CHARACTERISATION OF INDIGENOUS ZULU (NGUNI) SHEEP FOR UTILISATION, IMPROVEMENT AND CONSERVATION

By

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ABSTRACT

The Nguni sheep of Zululand, South Africa, are called the Zulu sheep. They are a source of food and cash for the rural farmers of KwaZulu-Natal. There is insufficient information available about the characteristics of this breed and accordingly the breed is classified as “insecure”. Documentation of characteristics of a breed is important for its utilisation, improvement or conservation. This study was undertaken to document (i) the utilization of the Zulu sheep, (ii) some morphological characteristics, (iii) establishing a cost effective body measurement recording means and (iv) the intra- and inter-population genetic variation of the breed using random amplified polymorphic DNA markers.

A survey was conducted to investigate the socio-economic and cultural values of the farmers attached to livestock including the Zulu sheep. A total of 76 rural farmers were interviewed in the areas of the Mhlathuze district in northern KwaZulu-Natal. Constraints and the indigenous knowledge of the farmers on livestock production were also recorded. The results confirmed that the Zulu sheep in the rural areas are indeed used as a source of protein and cash when necessary. Farmers reported that the Zulu sheep are tolerant to ticks and able to withstand the hot and humid conditions of northern KwaZulu-Natal. Goats and cattle as well as the Zulu sheep are also used for payment of dues in the tribal courts. Even so, Zulu sheep are not used for any cultural purposes. The system of management is fairly extensive. Some farmers apply indigenous knowledge as part of management practices. For instance, they use indigenous plants as nutrient supplements and for increasing the reproduction rate of these animals. Lack of modern animal husbandry skills was declared by the farmers as one of the main challenges. A perception among the farmers was that the Government could assist in addressing this challenge.

Three populations of Zulu sheep reared extensively in three localities were used for the morphometric and genetic studies. The areas were the community of KwaMthethwa (Enqutshini), University of Zululand (UNIZULU) and Makhathini Research Station. Makhathini and KwaMthethwa are 260 and 40 km, respectively, away from UNIZULU. The morphometric study was undertaken to determine the extent of phenotypic diversity between Zulu sheep populations using six morphological characteristics. Effects of some factors (location, age, sex and season) on some of these traits were estimated. Results showed that the size of the body measurements, wither height (WH), heart girth (HG), live weight (LW) and scrotal circumference (SC) were significantly different between the populations. Variation in these body measurements was influenced significantly by the location, season, the sex and the age of sheep. Mature ewes weighed up to 32 kg whereas the rams weighed up to 38 kg. The differences in LW, HG and WH between the seasons were small. The SC increased with the age of the ram up to 28 cm for mature rams. Other traits observed were the colour and the ear length of Zulu sheep. Ear size ranged from ear buds to the most common large ears (9 to 14 cm). The dominating colours observed were brown and a combination of brown and white. Live weight prediction equations were estimated employing HG, WH and SC data. The LW prediction equations showed that the regression of HG and WH produce the best estimate equations of LW; however the HG alone also showed reliable LW estimates. Scrotal circumference was more precise for estimating the LW of younger rams below 22 months of age (R^2 = 0.64 – 0.78).

Fifty-two Zulu sheep from the three locations were used to assess the genetic variation within the Zulu sheep breed. A total of 2744 RAPD bands were generated ranging from 0.2 to 2 kb; ~46% of these bands were polymorphic. The genetic diversity was the lowest (5.17%) within the UNIZULU population, 8.62% within the KwaMthethwa population and highest (11.04%) within the Makhathini population. The genetic diversity between all populations was estimated at 21.91 %. Phenotypic diversity was relatively similar for the UNIZULU and Makhathini populations (41.25% and 45.63%, respectively). The phenotypic diversity between the three populations was 48.26%. Genetic and phenotypic diversity was lower for Makhathini and UNIZULU populations than for the KwaMthethwa population.

It was concluded that the Zulu sheep is a smaller sized breed compared to the other South African indigenous sheep breeds like the Dorper which has been reported to have some similar characteristics to the Nguni sheep. The results confirmed that the Zulu breed has the capacity to survive without dipping and supplements during the dry season. This adaptation is of value to the communities of KwaZulu-Natal. Such characteristics warrant conserving the breed to prevent genetic erosion. The phenotypic and genetic diversity between the three populations of Zulu sheep may indicate that there is an opportunity of genetic exploitation by selecting animals based on phenotypic as well as genetic characteristics.

In order to promote the conservation and sustainable use of the Zulu sheep, it was recommended that an open nucleus breeding scheme from lower-tier flocks (of the farmers)

for pure breeding to nucleus flocks (in Government ranches) could be appropriate. The scheme would also address the challenges of animal husbandry as well as contribute to the improvement of the livelihood of the farmers. Farmers could use a tape measure to estimate the LW of sheep when they cannot afford scales. The morphological characteristics and the genetic diversity data generated from this study could be combined into a single data base for this sheep breed. More extensive studies, using the same or some additional phenotypic characters such as reproductive performance, need to be done. Genetic characteristics of Zulu sheep using microsatellites and mitochondrial DNA should be done to complement the present study.

PREFACE

The research work described in this study was carried out in the areas of northern KwaZulu-Natal and in the University of Zululand under the supervision of Professors Annabel E. Fossey, Ignatius V. Nsahlai, Carlos C. Bezuidenhout and Edward E. Nesamvuni.

These studies represent original work by the author and have not been submitted in any form for any degree or diploma to any university. Where use has been made of the work of others it is duly acknowledged in the text.

DECLARATION 1- PLAGIARISM

I, **Nokuthula W. Kunene** declare that:

1. The research reported in this thesis, except where otherwise indicated, is my original research.
2. This thesis has not been submitted for any degree or examination at any other university.
3. This thesis does not contain other persons' data, picture, graphs or other information, unless specifically acknowledged as being sourced from other persons.
4. This thesis does not contain other persons' writing, unless specifically acknowledged as being sourced from other researchers. Where other written sources have been quoted:
    a. Their words have been re-written but the general information attributed to them has been referenced
    b. Where their exact words have been used, their writing has been placed in italics and inside quotation marks, and referenced.

5. This thesis does not contain text, graphics or tables copied and pasted from the internet, unless specifically acknowledged, and the source being detailed in the thesis and in the References sections.

Signed…………………………………………..Date…………………………..

DECLARATION 2 –PUBLICATIONS

DETAILS OF CONTRIBUTION TO PUBLICATIONS that form part of research presented in this thesis:

1. Kunene, N., Fossey, A., 2006. A Survey on Livestock Production in Some Traditional Areas of Northern Kwazulu -Natal. Livestock Research for Rural Development (18) 06. http://www.utafoundation.org/lrrd1808/cont1.808 .htm
   Contributions: Kunene N., did research work, analysis and writing of the article; Prof A. Fossey involved in planning of research and revision of the article.

2. Kunene, N.W., Nesamvuni, E.A., Fossey, A. 2007. Characterisation of Zulu (Nguni) sheep using linear body measurements and some environmental factors affecting these measurements. S. Afr. J. Anim. Sci. 37 (1), 11-20.
   Contributions: Kunene N.W., involved in planning of research, carrying the research experiment, analysis and the writing of the article; Prof. A. Fossey and Prof. E.A. Nesamvuni involved in the planning of research and revision of the article.

3. Kunene, N.W., Nesamvuni, A.E., Nsahlai, I.V., 2009. Determination of prediction equation for estimating body weight of Zulu (Nguni) sheep. Small ruminant Res. 84, 41- 46
   Contributions: Kunene N.W., involved in data collection, analysis and writing of article; Prof. I.V. Nsahlai advised on analysis and revision of the article; Prof. E.A. Nesamvuni involved in the planning of the research and revision of the article.

4. Kunene, N.W., Bezuidenhout, C.C., Nsahlai, I.V., 2009. Genetic and phenotypic diversity in Zulu sheep populations: Implications for exploitation and conservation. Small Ruminant Res: 84, 100 -107.
   Contributions: Kunene N.W. did the research experiment, analysis and writing of article. Prof. C.C. Bezuidenhout involved in planning of the research, supervision of

research experiment, assistance in writing of article. Prof. I.V. Nsahlai involved in revision of the article.

Conference proceedings are presented in Appendix A

Signed………………………………………………………………………………..

Permission was granted by the auditors to use these publications in this thesis (Appendix B).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

AD	Anno Domini
AFLP	Amplified fragment length polymorphism
ANGR	Animal genetic resources
BC	Before Christ
DNA	Deoxyribonucleic acid
EDTA	Ethylenediaminetetraacetic acid
FAO	Food and Agriculture Organization
GLM	General linear Model
HG	Heart girth
ILRI	International Livestock research institute
ILRI	International Livestock Research Institute
LBM	Linear body measurements
LW	Live weight
MRS	Makhathini Research Station
mtDNA	Mitochondrial DNA
NDA	National Department of Agriculture
NRF	National research Foundation
OSCA	Owen Sithole College of Agriculture
PCR	Polymerase chain reaction
PNSO	Programme National de Sélection Ovine
RAPD	Random Amplification of Polymorphic DNA
RFLP	Restriction fragment length polymorphism
SC	Scrotal circumference
SNP	Single nucleotide polymorphism
UNIZULU	University of Zululand
UPGMA	Unweighted pair group method with arithmetic mean
VIF	Variance inflation factor
WH	Wither height

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CHAPTER 1

GENERAL INTRODUCTION AND LITERATURE REVIEW

1.1 General Introduction

Sheep are hollow-horned, even-toed ruminants. Domesticated sheep belong to the species *Ovis aries* (Hiendleder *et al*., 1998). This species is classified under the family Bovidae and subfamily Caprinae (Reybold and Herren, 1994). The origin of the modern sheep remains uncertain (Hiendleder *et al.*, 1998). Several Eurasian wild sheep of the highly polymorphic *Ovis* have been proposed as the ancestors of domestic sheep (Reed, 1960; Zeuner, 1963). Three major groups of Eurasian wild sheep, mouflon (*O. musimon or O. orientalis*), urial (*O. vignei*) and argali (*O. ammon*), have been proposed as ancestors of domestic sheep (Ryder, 1984). Using the archeological evidence the *O. orientalis* was suggested by Reed (1960) to be the ancestor of the domestic sheep. Zeuner (1963) suggested that the *O. vignei* was the first domesticated sheep in the Aralo-Caspian basin and that the domestic forms subsequently spread throughout the Middle East and into Europe. According to Zeuner (1963), the domestic sheep of south east Asia was derived from urial (*O. vignei*), but argali (*O. ammon*) alleles are supposed to have been introduced repeatedly into these lines. Another species of wild sheep that is believed to have been involved in the origin of domestic sheep is the bighorn sheep (*O. canadensis*) (Ryder, 1984). However, mitochondrial data by Hiendleder *et al.* (1998; 2002) revealed that there was no contribution of the urial and argali species to domestic sheep. The authors concluded that the mouflon (*O. musimon or O. orientalis)* contributed to the genetic pool of domestic sheep (*O. aries)* and their data suggested an additional wild ovine ancestor different from the proposed argali and the urial sheep.

According to the International Livestock Research Institute (ILRI) (2007), the ancestral wild stock of both the thin-tailed and fat-tailed sheep is identical. From an Asian origin, sheep spread westwards to beyond the Mediterranean, including Europe and Africa (Devendra and Mcleroy, 1982). The process of domestication resulted in some morphological and physiological modifications in sheep. For instance, wool replaced the hair coat in colder climates, the tail was lengthened and in some cases became a place of excess fat storage (Devendra and Mcleroy, 1982). Fat-tailed sheep were first realized in Egypt at the beginning of the second millennium. The assumption is that they entered Africa (Egypt) on various occasions through both Suez and Babel Mandeb. It is believed that from Egypt the population spread westwards into Lybia, Tunisia and eastern Algeria (ILRI, 2007). The group that entered through Babel Mandeb extended from Ethiopia into the Great Lake region of Uganda, Kenya and Tanzania but did not enter into Congo (Ryder, 1984). Archeologists have reported that a further southward migration from here may have arrived in South Africa (SA) as early as 400 BC (Bester, 2009). However, by 200 AD, the Khoi-Khoi pasturalists arrived at the northern borders with early sheep breeds. A second wave of migrators between the third and second centuries brought early Iron Age communities into the eastern parts of the country (Bester, 2009). One group of the Iron Age people came down the east coast to Natal and dispersed further south. This dispersal was limited by growing conditions of crops. These people brought sheep and cattle with them. These sheep are suspected to be the ancestors of the Nguni breeds (Ramsay *et al.*, 2000). The Nguni sheep of Zululand are called Zulu sheep and the Nguni sheep of Swaziland, Swazi sheep.

Philipsson (2000) suggested that in order to increase food production in developing countries, diversity within and between indigenous breeds should be efficiently exploited. The most productive and adapted animals for each environment must be selected for breeding purposes. Philipsson (2000) concluded that only then will it be possible to increase food production without further expansion of animal numbers and subsequent land degradation. According to the Food and Agriculture Organization of the United Nations (FAO) (2000) and Hall (2004), for many decades indigenous genetic resources have been perceived as unproductive and inherently inferior to high performance or improved breeds. As a consequence these were subjected to cross-breeding or even replacement with exotic breeds. The number of indigenous breeds has thus declined rapidly during the twentieth century. About one third of the more than 7000 livestock breeds (including poultry) registered in the FAO global database are regarded as threatened by extinction. Of the 1409 sheep breeds registered, 180 are extinct, 98 are endangered and 40 are critically endangered

(FAO, 2007). It has been reported by Kruger (2009) that Namaqua Afrikaners is already an endangered sheep breed in South Africa. The impact of these losses on the global or local diversity is not documented (Hanotte and Jianlin, 2005). There is therefore a need to document livestock genetic and phenotypic resources and to design and implement strategies for their sustainable conservation.

Livestock populations have evolved unique adaptation to agricultural production systems and agro-ecological environments. The genetic diversity represents a unique resource to respond to the present and future needs of livestock production both in developed and developing countries (Hanotte and Jianlin, 2005). Maintaining diversity in breeds and especially breeds of small population sizes requires understanding of both phenotypic and genetic relationships among animals within a breed.

According to Köhler-Rollefson (2000), traditional farmers in developing countries manage their livestock according to their indigenous knowledge. They take their local ecological constraints into account. The maintenance of the remaining livestock diversity in communal farming would require activities that can be carried out within the framework of technical cooperation. These would include support for research on indigenous knowledge and capacity building at grassroots level and at national level. Le Viet Ly (1994) suggested that the goal for conservation of biodiversity should focus on the diversity between and within indigenous populations of farm animals. The phenotypic and genetic characterisation of local breeds is a prerequisite for the establishment of a breed improvement programme. The aim of the improvement schemes is to increase production, product quality, cost efficiency, maintain genetic diversity and support the conservation and use of specific breeds. According to Philipsson *et al.* (2006), the general framework for the development of a breeding programme include: implication of agricultural policies, socio-economic and cultural values, characterizing populations, infrastructure, farmer involvement and genetic analysis. Some of these aspects will be discussed in this literature review.

There is a wide range of database information about the production characteristics of various South African sheep. Production characteristics of several sheep breeds such as Karakul, Merino, Black head Persian, Dormer, Dorper and Damara have been described by Bactawa (2003) and Schoeman (2007). There is, however, no mention of the Nguni breed in that database. Although certain characteristics of the Zulu breed have been mentioned by Ramsay *et al*. (2000) and Kruger (2001), the information is scanty and there is no evidence of studies done to quantify these characteristics. Genetic and phenotypic parameters of the Dorper have been documented by Inyangala *et al.* (1990). The molecular genetic work on Zulu sheep documented to date is that of Buduram (2004) where the author was concerned with the genetic relationships between 20 selected breeds of South Africa.

The objectives of the present study were:

(i) to obtain information on socio- economic and cultural values by the farmers using the breed;

(ii) to characterise and estimate variation within the Zulu sheep breed using six morphological characteristics;

(iii) to estimate the live weight prediction equations of the Zulu sheep breed using some linear body measurements and

(iv) to assess the genetic variation within this breed.

The aim was to characterise this indigenous sheep breed for utilization, improvement and conservation.

1.2 The structure of the thesis

Chapter One of this thesis presents the general introduction and a literature review which include the requirements for a successful improvement programme for communal farmers in the subtropics. This chapter highlights the importance of characterisation and the tools required for a successful communal improvement programme. Chapter Two is a report on a field survey undertaken to determine the livestock production system and the socio-economic and cultural values of communal farmers who keep the Nguni (Zulu) sheep. Constraints and the indigenous knowledge of the farmers which have an impact on the livestock farming are also reported. This work was published in the Livestock Research for Rural Development Journal. Chapter Three is a report on the characteristics (live weight, wither height, heart girth, scrotum circumference, colour and ear length) of Zulu sheep that were quantified during this research as a means of characterising the breed. The effects of some environmental factors on the above features are also reported. A paper on this chapter was published in the South African Journal for Animal Science. Chapter Four presents the regression formulas that were obtained for the weight of Zulu sheep using linear body measurements. The importance of this chapter is that farmers might estimate the weight of their sheep using a tape measure when they cannot afford scales as is the case in most rural community farming. Results were published in the journal, Small Ruminant Research. Chapter Five presents an article that was also published in the latter journal. It deals with the genetic diversity between three Zulu sheep populations using random amplified polymorphic DNA (RAPD). The aim was to evaluate RAPDs for estimating the genetic variability within and between these three Zulu sheep populations. Chapter Six presents the discussion, conclusion and recommendations which emanated from this research.

