)

4.1.1. Season of birth

Season had a significant effect ($p<0.05$) on birth weight of Kalahari red goats as shown in Appendix 6.2. A comparison of the mean birth weights for the different seasons is summarized in Table 4.1. Autumn and winter had higher average birth weight (3.12 ± 0.216 kg and 3.06 ± 0.215 kg respectively) than summer and spring (2.78 ± 0.218 kg and 2.97 ± 0.218 kg respectively). According to Hagan *et al*. (2014) the dams of these kids might have conceived during the latter part of the major wet season allowing for the latter stage of pregnancy to fall within the minor wet season (September-November) were there is a considerable amount of high quality forage prior to kidding in the dry season. Kids born in autumn, winter and spring had no significant differences in birth weight. Djemali *et al.* (1994) postulated that kids born in the summer months may be heavier at birth because dams may have access to better nutrition in the form of grazing during the spring season, just prior to the onset of summer. Kids born from dams that had a higher body condition score during their late pregnancy phase, due to good grazing, had heavier birth weight (Smith, 2010).

Table 4.1: Least squares means and standard errors (LSM ± SE) in kg of BW by season of birth of Kalahari Red goats.

Season of birth	N	Mean ± SE
Autumn	78	$3.12±0.21^{a}$
Winter	290	$3.02±0.21^{ab}$

Spring	125	2.97±0.21[ab]
Summer	49	2.77±0.22[b]

N- Number of records, SE- Standard Error. Means with the same superscripts not significantly different at P>0.05

The results correspond with the findings from Mishra (1983), Mishra and Rawat (1984), Signh *et al*. (1992), Mioč *et al*. (2011), who also observed that season of birth significantly affects birth weight. Mishra and Rawat (1984) found that season significantly affected all growth traits except weaning weight. The reason for this significant difference in birth weight is that, does with low tissue reserves and in a poor condition after the nutritionally stressful season will produce lighter kids (Carvalheira *et al.,* 1995). The effect of the kidding season can be related to the different feeding conditions generated in each season by irregular climatic conditions, especially in the arid areas (Najari, 2005). Pastoral resources change from one month to another, which affects the goats feeding during their pregnancy (Sajlu *et al.,* 1999; Najari *et al.,* 2007). Kataktalware *et al*. (2004) reported that birth weight in Alpine X Beetal (AB), Saanen X Beetal (SB), Alpine X Saanen-Beetal (ASB) and Saanen X Alpine-Beetal (SAB) breeds was affected by season of birth. In a study conducted in Eastern Ethiopia, Zeleke (2007) concluded that kidding season had no significant influence on kids' birth weight in Somali goats. These findings are in agreement with Kumar *et al.* (1993) who reported non-significant effects of season on birth weight and body weight in Sirohi goats. The possible reason for lack of significant influence of season on birth weight of kids may be availability of hay and concentrate supplement to the dams during the dearth of browse in the dry seasons.

4.1.2. Year of kidding

A comparison of the LS means for BW by year of birth is shown in Table 4.2. Year of birth had a significant effect ($p<0.05$) on birth weight of Kalahari red goats. Kalahari Red goat kids born during different years showed a wide variation in birth weight. The largest mean birth weight (3.39 ± 0.236 kg) was recorded for the kids born during the year 2015 and the smallest (1.91 ± 0.217 kg) was observed during 2016.

Table 4.2: Least squares means and standard error (LSM ± SE) for BW (kg) of Kalahari Red goats born between 2008 and 2017.

Year of Birth	N	Mean ± SE
2008	35	3.03 ± 0.24^{abc}
2009	3	3.34 ± 0.38^{abc}
2010	32	2.77 ± 0.22^{bc}
2011	94	3.16 ± 0.21^{ab}
2012	123	3.36 ± 0.21^{a}
2013	19	3.16 ± 0.24^{ab}
2014	11	3.00 ± 0.27^{abc}
2015	23	3.39 ± 0.23^{a}
2016	112	1.91 ± 0.21^{d}
2017	90	2.56 ± 0.21^{c}

N- Number of records, SE- Standard Error. Means with the same superscripts not significantly different at P>0.05

The results are in agreement with the findings of Talekar (2015), who found highly significant (P<0.01) effects of the year of birth on birth weight of kids. Sharma and Das (1995) reported a significant effect of year of birth on birth weight, except for the weight at third month of age, in Jamunapari goats. Thiruvenkadan *et al.* (2009) found significant differences in birth weight associated with the year of kidding. The significant effect of kidding year might be due to fluctuations in the availability of feeds from year to year or to instability of management practices related to feeding regimes and changes in climatic factors (Atoui *et al*., 2017). Ouni (2006) reported that the higher variation in birth weight due to the year of birth can be explained by variation in the amount of annual rainfall, which in turn influenced pasture production and availability of feed for the dam especially in late pregnancy, which affects the milk production and the birth weight of kids. There was variation in the mean for birth weight of Kalahari Red goat's kids from year 2008 to 2017.

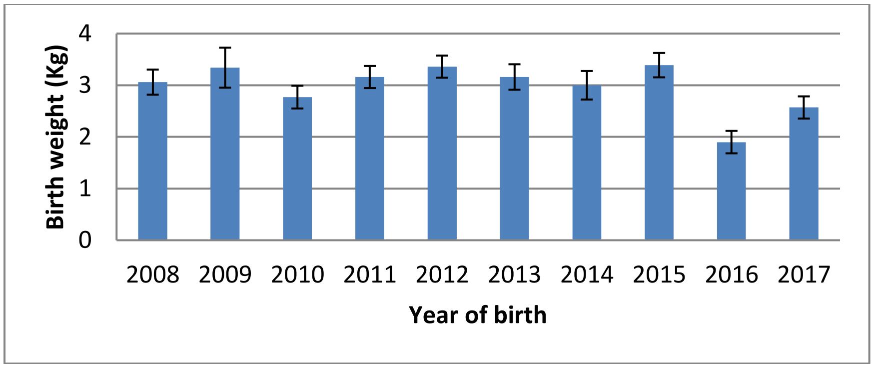

Figure 4.1: Means for birth weight per year for the Stud Kalahari Red goat.

Figure 4.1 shows means for BW per year. The year 2016 had a lower birth weight, which will negatively affect the future growth traits of the animal. Years 2010 and 2017 had moderate average BW. The contribution of the year of birth to variation in birth weight can be due to differences in climatic conditions, feeding, and management as well as the genetic composition of the herd (Smith, 2010). According to Assan (2013), the variation in birth weight of kids born in different year's shows differences in the level of environmental effects like temperature and humidity and availability of good quality feed in adequate quantity. The level of management can also fluctuate according to the ability of the farm manager, the system of crop husbandry, methods and intensity of culling and efficiency in the supervision of the farm labour as well as the availability of financial resources.

4.1.3. Region

Region had no significant effect ($p>0.05$) on birth weight, as shown in Appendix 6.2 and Table 4.3. The averages BW were 2.45 ± 0.571 kg, 3.33 ± 0.158 kg and 3.14 ± 0.089 kg for the Eastern, Northern and Southern region, respectively. According to Oltenacu (1999), low birth weight reflects the ability of a population to survive and it is considered as an adaptation to harsh environmental conditions in arid regions.

Table 4.3: Least squares means on effect of region on BW of Kalahari Red goats.

Region	Mean $\pm$ SE
Northern	3.33 ± 0.15^{a}
Southern	3.14 ± 0.08^{a}
Eastern	2.45 ± 0.57^{a}

SE- Standard Error. Values with different superscripts down the column are significantly different at P<0.05

Variation among regions may be due to the differences climatic conditions and management practices on the dam. Genotype by environment interaction has heavy implications on the evolution of species. Genetic variability plays the decisive role in allowing a population to persist and adapt in a changing environment (Lande and Shannon 1996).