1.3 Domestic animal diversity

Köhler-Rollefson (2001) mentioned the origin of domestic animal diversity as coming from the introduction of domestic species into new habitats. The author indicated that by taking animals into new environments and ecological niches, humans subjected animals to selection for adaptability to new sets of ecological factors and created new ecotypes. In addition, subjection of animals to different socio-cultural breeding regimes and economic utilization patterns as well as artificial selection depending on cultural preferences and needs has also led to manipulation of the genes of these animals (Rege, 2001).

Domestic animal diversity is a neglected aspect of biodiversity (Köhler-Rollefson, 2001). Some of the factors that have led to breed homogenization in the developing countries arose from Governments and extension personnel promoting the adoption of high performance breeds for intensive production systems (Cardellino, 2003). Such breeds are rated from the perspective of their performance and their productivity with regard to a particular product (often meat and milk) in the prevailing animal production paradigm. There is, therefore, little appreciation of the adaptability traits of indigenous breeds (Köhler-Rollefson, 2001). Breeds selected in more developed countries will tend to replace those in less developed countries. Other factors such as changes in tastes and demands have been reported to have contributed to diversity loss. For instance, preference of leaner meat is resulting in the demise of pig breeds that have fatter meat (Tisdell, 2003).

Locally adapted or indigenous breeds are usually owned by rural farmers and although they may not yield as much in production as the exotic breeds they represent the lifeline of rural farmers. Such breeds produce a wider range of products, thrive on low forage and require lower levels of health care. Their management is ecologically more sustainable, especially in marginal environments (Kohler-Röllefson, 2000). Mwacharo and Drucker (2005) reported that because of their adaptation characteristics, the indigenous breeds have been shown to outperform crossbreeds under harsh climatic, nutritional and management conditions typically associated with resource-poor livestock farmers. According to the World Watch list for domestic animal diversity prepared by the FAO (2000), breeds that utilize low-value feeds or survive harsh environments or have tolerance to or resistance against specific diseases, could be beneficial in future. This is because they are often genetically adapted to their environment. Their unique characteristics could be a source of genes needed for improving the health and performance of the commercial breeds (FAO, 2000). Many indigenous communities have been forced to abandon their traditional patterns of livestock production because of lack of resources resulting from the encroachment of agriculture, wildlife reserves, or population pressure (Adebambo, 1994). Abandoning of traditional rituals, customs and livelihoods inevitability also results in the loss of distinct breeds. For example, a Muturu cattle breed of Nigeria that was once distributed across Africa's Sahelian zone has survived total replacement by Zebu cattle because these animals are sacred and their milk is used for medicinal purposes (Rege *et al.*, 1994). Furthermore, since local communities utilize local breeds for survival, the disappearance or reduction of locally adapted breeds forces individuals from rural communities to migrate to already overcrowded urban areas (Cardellino, 2003).

1.4 Distribution of sheep including the Zulu breed in areas of South Africa

According to the National Industry Strategy and Implementation Framework for South Africa prepared by the National Department of Agriculture (NDA) (2004), out of the 80% of agricultural land in South Africa suitable for extensive livestock farming, 50% is occupied by sheep and goat farming. Although sheep are found in all the provinces, the largest numbers are found in the Eastern Cape (29%), Northern Cape (28%) and Free State (20%) (NDA, 2003). KwaZulu-Natal is one of the provinces with low numbers (3%). In 2003, the total number of sheep in South Africa was estimated at 29 million whereas in 2002 they were estimated at 29.03 million (NDA, 2004). This figure was even lower (25.1 million) by 2006 (Free State, Department of Transport, 2007). The number of sheep in KwaZulu-Natal was estimated at 863 000 in 2003, 776 123 in 2004 and 775 000 in 2005 (KwaZulu-Natal, Department of Transport, 2006). Records indicate that these numbers had been declining from 970 000 at the end of August 1999 to 775000 by the end of November, 2005 (NDA, 2004; KwaZulu-Natal, Department of Transport, 2006). The rural areas contribute 12.1 % to the total number of sheep in the country (NDA, 2004; KwaZulu-Natal, Department of Transport, 2006). Zulu sheep are found in the communal areas of KwaZulu-Natal, such as Jozini, Matubatuba, Msinga, Nkandla. However, the numbers are not currently known. Research flocks were established at the Makhathini Research Station below the Pongolo river dam and at the University of Zululand (UNIZULU) (Ramsay *et al.*, 2000). These flocks were established in 1989 and 1995 at Makhathini and University of Zululand, respectively. Sheep were bought from the local farmers around Jozini and Matubatuba to establish the research flocks. The farmers were interviewed extensively on the history of their sheep before the animals were bought. These flocks have never been bred with other sheep breeds (Mr. Du Toit, former farm manager, UNIZULU, and one of the organizers for the establishment of the flock at Makhathini Research Station, personal communication, 2003). These flocks were used for this study.

1.5 General characteristics of the indigenous Zulu sheep

The Zulu sheep breed is one of the indigenous breeds of South Africa (Ramsay *et al.*, 2000; Buduram, 2004). It is characterised by either thin or fat tails, is multicoloured and has a coat of either wool or hair (Kruger, 2001). There is variation of ear length, from ear buds and short prick ears to long pendulous ears. The breed has the genes necessary for the animals' adaptation to different and sometimes challenging conditions. This may imply that the breed can survive and flourish where other sheep breeds perish (Kruger, 2001).

Ramsay *et al.* (2000) reported that Zulu sheep are tolerant to tick-born diseases, internal parasites and have good walking and foraging ability. Such characteristics make them suitable for providing sustainable benefits to livelihood for rural farmers in Southern Africa. However, research is necessary to quantify characteristics such as the live weights of the Zulu sheep within different age groups and how they are affected by some environmental factors. Chapter Three of this thesis presents findings on some of the characteristics of Zulu sheep using live weight and some body linear measurements. The utilization of the Nguni sheep by the farmers who keep them is presented in Chapter Two.

1.6 Small ruminant production systems

The climate and other aspects of the environment have been the main factors contributing to the various livestock production systems that are found today. There are two major types of sheep production systems. These are:

(i) modern types in the commercial sector and

(ii) traditional systems in the communal sector.

A modern system involves ranching and finishing whereas the traditional type includes smallholder and migratory systems (Devendra and Mcleroy, 1982). Indigenous Zulu sheep are mainly kept under a traditional type of production system. The most common type of communal indigenous small stock production is that of the smallholder, where there is low-input (subsistence). Animals graze communally in a free range system and are brought back to the homestead in the evenings. In such areas, during the dry season, the forage value of the vegetation decreases. Digestibility, protein content, mineral content and the energy content become low (Devendra and Mcleroy, 1982). The animals graze on crop residues in winter. Farmers base their indigenous knowledge on the type of supplements, whether in the form of shrubs or tree leaves, to give to their livestock. Another common form of a small scale system is that of intensive "cut and carry" feeding of tethered or confined animals, found in densely populated areas, where most of the available land is dedicated to cultivation (Smith, 2004)

According to the training manual from ILRI (1995), pastoralism and agro-pastoralism are the two main production systems found in small-scale farming in Africa. In pastoralism, the numbers of livestock vary in size, poor families can have few sheep and goats only and wealthier families can own several hundreds of cattle and other livestock (ILRI, 1995). Pastoralists depend on the sale of livestock and livestock products to buy necessities. The size of herd/flock determines the share of feed resources obtained in the pastures grazed communally under the open access of common property tenure system. This system may be characterised by nomadism and transhumance as survival strategies. Agro-pastoralism is practiced by pastoral families or their descendants who have also taken up cropping to varying degrees (ILRI, 1995; Negi, 1998). Normally, animals of all ages and sex are left to run together at all times and mating is random within the flock.

Chapter Two of this thesis presents the type of livestock production systems used by farmers who keep Zulu sheep, their indigenous knowledge and potential impacts of these on the livestock production management practices. In this chapter, the contribution of livestock to the economy of the farmers in some areas of northern KwaZulu-Natal is also presented. It has been recommended by several authors (Kosgey *et al.*, 2006; Philipsson, *et al.,* 2006; Tibbo *et al.*, 2006) that when designing a breeding programme in communal areas, incorporation of the type of production system is necessary for success.

1.7 Socio-economic and cultural values

Socio-economic and cultural values largely determine the driving forces in society and thus development trends, policies, strategies, plans and interventions in the livestock sector. An initial step in designing a sustainable community-based breeding programme in developing countries in the tropics is to understand the socio-economic factors that influence small ruminants (Kosgey, 2004). Among the reasons for the failure of breeding programmes designed by development agencies, is not understanding the needs and aspirations of the farmers (Verbeek *et al.*, 2007). When farmers are not sufficiently involved in the design and implementation of a breeding programme and its breeding objectives are not in line with those of the farmers, the breeding programme will often not be successful (Kosgey *et al.*, 2006).

Keeping of livestock by rural communities, in many cases, provides food, economic opportunities and security. Livestock is a form of security because the capital invested in the herd forms a guarantee for meeting future unexpected financial needs. Sheep and goat manure are habitually applied to the soil and serve a vital input function to subsistence vegetable farmers. Social and cultural values attached to livestock and livestock products vary from society to society. Owning livestock can give social status and can be used in settling local disputes which require the payment of fines (Ayalew *et al.*, 2001). The socio-economic and cultural values of keeping livestock, including the Zulu sheep, by the farmers in some communities of KwaZulu-Natal are reported in Chapter Two of this document.

1.8 Agricultural policy and Market

Livestock breeding programmes should form an important part of national agricultural policies, aiming at improving the food and income of a country, region or locality (Philipsson *et al*., 2006). Animal breeding programmes should be seen in the context of long-term development programmes. Such programmes contribute to both more food and other livestock commodities produced as well as improve resource utilization and livelihood of the livestock owners (Philipsson *et al*., 2006).

In the Draft Animal Improvement Policy for South Africa prepared by the NDA (2003), it was stated that since the veld and pastures depend on the country's soil and water resources, optimal and sustainable use of these natural resources will largely determine South Africa's capacity for sustainable food security. In the Draft, the use of adapted and genetically sound animals was encouraged as a key component of animal improvement.

The South African Animal Improvement Act (Act No. 62 of 1998) as cited in the Draft Animal Improvement Policy for South Africa (NDA, 2003), also takes into account provision for the protection of South Africa's indigenous and locally adapted breeds. Included is the provision for the establishment of schemes to contribute to the national database to support accurate statistics, animal identification, animal recording and evaluation.

Among the proposed considerations to be included in the South African policy on animal improvement (NDA, 2003) is indigenous knowledge systems. In the same draft policy, it is proposed that a national animal recording and improvement scheme for emergent farmers should be started. The scheme has to be based on sound animal husbandry principles and should concentrate on effective identification of animals and the recording of basic information on births, birth weights, weaning and post weaning weights (NDA, 2003). Superior animals within indigenous livestock should be identified from the data. Breeding and improvement schemes could then be established to benefit both large and small scale farmers. Also stated in the draft is that the establishment of animal schemes in rural communities could serve as a platform for economic and community development. Therefore, introduction of a Nguni sheep improvement scheme for rural farmers would not only contribute to the protection of one of South Africa's indigenous breeds but also to the livelihood of rural farmers.

It was specified by NDA (2004) in the National Livestock Strategy and Implementation Framework for South Africa that the NDA should be responsible for financing the Livestock Improvement Schemes that provide the pivot for optimal utilization. In addition, the NDA must conserve gene pools vital to adaptability and production. The NDA should also put preventative measures in place to limit the export of comparatively advantageous genetic material. Boer goat, Nguni cattle, Bonsmara and ostriches were examples listed but not Nguni sheep. It is thus important that Nguni sheep be characterised before decisions about exports or hybridization are made.

According to Philipsson *et al.* (2006), a breeding programme must be market-orientated to be sustainable. This is true for both small-scale farmers or large-scale farming systems to be sustainable. However, the change from small to medium-scale commercial animal production provides opportunities for farmers to move from subsistence production to market-oriented production. Characterising the farming scenario of the farmers keeping Zulu sheep would provide evidence of the current situation regarding this sheep breed.

1.9 Breeding objectives

At macro-level, the agricultural development policy, market and production system direct the ultimate breeding goals of a breed. At this level the resources available in a country or region should be taken into consideration. However, at micro-level, the definition of breeding objectives implies that for a given production situation, the relative importance of improvement of different traits of the breed must be determined (Philipsson *et al.*, 2006). In a subsistence production system, livestock contribute to a variety of benefits; therefore breeding objectives need to take into account diversity of traits. Breeding goals must be set at national, regional or at local level to truly reflect the needs of the area (Kosgey *et al.*, 2006). Long-term goals, expressed at national or organizational level, and the interest of the farmers could be solved by regulations or incentives for participating in a co-operative breeding programme (Philipsson *et al.*, 2006). Consideration of the short term benefits for farmers is important when selecting a method for weighting traits. This will have an impact on the participation of farmers (Philipsson *et al*., 2006).

Tibbo *et al.* (2006) recommended that traits used for within breed-improvement must have a high heritability and be of a desirable economic value. Thompson and Freeman (1983) found that the heritability values of traits of linear body measurements are higher than subjectively scored traits. Janssens and Vandepitte (2004) reported heritability value ranges of 0.49 - 0.54, 0.40 - 0.57 and 0.40 - 0.45 for live weight, wither height and heart girth respectively for three different sheep breeds. Gizaw *et al*. (2008) reported the heritability estimates of 0.46, 0.36 and 0.31 for the live weight, wither height and heart girth respectively for the Menzi sheep in Ethiopia. Heritability values from 0.2 to 0.5 and above 0.5 depict a medium and high strength, respectively, of inheritance of a character (Microbiology procedure, undated). Pozono (1992) and Philipsson *et al.* (2006) recommended selection for growth, survival and reproduction rate. Net reproduction rate per ewe can be increased by improving some or all of its components. Selection for total weight of lamb weaned would also keep reproductive rate within optimum bounds (Olivier, 2002). The most important point raised by Köhler-Rollefson (2000), Mhlanga (2002) and Kosgey (2004) is the participation of the farmers in setting the breeding objectives. This is important because breeding goals in the communities do not consist of high productivity alone. Other goals that may be considered include aesthetic preferences, the ability of livestock to survive adverse conditions. In this thesis the variation in weight, heart-girth, wither height were studied in three Zulu sheep populations at different age groups in three geographically separated areas. These results are reported in Chapter 3.

1.10 Breeding strategies

When deciding on a breeding strategy it may be necessary to take into account the level of performance and the potential of genetic improvement through selection within the indigenous breed. Similarly, the long term costs and benefits of crossbreeding compared to within-breed selection aimed at improving the same set of traits may need to be considered (Philipsson *et al*., 2006)

In the tropics, breed substitution of exotic animals for indigenous breeds or crossbreeding with breeds from temperate regions have been widely used. Many of these have invariably been unsuccessful or unsustainable in the long-term (Hall, 2004). This has been due to incompatibility of the genotypes with the breeding objectives and the management approaches of the prevailing low-input traditional production systems in these areas (Rewe *et al.*, 2002; Ayelew *et al.*, 2003). According to Kosgey (2004), crossing of indigenous with exotic germplasm may have led to improvement of some production traits but could have been at the expense of fitness traits.

According to Bosso *et al.* (2007), within-breed selection of adapted indigenous breeds is a viable alternative. There is little information available on the results of within-breed selection programmes utilizing indigenous breeds in the tropics. However, within breed selection is a strategy for genetic improvement usually carried out in individual populations. Selection within breeds or strains is intended to increase the average level of genetic merit of the population. Within-breed selection usually involves measuring and selecting on productivity parameters, such as litter size, growth rate of young and mature size. It includes:

(i) defining the overall development objectives,

(ii) characterizing the production system,

(iii) identifying the breed to be improved by selection,
(iv) identifying a list of breeding goal traits and
(v) deriving the goal values for each of the breeding goal traits.

The goal traits must be easily measurable, or have a high genetic correlation with a measurable trait if they are not easily measurable (Tibbo *et al.*, 2006). Difficulty in measuring and evaluation of the intangible benefits such as savings, insurance, ceremonial and prestige derived from the animals also presents more complications (Roeleveld, 1996). Strategies for genetic improvement that overcome such problems need to be considered.