4.1.4. Breeder

Equal variances among breeders were assumed for the analysis of the effects of breeders on BW. The pooled standard deviation was 0.67. Appendix 6.3 illustrates the analysis of variance for the effects of breeder on BW. Breeder effect was significant ($p<0.05$). Sushma *et al*. (2006) found that young animals bred by different breeders differed significantly from each other due to environmental conditions as well as human choice variation. The decisions made by the breeder, mostly relating to management practices, selection objectives as well as the choice of breeding animal's accounts for the majority of the variation associated with growth traits. (Krupa *et al*., 2005). Every flock is different from the other due to the fact that each breeder's selection objectives and management regimes are different.

Table 4.4: LS Means for BW of Kalahari Red goats by breeder.

Breeder	N	Mean
134091563	220	2.26^{e}
480156152	232	3.49^{ab}
484770884	464	2.66^{d}
503407721	29	3.45^{abc}
509512900	95	3.34^{abc}
541020517	90	3.21^{c}
542190721	102	3.64^{a}
610190480	412	3.49^{ab}
614783869	162	2.72^{d}
698383515	19	2.62^{de}
782691341	82	3.31^{bc}

N- Number of records, SE- Standard Error. Values with different superscripts down the column are significantly different at P<0.05

4.2. Reproductive factors affecting birth weight (BW)

4.2.1. Sex of kid

As shown in Appendix 6.2 and Table 4.5, the average birth weight of male kids was higher than for female kids (3.05 ± 0.21 kg : 2.89 ± 0.20 kg), and the difference was statistically significant ($p<0.05$). The difference may be partly due to the fact that the pregnancy period of does carrying male kids is usually 1–2 days longer than for those carrying females (Ugur *et al.,* 2004). This sexual dimorphism is common in primitive unselected breeds and domestic animal populations. It exists along the life of animals from birth until adult age (Atoui *et al*., 2017). Furthermore, testosterone is known to exert a direct anabolic effect on protein synthesis in many non-reproductive organs and body tissues, which mainly accounts for the increased muscle mass associated with male calves, and thus heavier body weights (Raff *et al.*, 2004).

Table 4.5: Least squares means and standard error (LSM ± SE) of BW for male and female Kalahari Red goats.

Sex	N	Mean ± SE
Male	263	3.05±0.21[a]
Female	279	2.89±0.20[b]

N- Number of records, SE- Standard Error. Means with different superscripts within a column are significantly different at P<0.05

Some studies have, however, found no significant difference in BW between male and female kids. Nagpal and Chawla (1985) reported that sex had a significant effect on body weight in all groups except the triple cross of Saanen x Alpine x Beetal. In a study involving three breed groups – group A (Bulgarian White Dairy goat), group B (Bulgarian White Dairy goat x Toggenburg) and group C (Bulgarian White Dairy x Anglo-Nubian), Hristova *et al.* (2013) observed that average body mass at birth was heavier for male kids than for females, but the difference was not statistically significant ($p > 0.05$). These results agree with those from several other studies (Husain *et al.,* 1996; Alexandre *et al.,* 1999; Portolano *et al.,* 2002; Liu *et al.,* 2005). Mioč *et al.* (2011) also found that the average birth weight of male kids was higher than that of female kids, although the differences were not significant ($p>0.05$).

4.2.2. Litter size

The influence of Litter size on birth weight is shown in Appendix 6.2 and Table 4.6. The research found a significant effect of Litter size on BW ($p<0.05$). Average birth weights for single, twins, triplets and quadruplet kids were 3.10 ± 0.198 kg, 2.92 ± 0.200 kg, 2.99 ± 0.205 kg and 2.87 ± 0.36 kg kg respectively. The kids that were born as single were significantly heavier ($p<0.05$) than those that were born as multiples. There was, however, no significant difference among the multiple births (twins, triplets and quadruplets).

Table 4.6: Least squares means and standard errors (LSM ± SE) for birth weight of different Litter sizees of Kalahari Red goats.

Litter size	N	Mean ± SE

Single	142	3.10±0.19[a]
Twins	330	2.92±0.20[b]
Triplets	66	2.99±0.20[ab]
Quadruplets	4	2.87±0.35[ab]

N- Number of records, SE- Standard Error. Means with the same superscripts not significantly different at P>0.05.

According to Zhang *et al.* (2006), heavier birth weight for single kids might be attributed to the uterine environment which the foetus does not have to share with littermates, thereby attaining higher body weight than twin or triplet born kids. De Groot *et al.* (1992) reported that birth weight of twin kids remains significantly lower than that of single kids during the first six months after birth. Kumar *et al.* (1993) studied the growth rate of Jamunapari kids and found that singles were heavier than twins and triplicates at birth. Kuralkar *et al.* (2002) reported that Litter size had a significant effect on birth weight, with kids born as single being significantly heavier than those born as twins and triplets. Bharathidhasan *et al.* (2009) observed that single born kids were heavier than twin born kids. Thiruvenkadan *et al.* (2009) studied data on Tellicherry goats, and found that the kids born as twins had lower birth weight than those born as single. Litter size had a significant ($p<0.01$) effect on birth weight of Black Bengal goat at birth and (Mia *et al.,* 2013). Hristova *et al*. (2013) found that singles were significantly ($p< 0.05$) heavier than twins and triplet kids on Bulgarian White Dairy goat, Bulgarian White Dairy goat x Toggenburg and Bulgarian White Dairy x Anglo-Nubian.

4.2.3. Kidding interval

There were no significant ($p>0.05$) effects (R^2 values displayed on Figure 4.2) of kidding interval on birth weights. Mean of birth weight on kidding interval at 308 days was high, within a range of 170 to 390 days. Birth weight increased for the progeny from 260 to 340 days and peaked at a day 360 before beginning to decline. The possible reason for this observation is that there high kidding interval has been associated with controlled mating (Wilson *et al.,* 1989) and kidding interval is more under the influence of management restrictions than any other environmental factor. In this studies is was observed that kidding interval had no effect on birth. There is lack of research done on the goat population to evaluate non-genetic factor (kidding interval).

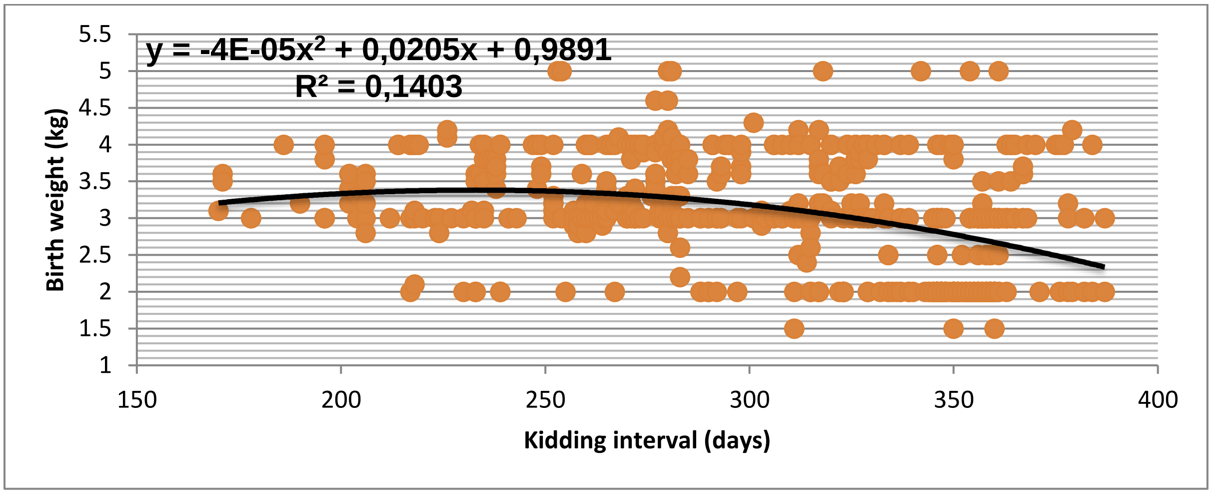

Figure 4.2: The regression of birth weight on kidding interval for the Kalahari Red goat.