1.11 Improvement strategy and lessons learnt from other case studies

Due to variation in performance among indigenous breeds and their unique characteristics, the strategy for improvement should be different for different indigenous sheep breeds (Tibbo *et al.*, 2006). According to Kosgey *et al.* (2006), small ruminant breeding programmes found in the tropics differ in design. Some are three-tiered with a nucleus, prenucleus (multiplier) and a base population. Others are two-tiered involving only a central performance evaluation station and farmer flocks. Some do not operate a nucleus at all. A breeding programme should be designed according to the ecological region and the production system at which it is aimed (Van der Waaij, 2001).

Breeding programmes recommended by Tibbo *et al.* (2006) and Mueller (2006) for traditional farming systems are those based on open-based nucleus flocks utilizing government ranches at the top of a three-tier system of flocks. Such a scheme is recommended for the tropics because of the limited scope for recording. It also stimulates discussion on breeding objectives and selection procedures involving all stakeholders. Views, goals and knowledge of the livestock owner should determine the level and intensity of a breeding scheme programme.

It was reported by Yapi-Gnaoré *et al.* (2001) that in West Africa an open-nucleus scheme worked for a communal improvement programme. In this case the breeding strategy is based on the individual performance of the indigenous Djallonké rams in West Africa. The structure was composed of one central performance evaluation station for rams (the nucleus) and the flocks of only the breeding ewes (the base population). The selection scheme included three phases: an on-farm pre-selection phase, an on-station first selection phase, and an on-station final selection phase followed by distribution of selected rams to farmers for mating. Selection criteria were based on the 180 day and 365 day weights. Yapi-Gnaore *et al.* (2001) reported that benefits to the farmers from the scheme included using the selected rams from the nucleus for mating. Ram lambs were sold by farmers to the nucleus for evaluation and the price offered for the ram lambs constituted reasonable revenue for the farmers. Farmers were responsible for keeping records, building shelters and enclosures and castrating unwanted rams. Genetic analysis of the programme indicated that the genetic values of the animals had been maintained or slightly increased during the process of selection. Limitations included a decline in the number of farms and breeding ewes caused by the change in the organization and coordination of the Programme National de Sélection Ovine (PNSO) programme. Flock sizes changed when farmers were required to deposit the recording sheets with the extension offices and were required to pay for the use of rams. It was concluded that farmers were less motivated when they were required to be involved financially. Financial involvement of the government at the beginning of the programme encouraged the farmers to believe that they should always be assisted. However, Iniguez (1998) argued that the cause of collapse of funded breeding programmes after subsidy collapses is most likely caused by inadequate involvement of the community at the beginning of the programme.

Tibbo *et al.* (2006) presented a plan for the indigenous Horro sheep open-nucleus breeding scheme in Ethiopia. In this case, the three-tier system consisted of nucleus, sub-nucleus and village flocks. The plan was to have 10 nucleus flocks each with 4000 breeding ewes and 160 fertile breeding rams. The nucleus flocks were established within the governmental ranches. In each year, about 4 % of the best rams would be selected at nucleus flock level. From the remaining rams in the nucleus, 30% would be selected for the sub-nucleus flock. The sub-nucleus flocks would be those owned by the participating owners. Sheep owners in this tier would be selected based on ease of access to a farm, availability of enough grazing and water, size of flock, and ability to follow prophylactic programmes, supplement their flocks and castrate unselected rams. About 11% of the best rams would be selected from the sub-nucleus to the village flocks. The village flocks were owned by people who were rarely accessed for monitoring and detailed evaluations (Tibbo *et al.*, 2006).

Yapi-Gnaorè (2001) advised that the extension officers have to be very closely involved in all aspects of a breeding programme. Another condition was that financial support should be available from the beginning. Additionally a veterinary health service should be available. Nutrition could be supported by the availability of agro-industrial crops to produce by-products required for feed. Yapi-Gnoarè (2000) recommended that when involving farmers, the breeding programme should be backed up with an effective extension service for maximum effect. The selection programme should be preceded by several years of extension work to boost the experience and skills of the farmers. It was noted by Kosgey *et al*. (2006) that in developing countries in the tropics the genetic improvement programme is affected by the extent to which breeding schemes involving farmers at the village are organized. Recording the activity and monitoring the progress of such flocks are additional factors. The constraints of implementing an improvement programme would depend on careful monitoring of measurements and possible conflict among participating and non- participating farmers. Moioli *et al.* (2002) suggested that the farmers should be made aware of benefits derived from the recording activity.

According to several authors (Turner, 1977; Kiwuwa, 1990; Jaitner *et al.*, 2001; Wollny *et al.*, 2002), the effective small ruminant breeding methods in smallholder production systems in the tropics are constrained by small animal populations. Further constraints are: lack of systematic animal identification, inadequate animal performance, data collection, inadequate pedigree recording, low levels of literacy and organizational shortcomings. These are thus issues to address in Zulu sheep research for the purposes of the establishment of effective improvement and breeding methods.

1.12 Infrastructure and recording schemes

Night enclosures, shelters, collecting yards, sorting pens and footbaths are some of the necessary structures required for an improved breeding programme

(Philipsson *et al.,* 2006). For a communal improvement programme, farmers can be taught to build such structures also taking into account their indigenous knowledge. They need to castrate unwanted rams, identify lambs at birth and record the required information for the programme (Mhlanga, 2002; Philipsson *et al.,* 2006). Other necessary requirements are communication, transport and computation facilities. Management structures at local level should include women who are normally marginalized even though they may have a wealth of knowledge and experience in the management of animal genetic resources (Mhlanga, 2002; Sobha, 2007). The youth should be included as well so they can gain skills and employment (Mhlanga, 2002). The type of recording scheme to be implemented is determined by the available infrastructure, including physical and human resources (Philipsson *et al.*, 2006). A weighing scale is the main tool required for recording the various weights of the animals. They are expensive and cannot be affordable to the traditional farmers (Slippers *et al*., 2000). Linear measurements of livestock can be used to estimate the live weights and tables are constructed for use by the farmers. In Chapter Four the live weight prediction equations computed from the heart girth, wither height and scrotum circumferences of Zulu sheep are presented.

1.13 Monitoring and evaluating of the genetic progress

A regular analysis of the outcome of a programme is necessary to demonstrate the genetic improvements obtained in all important traits and also the effect of total output of products per unit of measurement. Research should be done at certain intervals if regular monitoring of the programme can not be conducted (FAO, 1981; Philipsson *et al.*, 2006). However, data to be collected should be agreed upon by the farmers and the experts assisting the farmers before the programme begins. The monitoring should be done by both the experts and the farmers (Mhlanga, 2002). A recommendation by Mhlanga (2002) was that a group consisting of farmers, livestock personnel, researchers, government officials and development agencies could be established. They would carry out statistical comparisons, weigh the realized economic benefits and assess the genetic status of the improvement programme. It would be fitting for the South African government, some institutions and the communities to work together for the monitoring of the genetic progress in the improvement programme of Zulu sheep.

1.14 Conservation of Animal Genetic Resources (AnGR)

According to Windig *et al.* (2007) the conservation of farm animal resources involves the protection of the rare breeds. However, conservation in the developing countries can be defined as the rational use of existing local genotypes and protection of these (Rege and Liper, 1992). The main objective of farm AnGR conservation is to conserve breeds, including management for better utilization (breeding programmes) and conserving those at risk with the aim of minimizing the loss of diversity among breeds (Barker, 2001). It has become necessary to document the diversity of livestock genetic resources and to design strategies for their sustainable conservation. Mwacharo and Drucker (2005) suggested that the success of any conservation or improvement programme depends upon the actions of livestock keepers who own, utilize and adopt breeds and adapt them to their needs.

Two methods are used for conserving farm animal genetic resources (AnGR), namely *ex situ* and *in situ.* The *ex situ* method involves conservation of animals in a situation removed from their habitat. It is the storage of genetic resources not yet required by the farmer and it includes cryogenic preservation. The *in situ* method is the conservation of live animals within their production system, in the area where the breed developed its characteristics. It can also be referred to as "on-farm conservation." Such conservation consists of entire agro-ecosystems including immediately useful species of crops, forages, agroforestry species, and other animal species that form part of the system (Rege, 2001). Under the *in situ* conditions, breeds continue to develop and adapt to changing environmental pressures, enabling research to determine their genetic uniqueness.

According to the World Watch List for Domestic Animal Diversity prepared by the FAO (2000), the requirements for effective management for conservation needs at the country level for each species include identifying and listing the breeds. Furthermore, their description and characterisation is important to understand their unique qualities and potential contributions. Some factors which need to be considered for conservation include the current use of the breed, climatic, social and political stability of the area in which the breed is located, and the number of animals in the existing breed population.

1.15 Genetic characterisation of livestock

Genetic characterisation entails describing and classifying of livestock breeds and species at molecular level using techniques for DNA analysis (Appa Rao *et al.*, 1996). Tools of genetic characterisation using DNA include microsatellite markers, single nucleotide polymorphism (SNP), sequence and restriction of mitochondrial and nuclear DNA markers, restriction fragment length polymorphism (RFLP), amplified fragment length polymorphism (AFLP) and random amplified polymorphic DNA (RAPD) (Bowcock *et al.*, 1994; Appa Rao *et al.*, 1996). The microsatellite loci are sufficiently variable and are potentially powerful enough for distinguishing between closely related groups (Bowcock *et al.*, 1994; McGugh *et al.*, 1998; Buduram, 2004; Gizaw, 2008). A number of studies have used microsatellite markers to describe the relationship between various domestic animals. These include cattle and sheep breeds (Ciampolini *et al.*, 1995; Moazami-Goudarzi *et al.*, 1997; Tomasco *et al.*, 2002; Rendo *et al.*, 2004; Paiva *et al.*, 2005; Calvo *et al.*, 2006). Microsatellites were used by Buduram (2004) to compare the genetic similarity between various breeds in South Africa. Results from this study showed that the Zulu sheep breed is genetically similar to the Swazi sheep and this was attributed to the close geographic proximity of the populations. However, Karakul and Ronderib Afrikaner were included in the Nguni sheep cluster. This observation by Buduram (2004) needs further investigation.

Polymerase chain reaction-restriction fragment length polymorphisms (PCR-RFLPs) have been used to differentiate between the *Theileria annulata* and *Babesia bigemina* tick-borne infections (Ravindran *et al.* (2007) and have been used by Humpoličeka *et al.* (2007) in determining the effect of the myogenine gene on the reproductive traits of pigs. Negrini *et al.* (2007) used the AFLP method in differentiating between European cattle breeds. Mitochondrial DNA (mtDNA) polymorphisms have been used to investigate the structure of populations, interspecies variability and evolutionary relationships between populations or species (Avise *et al.*, 1987; Hiendler *et al.*, 1998: 2002). Mitochondrial DNA have also been used to identify remains of endangered animals (Hsieh *et al.*, 2001). SNP marker-derived relationship matrices have been used by Hayes and Goddard (2008) to predict breeding values of Angus cattle. Sanchez (2007) developed an identity test that can be used to confirm the breed and origion of meat in pigs using the SNP markers.

Random amplified polymorphic DNA amplification products can be classified as either variable (polymorphic) or constant (non-polymorphic). In a RAPD analysis both types of products can be exploited for establishing relationships (Gwakisa *et al.*, 1994). Random amplified polymorphic DNA fragments that are polymorphic among individuals of one breed or belonging to one pedigree or one sex have also been obtained when different primers are used (Kemp and Teale 1994; Gwakisa *et al.*, 1994). The RAPD technique has been successfully used in genetic studies of sheep breeds (Ali, 2003; Kumar *et al.,* 2003*,* Elmaci *et al.*, 2007), Tilapia fish (Baradakci and Skibinski, 1994), and identifying bulls with early reproductive maturation onset (Alves *et al.*, 2005). RAPD markers have also been used in the establishment of genetic linkage maps (Crawford *et al*., 1994) and identifying sex-specific markers (Cushwa and Medrano, 1994). Genetic diversity in Bangladeshi chicken was analysed by Mollah *et al*. (2009) using the RAPD markers. The RAPD technique is an attractive method because:

i) It is a quick and technically uncomplicated. There is no requirement for sequence information for the design of primers or probes. Different primers produce different banding patterns because the polymorphisms generated by any primer are due to differences in spacing between primer binding sites and point mutations (Appa Rao *et al.*, 1996; Zulu, 2008);

ii) RAPD-PCR is cost effective and allows rapid screening of DNA pools for average population specific fingerprints (Mburu and Hanotte, 2005);

iii) It is easy to screen hundreds of arbitrary 10-bp primers for fingerprint patterns that are favourable and moderately easy to score and use in the population under study (Williams *et al*, 1990; Welsh and McClelland, 1990);

iv) Importantly, the RAPD markers can be used for identification of desirable genotypes without previous knowledge of the genes determining a particular trait (Williams *et al.,* 1990; Bowditch *et al.*, 1993; Thu *et al*., 2002).

Shortcomings of the RAPD technique is that the markers are dominant and therefore heterozygotes cannot be detected (Ovilo *et al.*, 2000; Gwakisa, 2002). The RAPD technique is sensitive to reaction conditions, DNA quality and PCR temperature profiles. It is important to maintain strictly constant PCR reaction conditions to achieve reproducible results. When any change is introduced, it is worth analysing all samples again under new conditions since changes in the technique affect all the samples. However, it has been shown that reproducibility can be controlled with good quality DNA and by ensuring that adequate and optimal quantities of DNA and amplification reagents are used each time (Gwakisa, 2002). In RAPDs studies, relatively high annealing temperatures assist in the increase in reproducibility and to avoid the spurious formation of amplification product (Atienzer *et al*., 2000).

In the report by Simianer (2007) it is stated that the International Society of Animal Genetics (ISAG)/FAO advisory group on animal genetic diversity have recommended the microsatellites markers to be used molecular genetic studies of animals. The FAO has recommended a list of microsatellites for genetic studies which are now available (http://dad.fao.org/). However, because of the ease of use, relatively low technical requirement and unavailability of appropriate infrastructure at the moment at the University of Zululand, where the study was conducted, RAPD markers were used to preliminarily estimate the genetic diversity of this breed. Results are presented in Chapter Five.

1.16 Summary of the literature

The review above was compiled from various journals, internet sources, conference proceedings and books ranging from as early as 1955 to as recently as 2009. The authors articulated that at least the Eurasian wild sheep, the mouflon (*O. musimon* or *O. orientalis),* was the ancestor of the domesticated sheep (*O aries*). From their Asian origin the sheep spread westwards to Europe and Africa. It is believed the fat-tailed sheep reached South Africa around 400BC. Ancestors of Nguni sheep came with the Iron Age people who came down the east coast to Natal and dispersed further south. Nguni sheep of Zululand are called the Zulu sheep and they are found in the areas of KwaZulu-Natal.

Furthermore, the literature review demonstrated that indigenous breeds are usually owned by the rural farmers and are genetically adapted to their environment. They utilize feeds with low nutrient values, and have tolerance or resistance to specific diseases. Hence they require minimal inputs. Nguni sheep have been described as being tolerant to tick-borne diseases and internal parasites.

The literature review also showed that the most widely used indigenous small stock production systems in rural farming are the smallholder systems. Animals are grazed communally under open access of a common property tenure system. Although livestock provide food, economic opportunities and security to the rural farmers, there may be social and cultural values attached to the ownership of livestock and these may differ between communities.

It was also revealed in the review that provision for protection of indigenous and locally adapted breeds by the establishment of the schemes has been included in the animal improvement policies of South Africa. The National Department of Agriculture is the designated funder of any livestock improvement scheme. However, characteristics of the animals, including the traits of aesthetic value, should be known prior to the establishment of the breeding goals. Participation of farmers has been widely recommended during this phase by several authors. Genetic characterisation of the breed can be linked to the phenotypic characteristics. Various genetic markers can be used for genetic characterisation. Although the RAPD markers technique has some shortcomings, it is cost effective and has been widely used to estimate genetic variation between various animal breeds.

CHAPTER 2

A SURVEY ON LIVESTOCK PRODUCTION IN SOME TRADITIONAL AREAS OF NORTHERN KWAZULU- NATAL [1]

2.1 Abstract

A survey on livestock production was conducted through questionnaires among 76 rural farmers in the three wards of Enseleni district in northen Kwa-Zulu, Natal. The study showed that the livestock owned comprised chickens, cattle, sheep and ducks. Cattle and goats were the main livestock used for cultural purposes. Livestock were sold for cash to get other household needs and contributed 20.2% to farmers' total income. Production was extensive, groundnuts were used as a traditional supplement to increase production and some medicinal plants were used to increase reproductive rates. Dosing, vaccination and injections were used to control health. No breeding season or system was reported. Farmers kept indigenous Nguni cattle, sheep, goats and chickens. Sickly and deformed animals were castrated or culled. Main constraints included lack of extension, theft and parasites.

2.2 Keywords

cattle, goats, traditional farming

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[1]Kunene, N., Fossey, A., 2006. A Survey on Livestock Production in Some Traditional Areas of Northern Kwazulu -Natal. Livestock Research for Rural Development (18) 06. http://www.utafoundation.org/lrrd1808/cont1808.htm

2.3 Introduction

Livestock and crop farming are the major source of food production and income in rural farming. Livestock are also kept as a source of investment, insurance against disaster and also for cultural purposes (Sibisi, 1981). The South African government has, through extension programmes, supported rural livestock farming by introducing modern farming practices. However, it seems more effort is required to improve livestock production for food security in these areas. The indigenous knowledge, socio-economics and attitudes of the rural farmers should be taken into consideration when planning strategies for rural livestock improvement. The purpose of this study was to investigate the traditional livestock farming methods practiced by rural farmers, the impact of livestock on the cash economy of the farmers, the nature of problems encountered and the solutions farmers preferred.

2.4 Materials and Methods

The investigation was undertaken in three wards (Somopho, Mhlana, Yanguye) in the Enseleni district, situated South of the Umfolozi Game Reserve, North of Empangeni, in northern Kwa-Zulu Natal. These areas are located at 28^0 30'S - 28^0 43' S, 31^0 33'E - 31^0 50' E, the altitude range from 80 to 1900 meters above sea level, with a mean annual rainfall that ranges from 600 mm in the drier valley to over 1 400 mm near the coast. All the farms in the three communities were visited. A total of 76 farmers were available for questioning. Data were obtained by interviewing these farmers at their homesteads using structured questionnaires. Traditionally, the agricultural practices of the people in these wards consist of planting field crops, vegetables and raising livestock (Ministry of Agriculture and Forestry, 1997). Observations of the daily management practices of the livestock and the grazing areas were also recorded. The community income data were analysed using Statistica (1999).

The collected data were grouped as follows:

I. Farm and farmer information included, age of the farmer, sex of the head of the family, level of education of the farmer, sources of income and the size of the farmer's land.
II. Number and type of livestock owned, slaughtered, sold and other uses.

III. Management practices (grazing pattern, supplements and general husbandry).
IV. Breeding practices (selection, breeding systems and traits).
V. Problems.

Summary statistics were calculated to obtain a better understanding of the types of farms, farming methods and economical status of these rural communities.

2.5 Results and discussion

The characteristics of the farmers are provided in Table 2.1. A large percentage of heads of households were male (89,5%), while only a 10.5% were female, 75% women that headed households were widowed and the 25% had husbands that were migrant workers. There were few household headed by females in northern KwaZulu-Natal compared to the 60% households headed by widows or wives of migrant workers, reported by Bembridge (1984), for Transkei. A larger component of farmers (38%) were between the ages 41 and 50, 26% were between the ages 51 and 60 and 4 % were less than 30 years old, only one farmer was above 70 years old. More than half of the respondents (52,6%) did not go to school. Of the 47,4 % farmers, that had acquired some level of education, 21.1% had a high school qualification, 13,2% had higher primary education and 11.8% went as far as lower primary and only one farmer had a tertiary qualification. The level of the academic standard in this region was substantially lower to that of the Transkei, where 67.8% of the farmers had done some level in the lower primary and 4.3% had vocational qualifications (Bembridge, 1984).

Land ownership in these areas was reported by the livestock extension officer to be under tribal authority, the majority of the farmers (72,4%) estimated their land to be between four and five hectares in size, while 4 % estimated their land to be less than four hectares.

The main source of income was a combination of sales (agricultural produce and cold drinks) and work (36, 8%) (Table 2.1). Types of work reported were temporal jobs of cutting timber trees for Mondi, working for Richards Bay Minerals and Alusaf (Aluminum Company at Richards Bay). A pension was the sole income of 11, 8% of the farmers, while 10,5% of the farmers received an income from pension and from the sales.

Table 2.1 The background of the farmers at Enseleni district

Farmer Particulars	Number of Farmers	Percentage
Age		
Not sure	1	1.30
20 – 30	1	1.30
31 – 40	14	18.40
41 –50	29	38.20
51 – 60	20	26.30
61 – 70	10	13.20
71 – 80	1	1.30
Head of household		
Male	68	89.50
Female	8	10.50
Academic qualification		
None	40	52.60
Lower Primary	9	11.80
Higher Primary	10	13.20
High School	16	21.10
Tertiary	1	1.30
Reported estimate of size of land in hectares		
<1- 1	1	1.30
2 - 3	2	2.60
4 - 5	55	72.40
6 - 7	10	13.20
Did not know	8	10.50
Source of income		
Pension	9	11.80
Work	23	30.30
Sales	2	2.60
Pension and Sales	8	10.50
Sales and Work	28	36.80
Pension and Work	5	6.60
Pension, Work and Sales	1	1.30

The livestock types kept in the community were cattle, goats, sheep, chickens and ducks (Table 2.2). The majority (43.4%) of the cattle owners had between 11 and 20 cattle, similarly the common range in goat ownership was between 11 and 20. Most chicken owners (32.9%) had a range between 1 and 20 chickens, a considerable number of farmers (13.2%) had between 21 and 40 chickens. The results presented on Table 2.3, reflected that chickens were the highest percentage (36.9%) of the livestock in the community, followed by cattle (31.4%), goats (29.2%), however, the sheep were only 2 % of the total livestock. All the farmers were livestock owners. The composition of livestock type owned by farmers varied, the most common found was that of cattle, goats and chickens owned by 34.2% of the farmers followed by that of cattle and goats owned by 22.4% of the farmers (Table 2.3). The combination of livestock owned in these rural farms was similar to other investigations conducted in other rural areas of southern Africa; Swaziland (Sibisi, 1979) and Transkei (Bembridge, 1984).

Table 2.2 Livestock types owned by the farmers at Enseleni in rural northern KwaZulu-Natal

	Livestock	Number of farmers	Percentage of total farmers
Cattle	1 -10	23	30.30
	11 -20	33	43.40
	21 -30	5	6.60
	31 -40	1	1.30
	41 -50	1	1.30
	51 -60	1	1.30
		n = 64	
Goats	1 -10	18	23.70
	11 -20	29	38.20
	12 -30	3	4.00
	31 -40	1	1.30
	41 - 50	1	1.30
	51 -60	1	1.30
		n = 53	
Sheep	1 -5	2	2.60
	6 -10	8	10.50
		n = 10	
Chickens	1 – 20	25	32.90
	21 -40	10	13.20
	41 -60	2	2.60
	61 -80	2	2.60
		n =44	
Ducks	1 -14	1	1.30
		n =14	

The data gathered about the utilisation of livestock in 1998 and 1999 is provided in (Table 2.4). Cattle and goats were reported to be used for similar functions (consumption, sale and cultural use), the sheep were not reported to be used for any cultural purpose. More cattle (101) and goats (119) were slaughtered and consumed during cultural ceremonies than for paying dues. The rural farmers in Transkei and in Swaziland were also reported to use cattle and goats for similar purposes, (Sibisi, 1979; Bembridge, 1984). The chickens were regularly slaughtered (69) than the other livestock. These results support those of Ogle (1990) that versatile use of chickens to provide meat and eggs for households could be an attraction option. Though most of the animals used (56.3 %) were used for home consumption, a considerable number were sold (22.1%), goats, cattle and chickens seemed to have been sold equally.

Table 2.3 Proportions of livestock types and combinations owned by farmers at Enseleni

Livestock Type	Livestock Number	Percentage of total livestock	Combinations of livestock	Percentage of total farmers
Cattle	871	31.40	Cattle,goat,chickens	34.20
Goats	810	29.20	Cattle,goats	22.40
Sheep	51	2.00	Cattle,goats,sheep	4.00
Chickens	1025	36.90	Cattle,sheep	9.20
Ducks	14	0.50	Cattle,chickens	11.80
			Cattle	2.60
			Goats,chickens	10.60
			Goats,chickens,ducks	1.300
			Goats	4.00
Total	**2771**	**100**		**100**

Farmers reported to obtain their income from sales, pension, work or from any combination of these (Table 2.1). Figure 2.1, reflects the income distribution from all sources of income reported by farmers for the years 1998 and 1999. Of the total households that sold livestock, 76.3% earned less than R3999 and 3.9% earned over R16000. The majority (96.1%) of the farmers that sold crops, vegetables or cold drinks (other sales) got less or up to R3999. Fixed amounts were those obtained from work and pension, and 39.5% earned over R16000. The grand totals reflect that most of the income earners (47.4%) got over R16000 and the least (6.6%) got between R12000 and R15999.

Figure 2.2 demonstrate that, the largest contributor to the income of the homesteads was obtained through employment (55,9%), however, the income from livestock showed a substantial contribution (20.2%) of the total income. These results support those of Moorosi (1999) who reported that livestock provide income for South African small-scale farmers. It was reported by 79% of the farmers that livestock were sold when there was a need for cash e.g. for school fees. Very few farmers (1%) reported to sell when cattle were over 25, other farmers (20%) reported to sell because of draught and need for cash (Figure 2.3)

All the farmers reported an extensive rearing system. The livestock were reported to graze on communal grazing areas during the daytime and were brought back into kraals, which are within the homesteads at night. Similarly, all chicken farmers reported a free-range system.

The data collected from this investigation indicated that the farmers used various traditional supplements to enhance various reproductive and productive performances. Medicinal plants such as *Sarcostemma viminale (igotsha), Crinum macowanii* (*umduze), Rhoicissus tredentata* (*isinwazi)* and *Tetradenia riparia* (*ibozane)* were reported to be given to livestock anytime during the year to increase the milk production by stimulating the letdown process.

Table 2.4 Some functions of livestock in traditional farming

Total livestock used	Species	Number Slaughtered Only for home consumption	Number slaughtered /consumed for ancestral ceremonies	Number paid for Lobola	Penalty	Number of livestock sold	Percent of total farmers who sold the livestock type
259	Cattle	9	101	40	12	97	31.60
24	Sheep	20	0	0	2	2	1.30
239	Goats	10	119	9	4	97	22.40
793	Chickens	69	0	0	0	98	7.90
15	Duck	15	0	0	0	0	0.00
1330	Totals	749	220	49	108	294	63.20
100	**Percentage of livestock used**	56.3	16.5	3.7	1.4	22.1	

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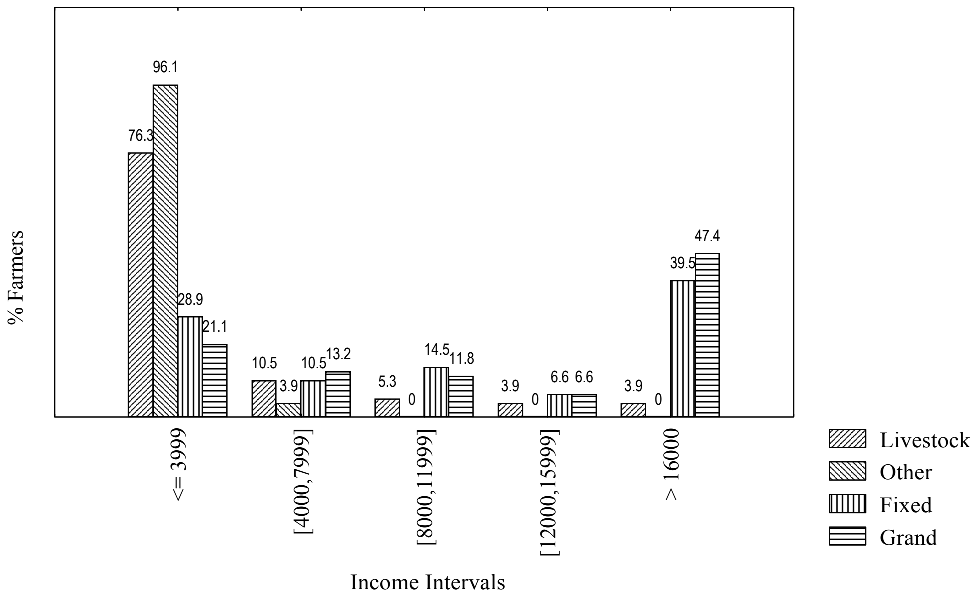

Figure 2.1 Income distribution for the farmers

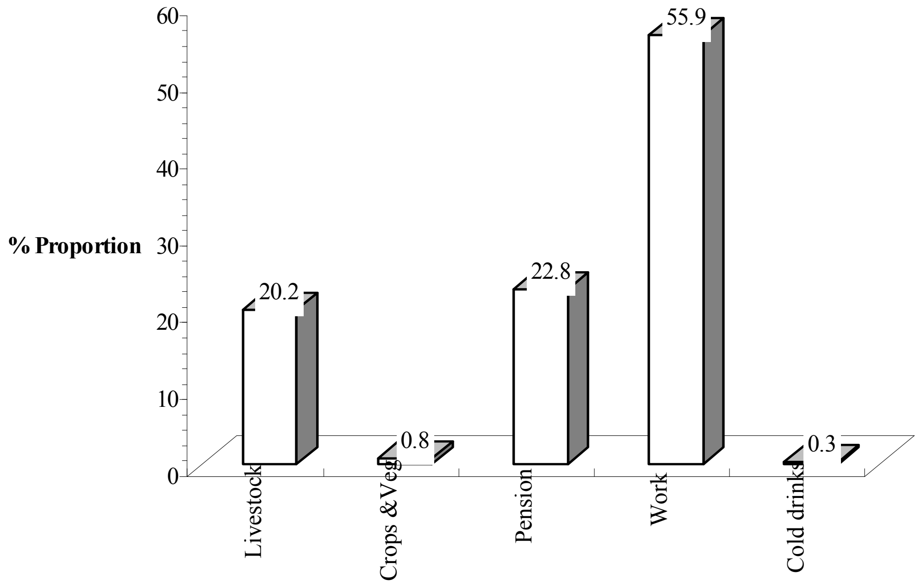

Figure 2.2 Proportion of sources of income for traditional farmers

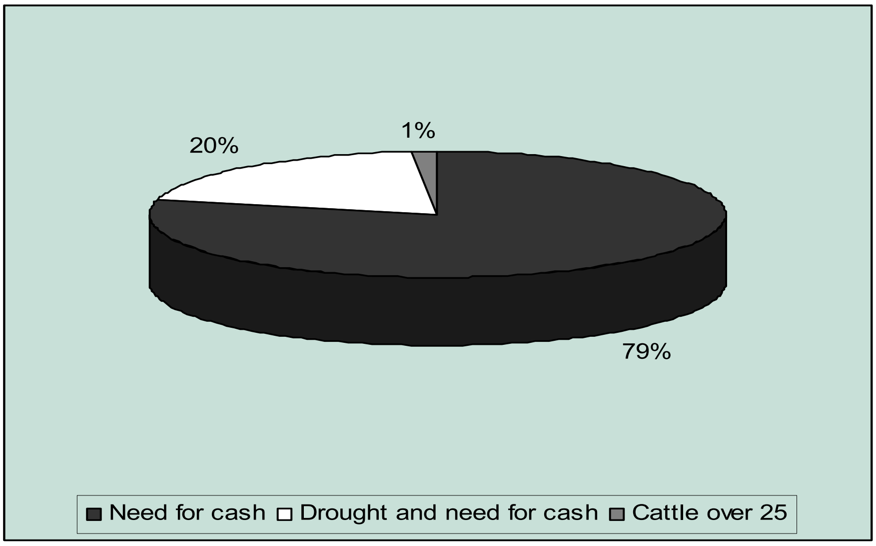

Figure 2.3 Main reasons given for selling livestock

Potassium permanganate dissolved in the drinking water was used to increase reproductive rate by increasing fertility and twinning. Ground peanuts and *Crinum macowanni* were given to cattle at anytime during the year to improve the reproductive rate (Table 2.5).

Table 2.5 Traditional supplements and veterinary use of plants reported by the farmers

Plant	Use	Percentage of Livestock farmers
Sarcostemma viminale (*igotsha*)	Increase the milk production	13.2
Crinum macowanii (*umduze*)	Increase the milk production	13.2
	Improve rate of reproduction	2.60
Rhoicissus tredentata (*isinwazi*)	Increase the milk production	10.6
Tetradenia riparia (*ibozane*)	Increase milk production	2.60
Potassium permanganate	Increase reproductive rate	15.8
Ground peanuts	Improve reproductive rate	6.60

Table 2.6 presents various methods of disease control. The cattle were taken by 92.2% of the cattle farmers to a communal dip where they were dipped to control ticks, 7.80% of the cattle owners used a spray dip. None of the farmers reported to dip sheep and goats. Dosing, vaccination and injections were reported by 85.5% of all the farmers to be main methods of improving health condition of livestock. Tail

docking of sheep was done by 30% of sheep owners to prevent attacks by parasites as well as to improve growth rate and meat production.

Table 2.6 Herd health control practised by the farmers

Health Practice	Number of farmers	Percentage of livestock type owners
Communal dipping of cattle	59	92.20
Cattle spray dip	5	7.80
Communal dip of sheep and goats	0	0.00
Spray dip of sheep and goats	0	0.00
Tail docking	3	30.00
Dosing, vaccination and injections of livestock when necessary	65	85.50

There were three types of cattle breeds owned in these areas, most of the cattle farmers (76.6%) kept the Nguni breed because they are well adapted to the local environment and were resistant to many diseases. Other farmers (21.9%) who owned Brahman and Nguni reported to keep the Brahman for increased meat production due to its large body size. Only a few farmers (1.6%) farmed Jersey for high milk yields and tolerance of the local environment. The small stockowners kept indigenous sheep and/or goats. The farmers reported to prefer the indigenous breeds to exotics because they are better adapted to the local hot climate, reasonable meat production and resistant to various diseases (Table 2.7). No particular breeding system could be identified. Mating occurred amongst animals of neighbouring homesteads, thus, all the animals of the farmers within an area could be considered as a single breeding population.