4.3. Effect of parental age on birth weight (BW)

4.3.1. Age of dam

There were significant (*p<0.05*) effects (R^2 values displayed on Figure 4.3) of dam age on birth weights. BW showed a steady increase with dam age up to 5 years, then declined with advancing dam age, from the age of 6 years. The maximum birth weight (5.2 kg) was found in the 5-6years group and minimum (1.8 kg) birth weight found in the 7-8 years group. The R^2 of 81% shows a better variation of average BW (3 kg) over different dam age. The equation was solved quadratically to give the optimum dam age of 4.5 years in order to increase production. The possible reason for this observation according to Zishiri (2009) is that there is a competition for nutrients between the growing ewe and the developing foetus. The capability of does to provide sustenance for the developing foetus increases once they have reached reproductive maturity.

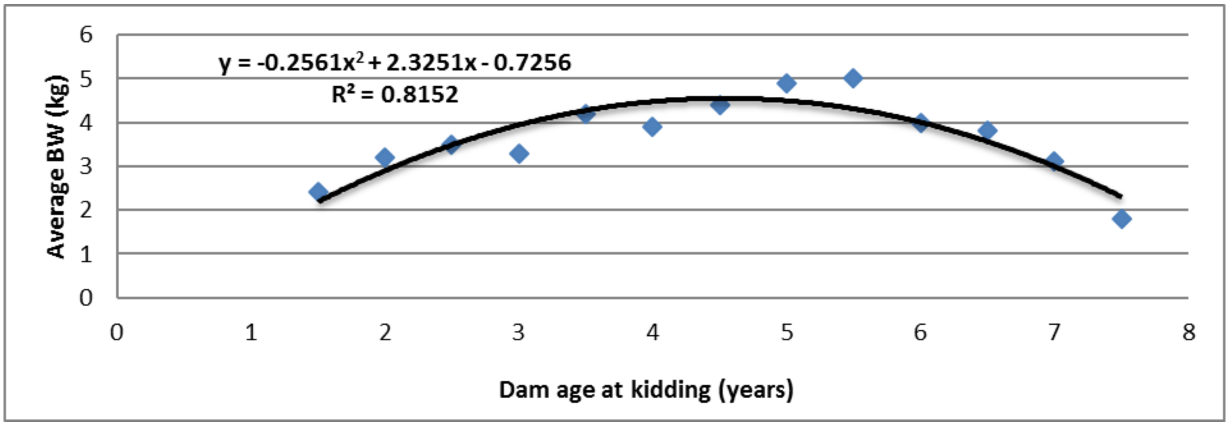

Figure 4.3: The regression of birth weight on dam age for the Kalahari Red goat.

A similar result was obtained by Wenzhbong *et al.* (2005). Djemali *et al.* (1994) observed that kids born from young dams had lower body weights than those from adult dams and that growth traits increased with the age of the dam up to 5 years of age. Despite differences in mature size, several authors observed that the weights of offspring of young goats were lower than for those born from older goats (Sánchez *et al.,* 1994; Alexandre *et al.,* 1999; Mourad and Anous, 1998; Portolano *et al.,* 2002; Liu *et al.,* 2005). The capacity of the dam to provide nourishment for the developing foetus increases once they have reached reproductive maturity (Zishiri, 2009). As does become older, their ability to provide an adequate uterine environment for the unborn kids may diminish (Zishiri, 2009).

Younger, as well as older dams gave birth to lighter kids when compared to mature dams (2 to 5 years). This trend is a reflection of the greater ability of mature dams to provide the foetus with the necessary nutrients and environmental conditions for its development (Elzo *et al*., 1987). Likewise, as dams become older, their ability to provide an adequate uterine environment for the unborn lamb may diminish. A similar trend has been observed in other livestock species such as cattle (Swiger, 1961; Elzo *et al.,* 1987).

4.3.2. Sire age

Sire age had a significant effect on birth weight ($p<0.05$). The young (1.5 years) and old (8.5 years) sires affects BW. The R^2 of 73% gives a better variation on average BW on different sire age, with the optimum age of 6 years to increase production.