It seems that some of the farmers believed that castration had an effect on the weight gain of an animal. The selection procedures practiced were that of castration, slaughtering of animals and sales. Some farmers (15.8%) castrated cattle that were, too thin, had presence of abnormalities such as small testicles and cryptorchids, but often some male calves were castrated for weight gain purposes. However, 1.3% castrated all the male calves, while others (3.9%) castrated all male calves of cows calving for the first time, mainly to increase weight. A number of the farmers (14.5%) castrated their goats at the age of six months, in order to gain weight and decrease the smell of the goat meat. Cattle, goats and sheep that suffered severe injuries, sterile, had reproductive disorders or were sick with contagious diseases were slaughtered by 67.1% of the farmers for home consumption. About 17% of the farmers mentioned that over two year old, fit, usually castrated, calm male cattle were chosen to draught (Table 2.8).

Table 2.7 Breeds owned and those preferred by the farmers

Breed/s Owned	Number of farmers	Percentage of livestock owners	Advantages mentioned by the breed type owner	Percentage of breed type owner mentioning the advantage
Brahman and Nguni	14	21.90	Both adapt well to local climate	78.10
Jersey	1	1.60	High milk yield and tolerate local conditions	1.60
Nguni cattle	49	76.60	Adapt to local conditions and have good disease resistance	76.60
Nguni (Zulu) sheep	10	100.00	Adapt well to hot climate, are resistant to diseases	90.00
			Meat quality	10.00
Nguni (Zulu) goats	53	100.00	Adapt well to hot climate have resistance to diseases	94.00
Zulu chickens	44	100.00	Can survive (by scavenging) even when maize is not available	68.20
			Do not need high inputs	22.70
			Nice meat	9.10

The farmers' observation of season of birth effect on their livestock is presented on Table 2.9. Their observations were, slow grow rates for livestock born in winter and good weaners were realised from livestock born in summer. However, animals born in spring or summer were more prone to get diseases. The lambs born in summer months experienced stress but also too much rain during the lambing season resulted in a high incidence of diseases and reduced production. This was reported by 80% of the sheep owners, however, 34% of the goat owners noted good weaning weight of goats when kidding took place in summer. Similarly, good weaning weight in calves born in summer and high growth rates in spring and summer born calves were observed by 31.3% and 43.8% of the cattle owners, respectively.

Table 2.8 Selection strategies practiced by farmers

Form of selection	Number of livestock owners	Percentage of livestock owners
Castration of calves with small or abnormal testicles	12	15.80
Castration of thin calves	12	15.80
Castration of all male calves	1	1.30
Castration of male calves from first calvers	3	3.90
Castration of goats at six months	11	14.50
Sale of cows which are sterile and have poor reproduction rates	17	22.40
Slaughter of unreproductive livestock	51	67.10
Cattle over two years old, fit calm, castrated and used for draught	13	17.10

Diarrhea or death of calves was reported to occur after spring calving. Some of these reports confirm the findings of Carles (1983) in Zimbabwe, when he reported fast growth and higher weaning weights of lambs born in summer because of the abundance of browse and forage. Although sheep lambing during the winter produced lambs with good birth weights, because the ewes were well fed during the previous summer pregnancy, the slower growth rate of these lambs resulted in high mortalities.

Table 2.9 Farmers observations on some season of birth effects

Season of birth	Effect on livestock type	Number of Farmers	Percentage of Livestock type owners
Summer	Stress and diseases in lambs mostly due to rains	8	80.00
Summer	Good weaning weights of goats	18	34.00
Summer	High weaning weight of calves	20	31.30
Spring	Diarrhea or death of calves	3	4.70
Spring or Summer	High growth rate in calves	28	43.80
Winter	Slow growth rates in kids	11	20.80

The farmers reported how they use some physical traits as indicators of traits of economic importance (Table 2.10).

Some of these relationships were similar to some of the relationships written by Dalton (1980) who found that traditional breeders believed that:

I. A flat bone denotes good meat potential.
II. Thin skin (when pinched between finger and thumb) denoted good milk potential in a dairy cow.
III. A kind eye (friendly look) in most stock denotes good temperament and hence good performance.

The farmers encountered various problems, ranging from, animal related problems such as low fertility and disease, to theft and a lack of extension services (Table 2. 11).

Table 2.10 Relationships between traits of livestock identified by farmers

Livestock trait	Related trait	Number of farmers	Percentage of livestock type owners
High milk yield in cattle	Small head, thin slender neck in cows	6	9.40
	Big udder	5	7.80
	Good milk veins on cow belly	6	9.40
	Large, hollow body cavity	5	7.80
	Big calf at birth will also be big at weaning	2	4.70
	Thin skin denotes high milk yields	5	7.80
	Fine tail of a cow	5	7.80
	A friendly look denotes good temperament, hence good lactation and fertility in cows	2	3.10
High fertility or improved reproductive performance in cattle	Udder like projections under the neck denote good fertility and reproductive performance and thus a capacity to twin.	3	4.70
	Long penis and big neck are related to good fertility in bulls.	3	4.70
	A hump and big neck denotes good fertility in bulls.	5	7.80
	Large scrotum/testicles denotes good fertility	32	50.00
	Large voice in bulls denotes good fertility	4	6.30
Improved meat production in cattle	A flat backbone, fit and straight legs denote good meat production	15	23.4
Improved milk yield in goat and sheep	Big udder and good reproductive performance	25	40.6
Improved reproduction in goats and sheep	Long penis and large scrotum/testicles denote good fertility	24	54.5
	Udder like projections under the neck denoted good fertility	17	38.6

Table 2.11 Constraints on livestock production experienced by of farmers and proposed solutions

Problem	Number of farmers Mentioning problem	Proposed Solution
Low fertility in animals	31	- injection and medication - vaccination - no solution except slaughtering
Miscarriage	40	- injection and medication - vaccination - dosing
Livestock theft	69	- education of community - thieves should be disciplined (arrested) - construction of fences
Incidences of drought	57	- irrigation
Parasite and predators	58	- injection and medication -dipping to combat external parasites - dosing, vaccination to combat internal parasites
Lack of grazing land	41	- no solution -relocation
Lack of extension services	71	- provision of extension support (especially education in livestock management) - farmers visit extension office at the office

2.6 Conclusion

The farms in the rural communities investigated were approximately five hectares, in most cases, under the control of male farmers, of which more than half had no education. Farming was mixed in nature with a variety of livestock. Livestock farming consisted of communal grazing during the day, and kraaling at night at individual homesteads. Livestock on most of the farms were cattle, goats, chickens, ducks and a few sheep. Most farmers had cattle, but chickens occurred in greater numbers. More than 50% of the farms' yearly income was between R12 000 – R16 000 generated mostly from non agricultural resources such as employment and pensions. However, 21% of farmers' income was about R4 000, generated on these farms mostly from agricultural practices.

From these results it can be concluded that interventions could contribute to more effective farming and increased income. However, assistance to these farmers could contribute positively to their household and food security, if prior knowledge is obtained and through collaboration with the farmers and suitable assistance is provided according to the needs of the different communities.

CHAPTER 3

CHARACTERISATION OF ZULU (NGUNI) SHEEP USING LINEAR BODY MEASUREMENTS AND SOME ENVIRONMENTAL FACTORS AFFECTING THESE MEASUREMENTS[2]

3.1 Abstract

Data on linear body measurements (LBM) of *ca.* 100 Zulu sheep raised under extensive management systems at four sites in northern Kwazulu-Natal, were collected over a period of 2.5 years (October 2000 to May 2003). Data were used to quantify the live weight (LW), heart girth (HG), wither height (WH) and scrotum circumference (SC) of sheep at different age groups as well as some environmental factors affecting the LBM. Teeth numbers were used to estimate the age of sheep. Mature rams that have three and four pairs of incisors had a LW of 37 and 38 kg, and HG of 79 and 80 cm and WH of 65 and 64 cm, respectively. Mature ewes had a LW of 30 and 32 kg, HG of 76 cm and WH of 62 and 63 cm. Differences of 15 kg, 18 kg and 22 kg in LW among sheep with full sets of milk teeth and 28 kg, 35 kg and 40 kg among mature sheep were found between populations. The SC increased with age, for mature rams (three and four pairs of incisors) it was 27 cm as compared to 18 cm for younger rams. The ear size ranged from ear buds to large ear length of 9- 14 cm. However, the type of ear-length was found not to have any particular influence on the variation in LBM of Zulu sheep. It was concluded that an investigation on genetic variation between the populations is necessary to develop an effective conservation and utilization programmes and strategies for the breed.

3.2 Keywords

Indigenous sheep, body measurements; scrotum circumference, extensive management.

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[2] Kunene, N.W., Nesamvuni, E.A., Fossey, A. 2007. Characterisation of Zulu (Nguni) sheep using linear body measurements and some environmental factors affecting these measurements. S. Afr. J. Anim. Sci. 37 (1) 11-20.

3.3 Introduction

Between 200 and 400 AD the original Nguni type of sheep migrated with Nguni people down the east coast of Africa southwards to the areas where they are presently located (Ramsay, *et al*., 2000). They are divided into three groups according to their distribution, namely Pedi in Sekukunniland, the Swazi sheep in Swaziland and the Zulu sheep in KwaZulu-Natal (Kruger, 2001). Documented populations of the Zulu sheep are flocks that have been established at the Makhathini Research Station (MRS) below Pongolo river dam and at the University of Zululand (UNIZULU) near Empangeni in Northern KwaZulu -Natal. The numbers of this indigenous Nguni breed are reported to be declining rapidly due to replacement by imported breeds (Kruger, 2001).

The indigenous breeds are an important part of livestock agriculture, especially in some rural areas of South Africa. They are kept as a source of investment and also to some extend as a source of food production. The Zulu sheep are known to have qualities of excellent mothering ability, tolerant to external and internal parasites and to tick borne diseases. They adapt well in hot humid to hot dry bushveld environment (Ramsay, *et al.*, 2000). They are reported to have thin or fat tails and have a coat of either wool or hair (Kruger, 2001). Not much work has been done to quantify the performance of the Nguni breed. Accurate description of Nguni sheep under the extensive areas would enable accurate comparison of this breed to other sheep breeds. Conservation and improvement programmes can be developed using such information.

Linear body measurements (LBM) can be used in assessing growth rate, feed utilisation and carcass characteristics in farm animals (Brown *et al.*, 1973). LBM are divided into skeletal and tissue measurements (Essien and Adesope, 2003). The height at withers is part of skeletal measurements, whereas the heart girth is part of tissue measurement (Blackmore *et al.*, 1958). Several authors have indicated that males with larger testes have either greater sperm production or higher daily sperm output and that testicular size is a good indicator of ram fertility (Schoeman and Combrink, 1987; Duguma *et al.,* 2002). Venter *et al.* (1984), proposed that minimum scrotal circumference standards at certain age should be known for individual breeds. The objective of this study was to phenotypically characterise Zulu sheep under extensive management using LBM and to quantify some environmental factors affecting these LBM.

3.4 Materials and Methods

Data was collected monthly from *ca.* 100 sheep in three populations of Nguni sheep and consisted of 2640 records. The sheep were in were from four locations in KwaZulu –Natal and were kept under natural pastures. The parameters recorded were live weight (LW), heart girth (HG), wither height (WH) and scrotal circumference (SC). The geographical location, time of data collection, number of sheep, number of records per traits and dominating grass species is shown in Table 3.1. The altitudes in these areas range from 60 m to 120 m above sea level with an annual rainfall ranging from 400 mm to above 1000 mm. From May, 2002 until November, 2002, the herd at MRS was reared at Owen Sithole College of Agriculture (OSCA) because of increased theft of the sheep at the station.

The LBM were taken *ca*. every 28 days using a measuring tape method as described by Fourie *et al.* (2002). The SC was measured as described by Schoeman and Combrink (1987). Since no records were available at Enqutshini at the beginning of the study, age of the sheep in all three populations was estimated from incisor teeth as described by Gatenby (1991). Pregnancy status data were obtained through observation of body part changes as described by Carles (1983). Least -square analysis of variance was done using the general linear model (GLM) procedure of minitab (Minitab, 1998).

Table 3.1 Geographical location and conditions at the sites of data collection

	University of Zululand (UNIZULU)	Makhathini Research station (MRS)*	Enqutshini	Owen Sithole College of Agriculture (OSCA)
Geographical location	28^{0}51'S:51^{0}51'E	25^{0}27'S:32^{0}10' E	28^{0}37'S:31^{0}55"E	27^{0} 38'S: 31^{0}56'E
Time of data collection (number of sheep)	October, 2000 (30) – May, 2003 (37)	October, 2000 (31)– April, 2002 (26) December, 2002 (37) -May, 2003 (45)	October, 2000 (27)-May, 2003 (43)	May 2002 (26) – November, 2002 (37)
Number of record per trait (LW/HG/WH)	843	652	874	271
SC	156	181	186	58
Dominating grass species	*Hyperrhenia hirta*	*Pennisetum clandestinum* and *Panicum maximum*	*Sporobolus* Species	*Cynodon nlemfuensis*
Common names	Thatch grass	Kikuyu and Guinea -grass	Dropseed	Stargrass

*Flocks kept at OSCA from May 2002 to November 2002

LW- live weight; HG- heart girth; WH- wither height; SC-scrotal circumference

Non- significant factors on the preliminary models such as year of data collection and some two-factor interactions of year with other fixed effects were removed from the final models. Not all possible interactions were obtained because of spaces created by unequal subclasses. Tukey's simultaneous test was used to separate significance of least-square means. Three models were used:

Model I:

$$Y_{ijklmnopq} = \mu + E_i + V_j + S_k + A_l + P_m + R_n + H_o + C_p + (VS)_{jk} + (VA)_{jl} + (SA)_{kl} + (AH)_{lo} + e_{ijklmnopq}$$

Where:

$Y_{ijklmnopq}$ is the qth record of LW and HG

μ = effect common to all sheep

E_i = effect of ith season (1= summer, 2 = autumn, 3= winter, 4=spring)

V_j = effect of jth area (1 =UNIZULU, 2 = Enqutshini ,3= Makhathini and 4= Owen Sithole College)

S_k = effect of k^{th} sex (1= male and 2 = female)

A_l = effect of l^{th} age (1= milk set (<15 months), 2= 1 pair of permanent incisors (15 to 22 months), 3 = 2 pairs of permanent incisors (22 to 28 months), 4 =3 pairs of permanent incisors (28 to 36 months) and 5= 4 pairs of permanent incisors (> 36 months)

P_m = effect of m^{th} status of pregnancy (1= pregnant and 2 =non pregnant)

R_n = effect of n^{th} ear length class (1= ear-buds, 2= small (3-6 cm),3= medium (> 6 -9 cm), 4=large (> 9 -14 cm))

H_o = effect of the o^{th} horn status (1= horned and 2= polled)

C_p = effect of p^{th} colour (1=brown, 2= black and white, 3= brown and white, 4 = brown, black and white patched, 5 = black, 6= dark brown, 7 = black and brown, 8=tan and 9 = tan and white)

$e_{ijkmnopq}$ = random error.

Model II:

$$Y_{ijklmnop} = \mu + E_i + V_j + S_k + A_l + R_m + H_n + C_o + (VS)_{jk} + (VA)_{il} + (SA)_{kl} + (AH)_{ln} + e_{ijklmnop}$$

Where $Y_{ijklmnop}$ is the p^{th} record of WH, with all terms defined as in MODEL I except for the subscript notation.

Model III:

$$Y_{ijklmn} = \mu + E_i + A_j + H_k + C_l + G_m + (AH)_{jk} + e_{ijklmn}$$

Where Y_{ijklmn} is the n^{th} record of SC, with all terms defined as in MODEL I except for G_m = effect of m^{th} year (1=2000, 2= 2001, 3= 2002 and 4= 2003) and for the subscript notation.

3.5 Results and Discussions

The analysis of variance for LW, HG and WH of sheep are presented in Table 3.2. The least- square means and standard errors are presented in Tables 3.3, 3.4 and 3.5. The models used to describe Zulu sheep accounted for 60%, 57% and 50 % of the variation in LW, HG and WH, respectively.