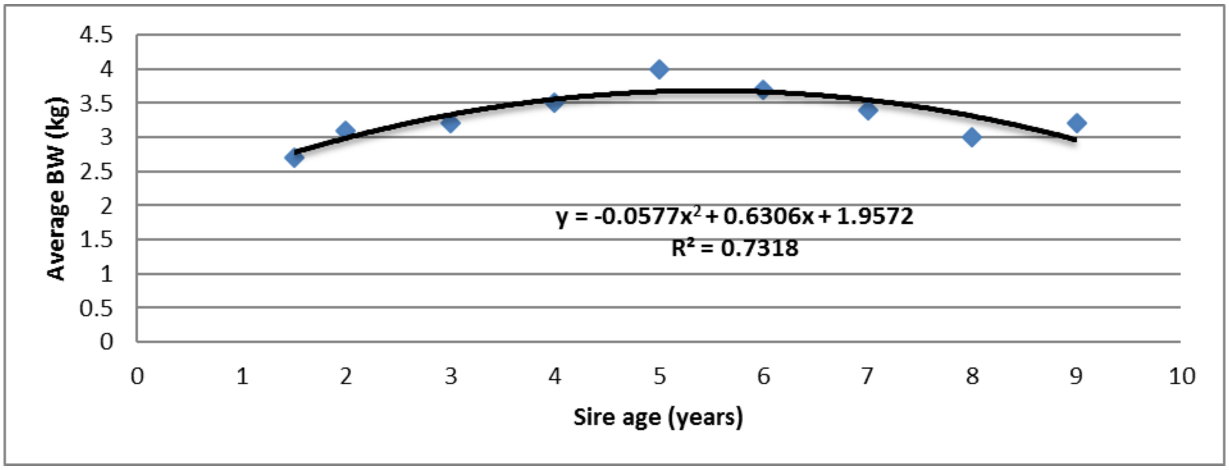

Figure 4.4: The effect of sire age on birth weight on for the Kalahari Red goat.

These may be attributed to lack of experience and low libido in young bucks, and senility in old bucks. Karna *et al.* (2001) also reported that sire age exerted a significant effect on birth weight in Cheghu kids. This may be due to higher body weight and larger scrotal circumferences resulting in increased semen, and sperm concentration in mature bucks. The results in Appendix 6.2 are in agreement with the findings of Salhab *et al.* (2003). The effect of sire age was found to be highly significant ($P<0.01$) on morphometric traits at birth (Dudhe *et al.,* 2015). This was in agreement with the observations of Kumar *et al*. (1992) in Jamunapari goats and Karna *et al.* (2001 and 2005) in Cheghu goats. Tomar *et al.* (2001) reported no significant effect of sire age on the three morphometric traits.

CHAPTER 5

5. CONCLUSION AND RECOMMANDATIONS

5.1. CONCLUSION

This study identified non-genetic factors including litter size, year of birth, sex of kid, breeder, sire age at kidding, dam age at kidding and season of birth influencing birth weight, which should be accounted for in genetic evaluation models for Kalahari Red goats. The fixed effects identified were sex, season of birth, year of birth, litter size and region, while random effects were sire age at kidding and dam age at kidding. These effects need to be controlled or adjusted for when comparing animals' birth weights. Since birth weight impacts on an animal's productive performance, it needs to be monitored and improved through the use of sound recording and genetic evaluation systems. These results, therefore, provide an important perspective on the selection objectives of Kalahari Red goats by considering different environmental factors, reproductive factors, and parental age factors. Adjustment procedures and adjustment factors often diverge for different populations within species. Many breeds have their own set of adjustment factors.

5.2. RECOMMENDATIONS

Based on the results of this study, the following recommendations can be made:

- Sire age at kidding, season of birth, Litter size, dam age at kidding and sex should be included in models for the genetic evaluation of BW in the Kalahari Red goat breed.
- Besides BW, recording and analysis of growth traits like weaning and mature weight should be undertaken, and an accurate estimation of genetic parameters of all these traits carried out, in order to achieve accurate selection in the Kalahari Red goat population.
- Recording of data should be promoted in all the regions producing Kalahari Red goats. In this study only data from three regions were used, because records from other regions were too few to be included in the analysis.