Table 3.2 Analysis of variance for live weight (LW), heart girth (HG) and wither height (WH) of Zulu sheep

Sources	DF	LW (MS)	HG (MS)	WH (MS)
Season	3	891.60***	1849.10***	292.20***
Area	3	8306.10***	2979.20***	2753.10***
Sex	1	2287.70***	588.40**	267.00**
Age	4	11318.40***	11277.90***	4586.00***
Status	1	1996.30***	2716.10***	
Ear	3	419.80***	623.10***	707.80***
Horn	1	104.30^{ns}	504.80**	349.30**
Colour	8	309.50***	800.70***	474.10***
Area*sex	3	1200.30***	998.20***	836.60***
Area*age	12	144.10***	103.40*	72.00*
Sex*age	4	798.90***	542.40***	224.10***
Age*horn	4	448.00***	1192.20***	520.10***
R^2		60.40 %	56.70%	50.00 %

DF- degrees of freedom; MS-mean squares
*P< 0.05; **P<0.01; ***P<0.001; ^{ns} non-significant

Age, location and pregnancy status seemed to have been the highest contributing (P <0.001) factors to the variation in LBM of Zulu sheep (Table 3.2). The LBM of the Zulu sheep increased with the age (Table 3.3). These results are in line with the conclusion made by Otte *et al.* (1992) and Benyi (1997) that, the HG, WH and LW are measurements that can be used to evaluate growth in ruminants. The LBM of the sheep with three pairs and those with four pairs of incisors, were found to be similar (Table 3.3). The LW for sheep with milk set of teeth (< 15 months) at Enqutshini (Table 3.4) was found to be 4.03 kg and 2.81 kg lower when compared to LW of animals of similar age group at MRS and at OSCA, respectively. The young sheep (< 15 months) at UNIZULU were even lower by 3.92 kg, 7.95 kg and 6.73 kg in LW than young sheep at Enqutshini, Makhathini and OSCA, respectively. The highest LW for the mature Zulu sheep (three and four pairs of incisors) was 39.76 kg and 40.26 kg at MRS with a HG of 79.95cm and 81.28 cm and WHs of 67.36 and 68.02 cm, respectively. The lowest LW for the mature sheep were 26.76 and 28.05 kg at UNIZULU with a HG of 73 cm and WH of 61.27 and 61.76 cm for sheep with three and four pairs of teeth, respectively. In addition, the least- square means of the location x age interaction (Table 3.4), indicate that moving of sheep from MRS to OSCA, resulted to reduced LW of sheep with 1- 4 pairs of incisors. When at MRS, the LW of sheep with 1,2, 3 and 4 pairs of incisors were heavier by 4.40 kg, 3.87 kg, 4.42 kg and 4.56 kg, respectively than the sheep of similar ages at OSCA. These differences could imply that the animals might have been undergoing a process of adaptation to the different environment. Provenza (2003), reported that during time of adaptation, animal performance declines before it improves and that the degree and time of the decline depends on the magnitude of change in environments. However, it seems the change of area did not affect the sheep aged below 15 months because the least -square means of their LBM at MRS was found to be similar (P> 0.05) to that of the same age group at OSCA.

Sex of animal and the interaction between sex and area where it was raised was found to have an effect (P<0.001) on the variation of the LBM of the Zulu sheep (Table 3.2). The least- square means of the interaction between area and sex of animal (Table 3.4) reflect higher differences in LBM between males and females on sheep reared at MRS. At MRS, the males were heavier by 8.72 kg, larger by 6.27 cm and higher by 5.40 cm in LW, HG and WH, respectively than the females in the same herd. Such differences were smaller or not significant between males and females in other study areas. It was remarkable to note that the difference in LBM between males and females was found to be non-significant when the herd from MRS was raised at OSCA. The change of environment from MRS to OSCA had a higher impact on males than on females. The rams at OSCA had lower LW, HG and WH by 7.64 kg, 4.84cm and 7.64 cm, respectively, than the rams at MRS. However, the LBM of the females were found to be similar (P>0.05) in these two locations. The fact that the LBM of dams were not affected by change of location could explain why the young sheep (milk set of teeth) at OSCA performed similar (P>0.05) in terms of LBM to those of the same age group at the MRS.

Table 3.3 Least- square means and standard errors for live weight (LW), heart girth (HG) and wither height (WH) of Zulu sheep

Source of variation	No	LW (kg) Lsm	s.e.	HG (cm) Lsm	s.e.	WH (cm) Lsm	s.e.
Season							
Summer	537	29.25	0.47^{a}	73.72	0.54^{a}	61.10	0.38^{a}
Autumn	719	30.62	0.41^{a}	74.21	0.47^{a}	61.24	0.34^{a}
Winter	727	28.25	0.41^{b}	72.48	0.47^{b}	60.69	0.32^{a}
Spring	659	28.04	0.43^{b}	70.31	0.49^{c}	59.72	0.34^{b}
Area							
UNIZULU	843	22.76	0.44^{a}	68.67	0.50^{a}	58.04	0.34^{a}
Enqutshini	874	28.54	0.50^{b}	72.58	0.57^{b}	59.84	0.42^{b}
MRS	652	34.28	0.44^{c}	75.48	0.51^{c}	64.58	0.36^{c}
OSCA	271	30.58	0.75^{d}	74.01	0.85^{b}	60.72	0.63^{b}
Males	581	30.88	0.51^{a}	73.62	0.58^{a}	61.30	0.40^{a}
Females	2059	27.20	0.37^{b}	71.75	0.42^{b}	60.07	0.31^{b}
Milk set teeth	913	19.14	0.42^{a}	62.13	0.48^{a}	54.03	0.32^{a}
One pair of incisors	361	27.25	0.57^{b}	72.23	0.65^{b}	60.32	0.47^{b}
Two pairs of incisors	302	30.62	0.86^{c}	74.18	0.98^{b}	61.92	0.73^{b}
Three pairs of incisors	260	33.46	0.82^{d}	77.65	0.94^{c}	63.51	0.70^{c}
Four pairs of incisors	804	34.72	0.45^{d}	77.22	0.51^{c}	63.66	0.36^{c}
Pregnant	242	30.38	0.48^{a}	74.25	0.55^{a}		
Non-pregnant	562	27.70	0.32^{b}	71.12	0.37^{b}		
Horned	435					61.41	0.42^{a}
Polled	2205					59.96	0.28^{b}
Ear length type							
Ear buds	187	28.26	0.61^{a}	72.35	0.70^{a}	59.73	0.51^{a}
Short ears	358	29.25	0.47^{b}	72.64	0.53^{b}	60.55	0.38^{a}
Medium ear length	793	28.55	0.40^{a}	71.87	0.46^{b}	60.30	0.32^{a}
Long ear length	1302	30.09	0.38^{b}	73.87	0.43^{b}	62.18	0.30^{b}
Colour							
Brown	501	29.10	0.45^{a}	72.42	0.51^{a}	60.14	0.36^{a}
Black and white	258	28.93	0.56^{a}	71.10	0.64^{a}	59.39	0.47^{a}
Brown and white	465	28.94	0.44^{a}	72.49	0.50^{a}	61.03	0.35^{a}
Brown, black and white patched	159	28.90	0.66^{a}	73.04	0.75^{a}	61.14	0.55^{a}
Black	76	26.50	0.63^{b}	68.56	0.72^{b}	57.43	0.53^{b}
Darkbrown	82	28.20	0.75^{a}	73.14	0.96^{a}	61.47	0.71^{a}
Black and brown	426	30.58	0.44^{c}	74.27	0.51^{a}	62.01	0.36^{a}
Tan	440	30.04	0.47^{c}	74.71	0.54^{a}	61.88	0.39^{a}
Tan and white	133	30.06	0.70^{c}	74.41	0.80^{a}	61.70	0.59^{a}

"a,b,c,d column means with common superscripts do not differ ($P < 0.05$)"

Table 3.4 Least- square means and standard errors showing effect of area-sex and area-age interactions on live weight (LW), heart girth (HG) and wither height (WH) of Zulu sheep

Source of variation	No	LW (kg)	s.e	HG (cm)	s.e.	WH (cm)	s.e
Area* sex							
11	156	23.90	0.65^{a}	68.59	0.74^{a}	57.98	0.52^{a}
12	687	21.62	0.43^{b}	68.74	0.50^{a}	58.09	0.35^{a}
21	186	29.98	0.79^{c}	73.49	0.90^{c}	60.31	0.66^{b}
22	688	27.09	0.44^{d}	71.66	0.50^{c}	59.38	0.38^{a}
31	181	38.64	0.63^{e}	78.61	0.72^{d}	67.28	0.51^{c}
32	471	29.92	0.50^{c}	72.34	0.57^{c}	61.88	0.42^{b}
41	58	31.00	1.14^{c}	73.77	1.30^{c}	59.64	0.97^{b}
42	213	30.17	0.70^{c}	74.25	0.80^{c}	60.94	0.60^{b}
Area * age							
11	186	14.49	0.66^{a}	59.08	0.75^{a}	51.84	0.54^{a}
12	140	20.16	0.83^{b}	67.12	0.95^{b}	55.98	0.69^{b}
13	181	24.32	0.90^{c}	71.01	1.03^{c}	59.35	0.76^{c}
14	115	26.76	0.93^{d}	73.37	1.06^{c}	61.27	0.79^{c}
15	221	28.05	0.64^{d}	72.76	0.73^{c}	61.76	0.53^{c}
21	354	18.41	0.49^{e}	61.34	0.56^{d}	52.74	0.38^{a}
22	81	27.74	0.90^{d}	73.53	1.02^{c}	60.71	0.76^{b}
23	54	29.69	0.99^{d}	73.72	1.37^{c}	60.49	1.03^{b}
24	71	31.97	0.87^{d}	76.85	1.26^{e}	62.36	0.95^{c}
25	314	34.87	0.59^{f}	77.44	0.68^{e}	62.92	0.51^{c}
31	259	22.44	0.58^{b}	64.41	0.66^{f}	57.52	0.47^{b}
32	90	32.76	0.81^{d}	74.37	0.92^{c}	64.47	0.68^{d}
33	48	36.16	1.01^{f}	77.37	1.27^{e}	65.53	0.95^{d}
34	62	39.76	0.99^{g}	79.95	1.13^{e}	67.36	0.85^{e}
35	193	40.26	0.63^{g}	81.28	0.72^{e}	68.02	0.53^{e}
41	114	21.22	0.75^{b}	63.68	0.86^{f}	54.01	0.63^{b}
42	50	28.36	0.87^{c}	73.91	1.33^{c}	60.13	1.00^{c}
43	19	32.29	1.86^{d}	74.62	2.12^{c}	62.30	1.59^{c}
44	12	35.34	2.09^{f}	80.42	2.38^{e}	63.05	1.80^{c}
45	76	35.70	0.92^{f}	77.41	1.05^{e}	61.95	0.78^{c}

“a,b,c,d,e,f column means with common superscripts do not differ ($P < 0.05$)”

The least-square means of LBM resulting from the interaction between sex and age ($P < 0.001$) in Table 3.5, showed that there were no difference in LBM between males and females at the milk teeth stage. The differences in LW between males and females increased with the age of the animals to 3.19 kg, 3.41 kg and 6.90 kg between rams and ewes with one pair of teeth, two pairs and three pairs of teeth, respectively. Hassen *et al.* (2002) found that male and female lambs had similar weights between 30 and 90 days of age, but differed in later stages. They reported that the significance level of sex of animal on weight of indigenous Ethiopian sheep increased with age. Similar findings were reported by Blackburn and Field (1990) on Somali Blackhead sheep.

Table 3.5 Least-square means and standard errors showing effect of sex-age and age-horn interactions on live weight (LW), heart girth (HG) and wither height (WH) of Zulu sheep

Source of variation	No	LW (kg)	s.e	HG (cm)	s.e.	WH (cm)	s.e
Sex * age							
11	303	18.69	0.52[a]	61.15	0.59[a]	53.34	0.41[a]
12	75	28.85	0.90[b]	73.32	1.03[b]	60.72	0.75[b]
13	40	32.32	0.87[c]	74.78	1.45[b]	62.69	1.08[b]
14	49	36.91	1.16[d]	79.84	1.33[c]	65.34	0.99[c]
15	114	37.64	0.72[d]	78.99	0.82[c]	64.42	0.59[c]
21	610	19.60	0.48[a]	63.10	0.55[a]	54.71	0.39[a]
22	286	25.66	0.66[e]	70.15	0.55[d]	57.92	0.56[d]
23	262	28.91	0.93[b]	73.58	1.06[b]	61.14	0.79[b]
24	211	30.01	0.64[b]	75.46	1.08[b]	61.68	0.81[b]
25	690	31.80	0.43[b]	75.45	0.49[b]	62.91	0.37[b]
Age * horn							
11	153	21.74	0.66[a]	66.58	0.76[a]	57.10	0.55[a]
12	760	16.55	0.39[b]	57.68	0.44[b]	50.96	0.28[b]
21	62	27.18	0.94[c]	71.90	1.07[c]	60.99	0.80[c]
22	299	27.33	0.66[c]	72.57	0.76[c]	59.66	0.55[c]
31	28	30.69	1.42[d]	74.26	1.62[c]	61.97	1.22[c]
32	274	30.54	0.85[d]	74.09	0.97[c]	61.87	0.72[c]
41	31	32.69	1.34[e]	77.36	1.53[d]	63.03	1.15[d]
42	229	34.23	0.82[f]	77.94	0.93[d]	63.99	0.70[d]
51	161	34.88	0.62[f]	77.67	0.71[d]	63.98	0.53[d]
52	642	34.56	0.50[f]	76.77	0.57[d]	63.34	0.41[d]

“[a,b,c,d] column means with common superscripts do not differ (P < 0.05)”

Season was found to have an influence on the variation of LBM (P<0.001) (Table 3.2). Nguni were found to have larger LW and HG in summer and autumn than in winter and spring (Table 3.3). However, these differences were small (1-3 kg and 1-4 cm). Hassen *et al.* (2002) reported a less important seasonal influence on sheep aged above 150 days compared to sheep aged below 150 days. However, in this study, it was not possible to determine the interaction between season and age of sheep because of unequal subclasses.

The least-squares means for the age-horn interaction (Table 3.5) showed that the LBM of young horned sheep (with milk set of teeth) were higher by 5.19 kg, 8.90cm and 6.14 cm in LW, HG and WH, respectively, than those of the polled sheep. However, as the age of sheep increased, no differences (P> 0.05) in LBM were realized between horned and polled sheep. It is possible that there is a period of rapid growth of horns at this stage. Horn production takes energy from the animal that might be used for meat production (Carlson, 2001). Colour was found to have a significant effect on the LBM of Zulu sheep (P < 0.001). The sheep that had black colour were found to have lower LBM compared to sheep with other colours. During the collection of data, it was observed that as the black lambs grew, they gradually changed from black to a brown or dark brown colour. These results are in line with the report on *deerrunssheepfarm.com* website by Sponeburg (undated) where a mechanism called "dark brown" was explained. It was reported that sheep carrying the dark -brown gene are born nearly black. As they grow older their colour fades to a distinctive dark-brown. The dominating colour was brown (19%), combination of brown and white (18%) and black and brown (16%). Ramsay *et al.* (2000), documented that with the Nguni sheep of Zululand and Swaziland, the most common colour combination was brown and black but could include white.

In the present study a large percentage (44 %) of sheep had large ears and only 7% had ear buds (Table 3.3). However, the ear length had no influence on LBM of the Zulu sheep (Table 3.3). Among males, 41% were horned while 10% of the females had horns.

The analysis of variance for SC is presented in Table 3.6. The least- square means and standard errors for SC are shown in Table 3.7.

Table 3.6 Analysis of variance for scrotum circumference of Zulu sheep

Source of variation	DF	MS
Season	3	265.36***
Area	3	633.95***
Age	4	1909.99***
Horn	1	103.69*
Colour	8	133.20***
Year	3	155.43**
Age*horn	4	163.30***

MS : mean square ; *P < 0.05 ; **P< 0.01 ; ***P< 0.001 ; ^{ns} Non-significant

Larger SC were observed in autumn and in summer (25 and 26 cm) compared to winter and spring (23 cm). Probably, the seasonal fluctuation of fodder quality and quantity did have an influence on the SC. Dana *et al. (*2000) reported a reduced SC by 10 % on low quality diet in comparison to animals on a good quality diet. They explained that this could have been caused by loss of fat from scrotal tissue of rams maintained on poor quality diet. This is based on a report by Coulter and Kozub (1984) that a reduction in testicular size of Hereford and Angus bulls was caused by loss of fat in scrotal tissue. The rams at MRS had the highest SC (27 cm) and the rams at UNIZULU and Enqutshini had the lowest (22 and 23 cm) values. Scrotal circumference increased with age. The youngest rams with full set of milk teeth (< 15 months) had the smallest SC of 18 cm. The mature rams (three and four pairs of incisors) had the highest SC of 27 cm, whereas the rams in age groups of one and two pairs of incisors (P > .05) had an SC of 24 cm. The least-square means for interaction between age of sheep and the presence or absence of horns (Table 3.7) reflected that the difference on the SC between the horned and polled rams only occurred among young rams with full set of milk teeth (<15 months). Black rams had the lowest SC compared to rams with other colours (Table 3.7).

Table 3.7 Least-square means and standard errors for scrotum circumference of Zulu sheep

Source of variation	No	Lsm (cm)	s.e.
Summer	109	25.16	0.73[a]
Autumn	83	26.10	0.60[a]
Winter	153	23.12	0.57[b]
Spring	136	22.76	0.56[b]
UNIZULU	156	22.11	0.54[b]
Enqutshini	186	23.32	0.59[a]
Makhathini	181	27.35	0.58[a]
Owen Sithole	58	25.37	0.99[b]
Milk set	284	18.00	0.49[a]
One pair of Permanent incisor	84	24.32	0.67[a]
Two pairs of permanent incisors	45	24.26	0.89[b]
Three pairs of permanent incisors	54	27.34	0.80[c]
Four pairs of permanent incisors	114	27.58	0.59[c]
Horned	236	24.85	0.55[a]
Polled	345	23.72	0.51[b]
Colour			
Brown	90	24.78	0.69[a]
Black and white	58	22.36	0.82[a]
Brown and white	158	24.33	0.53[a]
Brown, black and white	31	25.39	1.04[a]
Black	37	20.49	0.96[b]
Dark brown	31	24.87	1.00[a]
Black and brown	94	26.11	0.62[a]
Tan	54	24.53	0.79[a]
Tan and white	28	25.69	1.10[a]
Year			
2000	41	27.32	1.32[a]
2001	239	24.65	0.51[b]
2002	161	23.17	0.57[b]
2003	145	22.62	0.65[b]
Age*horn			
11	92	20.33	0.68[a]
12	192	15.67	0.49[b]
21	43	24.54	0.87[c]
22	41	23.96	0.90[c]
31	25	24.64	1.18[c]
32	23	23.89	1.18[c]
41	25	27.43	0.99[d]
42	60	27.25	0.87[d]
51	54	27.33	0.79[d]
52	60	27.82	0.75[d]

"[a,b,c,d] column means with common superscripts do not differ ($P < 0.05$)"

3.6 Conclusion

Zulu sheep are a multi-coloured breed. The LBM of the males are higher than those of females, the difference in LBM between males and females increase with age of sheep. The rams are more affected in terms LW by change of their usual environment than the ewes. The highest LW and HG for mature Zulu rams was 38 kg and 80 cm, respectively whilst the ewes were 32 kg and 76cm. A difference of up to 12 kg can be observed between Zulu sheep of the same age in different populations. A study on genetic variation between and within the populations would be necessary to make conclusive statements on the findings from this study. Scientific research on how the change of environment affects the rams and the ewes would enlighten some of the observations made on this research. Observations on effect of dehorning Zulu sheep on LW performance may also explain some of the findings in this study. It can also be concluded from this study that although the Zulu sheep have varied ear length type, this character is not correlated to the LBM of Zulu sheep. The results of this study will be used as a benchmark for further studied to predict live weight using LBM as a tool for efficient measurements in rural areas. It is also envisaged that the results of this work could be used to support genetic analyses to determine genetic variation between and within these small populations to develop an effective conservation and utilization programme.

CHAPTER 4

DETERMINATION OF PREDICTION EQUATIONS FOR ESTIMATING BODY WEIGHT OF ZULU (NGUNI) SHEEP[3]

4.1 Abstract

Data on linear body measurements (LBM) of 403 sheep collected in three areas of KwaZulu-Natal were utilized to develop a prediction equation for live body weight of Zulu sheep. Data were collected on live weight (LW), heart girth (HG), wither height (WH) and scrotum circumference (SC) on sheep of all ages. The age of sheep was estimated by dentition. The analysis of variance showed that age and sex were important factors contributing to variation in LW of Zulu sheep. Phenotypic correlation coefficients and regression equations of LW on HG, WH and SC were computed within different age groups (milk set of teeth, one pair, two pairs and the three and four pairs of incisors). Low correlation coefficients (r = 0.21 – 0.48) between LW, HG and WH were found among the pregnant ewes. The relationship between LBM and LW was stronger (r = 0.66-0.86) for males than among females (r = 0.42-0.75). The cubic polynomial of HG was the best fit (R^2 = 0.76) for the live weight prediction of young sheep with milk set of teeth. The combination of HG and WH produced the best fit for the two tooth and above males and non-pregnant females. The LW prediction equations for pregnant females were not reliable (R^2 = 0.05 -0.26). The SC was more precise (R^2 = 0.61- 0.79) when estimating the live weight of young males (<15 - 22 month old) than of the older rams (R^2 = 0 .23-0.56). It was concluded that LW of Zulu sheep can be reasonably estimated using the HG and WH. A table could be constructed for the farmers to estimate the LW of their animals.

4.2 Keywords

Live weight; correlation; sheep; regression.

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[3] Kunene N.W., Nesamvuni, A.E., Nsahlai, I.V., 2009. Determination of prediction equation for estimating body weight of Zulu (Nguni) sheep. Small ruminant Res. 84, 41- 46.

4.3 Introduction

The Nguni sheep of Zululand (KwaZulu-Natal province) are called the Zulu sheep (Ramsay *et al.*, 2000). This breed is indigenous and is kept mainly by rural livestock farmers in South Africa. The Zulu sheep are sources of food and for income generation. During a survey on livestock production in rural KwaZulu-Natal, the reasons given by communal farmers for keeping Nguni sheep, included the ability of the breed to resist many diseases and produce quality meat (Kunene and Fossey, 2006). In addition, Ramsay *et al.* (2000) recommended this breed as the best alternative for sustainable meat production in the rural areas because of their ability to tolerate external and internal parasites, tick-borne diseases and their good walking and foraging ability. Body weight is important for assessing the condition of the animal represents a criterion of selection. The dosage of medication during health care and the required amount of feed depends on the weight of the animal. Though body weight is an important economic trait, it is rarely measured by rural livestock farmers due to lack of weighing scales. Small scale farmers rely on guess-estimates of the animal's body weight, which add to inaccuracies in animal husbandry practices (Slippers *et al.*, 2000). Often marketing of animals is customary based on visual assessment (Ojedapo *et al.*, 2007). Thiruvenkadan (2005) highlighted that this problem could be overcome by regressing body weight on a number of body characteristics which can be measured easily. Such a method has been used by several authors for different species. The heart girth has been used to predict body weight in various species of some indigenous animals like the sheep of Cameroon, goats in West Africa and cattle in South Africa (Thys and Hardouin, 1991; Mayaka *et al.*, 1995; Nesamvuni *et al.*, 2000). It has been observed, however, that different models might be needed to predict body weight in different environmental conditions, body condition and breeds (Enevoldsen and Kristensen, 1997). The testicular growth and development was reported by Dunn (1955) to be closely related to male body size. Bongso *et al.* (1982) found that male goats with higher values of testicular parameters including scrotal circumference (SC) had higher body weights. Little work has been done on use of linear body measurements (LBM) or of scrotal circumference of Nguni sheep and their possible use for estimating body weight. The objectives of this study were (i) to estimate the phenotypic relationships among LW, HG, WH and SC of the Zulu sheep, (ii) to derive prediction equations for live weight (LW) of the Zulu sheep using the heart girth (HG) and/or wither height (WH) and (iii) to establish the best regression model for estimating the LW of Zulu rams using the SC.

4.4 Materials and Methods

Data consisting of LW, HG, WH and SC records of 403 Zulu sheep of different ages were collected for this study. The sheep were reared at the University of Zululand (UNIZULU), Makhathini research station (MRS) and Enqutshini/KwaMthethwa community. These areas are located at $28^0 51^{'}$S:$31^0$51'E, $25^0$27'S:$32^0$10'E and $28^0$37'S:$31^0$55'E respectively. The sheep were grazed on natural pastures. The dominating grass species in these areas were *Hyparrhenia hirta, Pennisetum clandestinum* and *Panicum maximum* and *Sporobolus species,* respectively. The age of animals was estimated by counting permanent incisors as described by Gatenby (1991). Data on body measurements were collected using a measuring tape as described by Fourie *et al.* (2002). The SC of the 133 male sheep was measured using the method described by Schoeman and Combrink (1987). The analysis included the least-squares analysis of variance conducted using the general linear model (GLM), the regression and Pearson correlation coefficients procedures of Minitab Inc. (1998). Preliminary results showed that sex and age strongly influenced the variation in LW of the Zulu sheep. The results showed that according to live weight, the age of Nguni sheep could be grouped into four classes; the milk set of teeth; one pair of incisors; two pairs of incisors; the three and four pairs of incisors as one group. The analysis of variance was done within these age groups. The model equation used for each age group was:

$$Y_{ijpr} = \mu + L_i + P_j + S_p + e_{ijpr}$$

where:

$Y_{ijpr}$is the r^{th} record of LW

μ = effect common to all sheep

L_i = effect of i^{th} location (1 = UNIZULU, 2 = Enqutshini and 3 = Makhathini

P_j = effect of j^{th} status of pregnancy (1 = pregnant and 2 = non-pregnant)

S_p = effect of p^{th} sex (1 male and 2 female)

e_{ijpr} = random error

Ages associated with dentition status were as follows: milk set of teeth = <15 months; one pair of incisors = 15 - 22 months; two pairs of incisors = 22-28 months; three and four pairs of incisors = > 28 months.

Since there were limited number of observations for the pregnant sheep (<15) among the group with milk set of teeth, the data of pregnant sheep in this group were excluded.

Prediction equations were developed for different age and/or sex groups according to results obtained from the analysis. The extent of multicollinearity was assessed using the variance inflation factor (VIF) of Minitab (1998). According to the Minitab (1998) manual if the VIF is >5-10, then the regression coefficients are poorly estimated. The following regression model was used:

$$Y_i = b_o + b_1X_{ik} + b_2X^2_{ik} + b_3X^3_{ik} + e_i$$

where;

Y_i = observation on LW

b_o = intercept

b_1,b_2,b_3 = corresponding linear, quadratic and cubic regression coefficients;

X_{ik} = body measurements k (HG, WH or SC) on the i^{th} animal

e_i = residual error.

The estimated LW equations were tested by randomly selected data using a procedure of Minitab (1998) and the randomly selected data were not included in the analysis.

4.5 Results and discussion

Table 4.1 indicates that the location and the status of pregnancy were the common factors causing variation to the body live weight of Zulu sheep of all ages. Sex had no influence on the variation of LW of the sheep with milk sets of teeth but was an important factor among the older age groups. Frandson and Elmer (1981) have clarified that in young males, the androgen (which has a growth and weight stimulating effect) is not released until the testes are well developed. This could partly be the cause of the non significant difference between the live weight of the young Zulu rams and ewes with milk sets of teeth. Consequently, regression models for predicting LW of Zulu sheep of 15 months and above may better be developed within sex groups.

Table 4.1 Analysis of variance for LW of Nguni sheep for various age groups

Number of observation (n)	Age	Sources	DF	LW Mean Square (MS)
65	Milk set	Location	2	2314.40***
		Sex	1	88.80^{ns}
108	One pair	Location	2	2500.80***
		Pregnancy status	1	1046.50***
		Sex	1	586.40***
119	Two pairs	Location	2	1646.50***
		Pregnancy status	1	527.60***
		Sex	1	618.80***
111	Three and four pairs	Location	2	6247.50***
		Pregnancy Status	1	5654.50***
		Sex	1	1279.50***

*P < 0.05, **P < 0.01, ***P< 0.001, ^{ns} P>0.05

The Pearson correlation coefficients (r) for LW with HG, WH and SC (for males) were positive and ranged from 0.21 to 0.86 as shown in Table 4.2. The highly significant (P < .001) and stronger relationship (r = 0.42-0.86) between LW, HG and WH were obtained among the rams and the non pregnant ewes indicating that the LBM could be reliable estimators of LW for such animals. Lower correlation coefficients (r = 0.21-0.48) were found between the LBM and body weight of the pregnant ewes. Low correlation is a confirmation of non-suitability of HG and WH as a measure of LW of pregnant females in Zulu sheep. Furthermore, it is worth noting that in overall, the relationship between the LW and LBM is weaker in females than in males. Hassan and Ciroma (1990) and Fajemilehin and Salako (2008) also reported higher correlation coefficients for males than females in most cases between LW and WH or HG or Body length of Red Sokoto goats in different age groups and West African Dwarf goats, respectively.

The relationship between LW and SC of the mature rams with three pairs of incisors and above was not strong (r = 0.44 - 0.49) as between these parameters among younger rams with one pair and two pairs of teeth (r = 0.56 - 0.74). Fourie *et al.* (2002) reported medium correlations between SC and HG (0.47) or LW (0.50) of young Dorper rams (4 - 6 months of age) in Northern Cape and Free State in South Africa.

Tables 4.3- 4.6 show the regression equations predicting LW of Zulu sheep at different age categories. All the models of LW computed with HG and WH combination had lower VIFs than the proposed cut-off range of 5-10 by Minitab (1998) thus indicating that there was no serious collinearity problem among the two variables.

It is evident that for the young Zulu sheep (< 15 months) the HG is a more accurate predictor of LW compared to the WH (Table 4.3). The coefficient of determination (R^2) based on the use of linear HG was 0.71 but the third degree polynomial of HG increased R^2 to 0.76. Atta and El Khidir (2004) also reported an increased coefficient of determination based on curvilinear functions when estimating the live weight using HG of two to eight month old Nilotic sheep. Lawrence and Fowler (1997) reported that the relationship between LW and HG is curvilinear for animals growing over a wide weight range. Goe *et al.* (2001) suggested that higher order polynomial equations are more appropriate for predicting the weight of growing animals. Although the use of WH produced fairly good estimates (R^2 = 0.64 - 0.67) of LW for the sheep with milk set of teeth, these results indicate that more parameters would need to be added to WH to obtain a higher R^2. The LW regression equation constructed from HG and WH increased the coefficient of determination to 0.73. Thiruvenkadan (2005) obtained higher R^2 when he used WH and HG compared to the use of WH or HG alone to compute LW equation of 1-12 months old Kanni-Adu goats in India.

Table 4.2 Phenotypic correlations between live weight (LW), heart girth (HG), wither height (WH) and scrotal circumference (SC) of Zulu (Nguni) sheep in different age groups

Age	No. of observations		HG	WH	LW
Milk set of teeth	65	WH	0.86***		
		LW	0.84***	0.80***	
One pair of incisors Males	31	WH	0.77***		
		LW	0.79***	0.78***	
		SC	0.56***	0.69***	0.72***
One pair of incisors Pregnant females	36	WH	0.39**		
		LW	0.48**	0.43*	
One pair of incisors Non-pregnant females	41	WH	0.60***		
		LW	0.75***	0.67***	
Two pairs of incisors Males	35	WH	0.76***		
		LW	0.86***	0.84***	
		SC	0.74***	0.68***	0.73***
Two pairs of incisors Pregnant females	39	WH	0.35**		
		LW	0.33**	0.43**	
Two pairs of incisors Non-pregnant females	45	WH	0.53***		
		LW	0.68***	0.56***	
Three and four pairs of incisors Males	30	WH	0.66***		
		LW	0.75***	0.78***	
		SC	0.47***	0.44***	0.49***
Three and four pairs of incisors Pregnant females	31	WH	0.25***		
		LW	0.42***	0.21***	
Three and four pairs of incisors Non-pregnant females	50	WH	0.42***		
		LW	0.65***	0.45***	

*P < 0.05, **P < 0.01, ***P< 0.001

Table 4.3 Regression equations for predicting live weight of Zulu sheep with milk set of teeth using heart girth and wither height

Age group	Model	Intercept	Linear	Linear	Quadratic	Cubic	Adj.R^2
Milk	LW_1	-21.4	0.40 HG	0.28 WH			0.73[a]
set	LW_2	-17.30	0.58 HG				0.71
teeth	LW_3	33.42	-1.98 HG		$4.02 \times 10^{-2} HG^2$	$-1.97 \times 10^{-4} HG^3$	0.76
	LW_4	-21.8	0.73 WH				0.64
	LW_5	109.53	-6.83 WH		$0.14\ WH^2$	$-8.32 \times 10^{-4} WH^3$	0.67

[a] VIF = 3.3

Tables 4.4- 4.6 show that the linear body measurements were not a good estimate of LW of pregnant ewes. R^2 was found to range from 0.05 to 0.26 suggesting that the change in LW of pregnant sheep does not correspond to the change in LBM. Mohammed and Amin (1996) reported a high relationship (r = 0.71) between LW and HG of adult does at advanced pregnancy in Sahel does. However, for this study, the level of pregnancy of the ewes was not recorded and therefore the fact that the females at different levels of pregnancy within the different age groups are mixed, may have contributed to the two parameters being less variable for body weight.

Based on the linear and polynomial regression models, the live weight changes with linear body measurements of rams and non-pregnant Zulu sheep with one or more pairs of incisors. These changes were strongly predictable in males with R^2 ranging from 0.49 to 0.81 (Tables 4.4 -4.6). The coefficients of determination for the estimates of LW among females that were not pregnant ranged from 0.20 to 0.64. In both genders, the use of heart girth and wither height increased R^2 (0.54 - 0.81) compared to the use of simple or multiple regression of heart girth or wither height on body weight (R^2 = 0.20 - 0.75). However, linear and the polynomials of HG were considered to be fairly good estimates (R^2 = 0.47- 0.75). When working with Nilotic sheep Atta and El Khidir (2004) observed that the prediction of live body weight based on heart girth increased the coefficient of determination compared to the use of wither height. Lawrence and Fowler (1997) reported that in farm animals, the skeletal measurements (wither height and body length) were less variable for body weight compared to heart girth. Thiruvenkadan (2005) attributed such findings to the fact that the height is due to growth of bones whose function of increase in weight is probably not proportionate to increase in body weight. He suggested that the higher association of body weight with HG was possibly due to a larger contribution in body weight by the girth consisting of bones, muscles and viscera.