5.3. SCOPES FOR FUTURE STUDY

- In the current study, non-genetic effects affecting birth weight were investigated. Further studies are required to confirm the current findings by generating sizable datasets. Non-genetic factors affecting other growth traits (WW, ADG and MW) should also be investigated, and genetic parameters for growth traits of the Kalahari Red goat breed estimated, in order to genetically improve production.

- The current study focused only on non-genetic factors affecting BW in the Kalahari red indigenous goat breed. Further work is required to focus on estimating genetic parameters for BW and other growth traits. This will enable the estimation of accurate breeding values, which will help farmers to improve the breed through selection.

CHAPTER 6

6.1. REFERENCES

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6.1. APPENDICES

6.1.1. Descriptive statistics of data used

Appendix 6.1: Descriptive statistics of data after editing that were used in the analyses of non-genetic factors affecting BW of Kalahari Red goats.

	Records kids
Number of animals before editing	26204
Number of animals after editing	1902
Number of Males after editing	978
Number of Females after editing	929
Kidding interval range	170 to 390
Litter size	1-4 (single, twins, triples and quadruplets)
Period	2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017

6.1.2. ANOVA tables

Appendix 6.2: Analysis of variance (ANOVA) for non-genetic factors affecting birth weight of Kalahari Red goat.

Source	DF	SS	MS	F-Value	P-Value
Kidding interval	1	0.04	0.04	0,12	0,73
Sire age at kidding (days)	1	1.62	1.64	5,50	0,02
Sex	1	2.16	2.16	7,25	0,01
Litter size	3	3.23	1,08	3,61	0,01
Season of birth	3	2.59	0.86	2,89	0,04
Year of birth	9	90.51	10.06	33.72	0.00
Region	2	1.03	0.52	1.73	0.18
Sex*Season of birth	3	2.35	0.78	2.62	0.05
Error	517	154.20	0.29		
Lack of fit	422	143.82	0.34	3.12	0.00
Pure error	95	10.38	0.11		
Total	541	312.53			

DF- degree of freedom, SS- sum of squares, MS- mean of squares

Appendix 6.3: Analysis of Variance (ANOVA) for effects of breeder on birth weight.

Source	DF	SS	MS	F-Value	P-Value
Breeder	10	411.4	41.1	92.73	0.00
Error	1896	841.2	0.44		
Total	1906	1252.6			

DF- degree of freedom, SS- sum of squares, MS- mean of squares

Appendix 6.4: Means +/-SD for the data used in estimating the effect of breeder on birth weight of Kalahari Red goat at 95% level of significant.

Breeder	N	Mean	SD	95% CI
134091563	220	2,26	0,43	(2,17 ± 2,34)
480156152	232	3,48	0,66	(3,40 ± 3,57)
484770884	464	2,65	0,80	(2,59 ± 2,72)

503407721	29	3,44	0,68	(3,20 ± 3,69)
509512900	95	3,34	0,93	(3,20 ± 3,47)
541020517	90	3,20	0,61	(3,07 ± 3,34)
542190721	102	3,63	0,76	(3,50 ± 3,76)
610190480	412	3,49	0,47	(3,43 ± 3,55)
614783869	162	2,71	0,70	(2,61 ± 2,81)
698383515	19	2,62	0,08	(2,32 ± 2,92)
782691341	82	3,31	0,65	(3,16 ± 3,45)

SD- Standard deviation, CI- correlation interval.

6.1.3. Factor information

Appendix 6.5: Factors Information used to estimate non-genetic factors affecting birth weight of Kalahari Red

Factor	Type	Levels	Values
Sex	Fixed	2	Female and Male
Litter size	Fixed	4	Single, Twins, Triplets and Quadruplets
Season of Birth	Fixed	4	Autumn, Spring, Summer and Winter
Year of Birth	Fixed	10	2008. 2009. 2010. 2011. 2012. 2013. 2014. 2015. 2016. 2017
Region	Fixed	3	Eastern. Northern. Southern