The fact that higher R^2 were realized in males than in females may be explained by the likely difference of the fat deposition in the two sexes as suggested by Bassano *et al.* (2001). However, contrary to these results Adeyinka and Mohammed (2006) found the prediction equations of live weight using heart girth, wither height and body length to be more accurate in females than in male Nigerian Sekoto goats. Similar observations were reported by Thys and Hardouin (1991) on sheep in Cameroon but they attributed their findings to the distribution of ages in their sex groups. The accuracy of LW estimates from HG and/or WH decreased with the age of ewes from 15 months and of males from 22 months.

Table 4.4 Regression equations for predicting live weight of Zulu sheep with one pair of incisors based on heart girth, wither height

Age group	Model	Intercept	Linear	Linear	Quadratic	Cubic	Adj R^2
One pair of incisor (males)	LW_1	-56.80	0.63HG	0.63 WH			0.73[a]
	LW_2	-45.90	1.02HG				0.63
	LW_3	-6.24	-.048HG		$7.17 \times 10^{-3}HG^2$		0.65
	LW_4	-47.70	1.11WH				0.60
	LW_5	683.67	-33.37WH		$0.54WH^2$	$-2.81 \times 10^{-3}WH^3$	0.62
One pair of incisors (non-pregnant females)	LW_1	-35.50	0.52HG	0.40 WH			0.64[b]
	LW_2	-24.40	0.69HG				0.57
	LW_3	-28.76	0.81HG		$-9.36 \times 10^{-4} HG^2$		0.57
	LW_4	-24.23	0.80WH				0.45
	LW_5	767.62	41.27WH		$0.74 WH^2$	$-4.29 \times 10^{-3}WH^3$	0.50
One pair of incisors (pregnant females)	LW_1	5.51	0.40HG	-0.08WH			0.20[c]
	LW_2	-3.40	0.45HG				0.26
	LW_3	99.47	-2.16HG		$0.65 \times 10^{-2}HG^2$		0.25
	LW_4	-4640.05	183.60HG		$-2.40 HG^2$	$1.05 \times 10^{-2} HG^3$	0.18
	LW_5	23.60	0.12WH				0.15

[a]VIF = 1.9, [b] VIF = 1.4, [c]VIF = 1.2

Table 4.5 Regression equations predicting live weight of Zulu sheep with two pairs of incisors based on heart girth, wither height

Age	Model	Intercept	Linear	Linear	Quadratic	Cubic	AdJ R^2
Two pairs of incisors Males	LW_1	-49.70	0.53 HG	0.65WH			0.81[a]
	LW_2	-34.00	0.88 HG				0.73
	LW_3	433.28	-18.95HG		0.28 HG^2	$-1.28x10^{-3}HG^3$	0.75
	LW_4	-46.80	1.22 WH				0.70
	LW_5	-136.71	4.03 WH		$-2.17x10^{-2}WH^2$		0.72
	LW_6	873.97	-44.14 WH		0.73 WH^2	$-3.94x10^{-3}WH^3$	0.75
Two pairs of incisors (non-pregnant females)	LW_1	-38.00	0.55 HG	0.40WH			0.54[b]
	LW_2	-24.30	0.70 HG				0.51
	LW_3	-232.69	9.60 HG		-0.12 HG^2	$5.95x10^{-4}HG^3$	0.53
	LW_4	-19.70	0.74 WH				0.32
	LW_5	343.64	-15.97 WH		-0.25 WH^2	$1.27x10^{-3}$ WH^3	0.34
Two pairs of incisors (pregnant females)	LW_1	17.50	0.08 HG	0.10WH			0.16[c]
	LW_2	21.30	0.12 HG				0.15
	LW_3	-245.76	6.97 HG		$-4.38x10^{-2}HG^2$		0.19
	LW_4	-989.56	35.21 HG		-0.40 HG^2	$1.48 \times 10^{-3}HG^3$	0.21
	LW_5	21.80	0.13 WH				0.16

[a] VIF = 2.3, [b] VIF = 1.3, [c] VIF = 1.2

The trend shown in Tables 4.4 - 4.6 implies that the relationship between growth and LW decreased with the increase in age. This may be explained by the fact that at maturity, linear body measurements are essentially constant, thereby reflecting heritable size skeleton as suggested by Jeffrey and Berg (1972) and Fajemilehin and Salako (2008). Atta and El Khidir (2004) found similar estimates of LW equations using HG or WH for both males and female lambs of Nilotic sheep aged two to eight months but these estimates were different for the adult sheep. But also, the fact that the condition of the animals is not usually uniform can also affect the accuracy of LW prediction models based on body measurements like the HG. This could be a consequence of poor protein and energy nutrition. Goe *et al.* (2001) observed that regression equations of LW using heart girth of Ethiopian working oxen were more accurate when the oxen were heaviest.

The results in Table 4.7 indicate that SC is more reliable for estimating the LW of young Zulu sheep rams (with milk set and one pair of teeth) than for older rams. It may be necessary to include more variables to SC to get a reliable LW equation for the adult rams. In their work Raji *et al.* (2008) found R^2 to be 0 .414 when using the SC alone to determine the LW of Borno white goats, however, when they included more variables ie. scrotal length and testicular weight, R^2 increased to 0.625. Although in these results the coefficients of determination were slightly higher for the polynomial than those of the simple linear regression models using SC, the differences were minimal. Hence both types of equations can be used to best estimate the live body weight of Zulu sheep aged 22 months and below.

Table 4.6 Regression equations predicting live weight of Zulu sheep with three and four pairs of incisors based on heart girth, wither height

	Model	Intercept	Linear	Linear	Quadratic	Cubic	Adj R^2
Males	LW_1	-56.20	0.54HG	0.80 WH			0.66[a]
	LW_2	-35.60	0.93 HG				0.49
	LW_3	941.79	-36.11 HG		$0.47HG^2$	$1.93x10^{-3}HG^3$	0.51
	LW_4	-40.50	1.17 WH				0.55
	LW_4	-61.11	1.78 WH		$-4.5x10^3WH^2$		0.56
Three and four pairs (Non pregnant females)	LW_1	-35.00	0.66HG	0.25 WH			0.54[b]
	LW_2	-25.00	0.74 HG				0.48
	LW_3	-0.02	0.06HG		$4.55x10^{-3}HG^2$	$3.15x10^{-3}WH^3$	0.47
	LW_4	-8.47	0.61 WH				0.20
	LW_5	843.12	-39.14WH		$-0.62WH^2$		0.23
Three and four pairs (pregnant females)	LW_1	-10.40	0.46HG	0.13 WH			0.18[c]
	LW_2	-4.63	0.49 HG		$-2.29x10^{-2}HG^2$		0.17
	LW_3	-144.62	4.07HG		$1.30HG^2$	$-5.64x10^{-3}HG^3$	0.19
	LW_4	2506.78	-98.50 HG				0.23
	LW_5	17.80	0.25 WH				0.05
	LW_6	627.92	-26.80WH		$0.40WH^2$	$-1.90x10^{-3}WH^3$	0.07

[a] VIF = 2.2, [b] VIF = 1.5, [c]VIF = 2.2

Table 4.7 Regression equations predicting live weight of Zulu rams based on Scrotum circumference

	Model	Intercept	Linear	Quadratic	Cubic	Adj R^2
Milk set of teeth n = 37	LW_1	-1.01	1.08SC			0.78
	LW_2	3.31	0.19 SC	0.05 SC^2	$-9.25x\ 10^{-4}SC^3$	0.80
One pair of incisors n =31	LW_1	-9.66	1.53 SC			0.61
	LW_2	70.68	-8.47 SC	0.40 SC^2	$-5.12x10^{-3}SC^3$	0.64
Two pairs of incisors n = 35	LW_1	-13.0	1.78 SC			0.49
	LW_2	43.80	-3.27SC	0.11 SC^2		0.56
Three and four pairs of teeth n = 30	LW_1	10.50	0.95 SC			0.23
	LW_2	38.05	-4.21 SC	0.23 SC^2	$-3.12x10^{-3}SC^3$	0.38

Table 4.8 shows the predicted against the observed LW of the Zulu sheep at various age groups and locations for an independent data set based on equations with high R^2. The predicted and observed are reasonably close to warrant the use of this equation set to predict live weight particularly where other methods of measuring live weight are lacking.

Table 4.8 Observed and Estimated LW for Zulu sheep

Observed								Predicted
SC	Age	Area	Sex	HG	WH	LW	Equation/equations	
	1	2	2	66	60	23.45	Cubic polynomial of HG	22.82
	1	3	2	62	56	19.00	Cubic polynomial of HG	18.24
	2	1	2	66	61	23.50	HG and WH linear combination	23.21
	1	3	1	54	50	11.50	Cubic polynomial of HG	12.70
	4	3	1	81	73	44.00	HG and WH linear combination	46.14
	3	1	2	63	56	20.00	HG and WH linear combination	20.90
	5	2	2	76	60	32.00	HG and WH linear combination	30.16
	5	3	2	75	61	29.50	HG and WH linear combination	29.75
	2	1	2	66	61	23.00	HG and WH linear combination	22.00
	4	3	1	70	66	29.50	HG and WH linear combination	30.30
	2	2	2	58	57	17.00	Cubic polynomial of HG	17.46
19	1	2	1	63	54	19.00	Cubic polynomial of SC	18.63
26	2	3	1	75	63	31.00	Cubic polynomial of SC	30.87
18	1	2	1	62	52	18.34	Linear regression of SC	18.43
19	1	1	1	61	52	18.00	Cubic polynomial of SC	18.53
24	1	2	1	69	60	23.50	Cubic polynomial of SC	23.88

SC = Scrotum circumference, HG = Heart girth, WH = Wither height, LW= live weight

4.6 Conclusion

The regression coefficients of HG and WH or HG to LW have shown that such parameters could be used to estimate the body weight of the Zulu sheep. From these results, it is safe to infer that the prediction of LW from Zulu sheep with milk set of teeth can be best estimated from the equation of cubic polynomial of HG whereas the LW of Zulu sheep with one pair of incisors and older excluding pregnant females would be best estimated from the equations obtained from the linear regression using HG and WH. Conversion tables can be established and be given to rural livestock farmers for use. Research work on estimating LW for pregnant ewes, using HG and WH at different stages of pregnancy may give more insight if these parameters can be used to estimate the LW of such Zulu sheep.

CHAPTER 5

GENETIC AND PHENOTYPIC DIVERSITY IN ZULU SHEEP POPULATIONS: IMPLICATIONS FOR EXPLOITATION AND CONSERVATION[4]

5.1 Abstract

Zulu sheep are indigenous to KwaZulu-Natal, South Africa and provide food security for traditional farmers. Through traditional selection they adapted to the climatic conditions of KwaZulu-Natal. The goal of this study was to use genetic diversity and existing phenotypic data for the breed to argue exploitation opportunities and conservation needs. Three populations (52 Zulu sheep) were included and random amplified polymorphic DNA profiles were used to provide genetic diversity data. A similarity matrix consisting of 2744 RAPD bands (~46.0% polymorphic) was constructed. Complete linkage analysis indicated lowest genetic similarity (88.96%) within the Makhathini population, greatest (94.83%) in the UNIZULU population and intermediate (91.38%) in the KwaMthethwa population. Similar phenotypic similarity was observed for UNIZULU and Makhathini populations (58.75% and 54.63% respectively). Complete linkage dendrograms for genetic and linear body measurement data also show that UNIZULU and Makhathini populations are more closely related to each other than to the KwaMthethwa. This study demonstrated usefulness of RAPD profiling for genetic data for Zulu sheep[5]. It also demonstrated that phenotypic and genetic data could be sensibly combined into a single database for this sheep breed. This is important since such information will be critical for decisions regarding Zulu sheep breed exploitation and conservation.

5.2 Keywords: Zulu sheep, conservation, genetic characterisation, RAPDs, linear size traits

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[4] Kunene, N.W., Bezuidenhout, C.C., Nsahlai, I.V. 2009. Genetic and phenotypic diversity in Zulu sheep populations: Implications for exploitation and conservation. Small Ruminant Res: 84, 100 -107.

[5] Initial genetic diversity results were presented at the World Congress of Animal Production, Cape Town 23 – 28 November 2008 as a poster presentation.

5.3 Introduction

In developing countries, indigenous sheep and goat breeds (small ruminants) are important for subsistence and socio-economic livelihoods of rural and peri-urban communities (Dovie *et al.*, 2006; Kunene and Fossey, 2006; Kosgey and Okeyo, 2007). It is estimated that 20% of animal breeds are at risk of extinction. Furthermore, it is estimated that 70% of animal breeds for which no extinction risk data is available is in the developing world.

Indigenous sheep breeds are a valuable source of genetic material due to adaptation to local, sometimes, harsh environmental conditions, nutritional fluctuations and resistance to diseases and parasites (Nsoso *et al.*, 2004; Kunene and Fossey, 2006; Kosgey and Okeyo, 2007; Galal *et al.*, 2008). It is estimated that globally 14% of sheep breeds already have become extinct. By 2000, 147 existing African sheep breeds were recognized (Taberlet *et al.*, 2008). It was estimated by FAO (2007) that already 180 sheep breeds were extinct world-wide and 5 of these were from the African continent. Reasons for indigenous sheep breeds becoming extinct could be ascribed to economic (cross-breeding with industrial breeds, abandoning traditional breeds and change to the presently more competitive industrial breeds) or socio-political reasons (preserving genetic resources of domestic breeds does not have the same image as preserving wild animals such as the black rhino or the cheetah (Taberlet *et al.*, 2008). Several recent studies are arguing for the conservation of indigenous genetic resources, including sheep breeds (Dovie *et al.*, 2006; Du Toit, 2008; Gizaw, 2008; Mariante *et al.*, 2009; Taberlet *et al.*, 2008).

Zulu sheep is one of the Nguni sheep breeds. The ancestors of this breed were brought to the east coast of South Africa (between 200 – 400 AD) by the Nguni people (Kruger, 2001; Du Toit, 2008). Zulu sheep are adapted to the high rain fall and humid KwaZulu-Natal climatic conditions and can tolerate parasites indigenous to this region (Kruger, 2001; Kunene and Fossey, 2006; Du Toit, 2008). The morphological characteristics of the sheep breed had been described elsewhere (Kruger, 2001; Kunene and Fossey, 2006; Kunene *et al.*, 2007) and could potentially be ascribed to a broad ancestral gene pool (Kruger, 2001). It could be argued that this broad gene pool may harbour genes necessary for future adaptations. Furthermore, it has also been reported by Kruger (2001) that the numbers of these sheep are rapidly declining. At round table talks in Paris, prominent scientists warned that indigenous domestic animal breeds (including Zulu sheep) may face extinction unless immediate conservation measurements are taken (Du Toit, 2008). However, there is no extensive database for phenotypic and genetic characterisation of this breed (Kunene and Fossey, 2006; Kunene *et al.*, 2007; 2008). Some general morphological characteristics and utilization data (Kruger, 2001; Kunene and Fossey, 2006), linear body measurements (Kunene *et al.*, 2007) and preliminary genetic characterisation (Buduram, 2004; Kunene *et al.*, 2008) is available. These data are insufficient and there is a need to further expand on it.

A number of DNA profiling techniques have been developed for estimating genetic polymorphisms in populations. The techniques include restriction fragment length polymorphisms (RFLP), microsatellites, single nucleotide polymorphism (SNP's) and random amplified polymorphic DNA sequences (RAPDs). These methods are polymerase chain reaction (PCR) based and have been used in sheep genetic diversity studies (Kantanen *et al.*,1995; Buduram, 2004; Dalvit *et al.*, 2008; Mariante *et al.*, 2009) and mapping of the sheep genome (Cushwa *et al.*, 1996; Maddox and Cockett, 2007). RAPD analysis is a cost effective DNA profiling method that may be useful for initial screening of populations for genetic diversity. Random DNA fragments are amplified by PCR using short (10 bp) oligonucleotides (Williams *et al.*, 1990). The method is not labour intensive and also not technically challenging. Infrastructure and equipment required for successful RAPD studies are minimal, making this technique attractive as an initial method for screening for DNA based diversity. RAPD analysis had been successfully used in sheep genetic diversity studies (Kantanen *et al.*, 1995; Ali, 2003; Kumar *et al.*, 2003; Devrim *et al.*, 2007; Elmaci *et al.*, 2007; Dalvit *et al.*, 2008; Mariante *et al.*, 2009).

The aim of this study was to use the genetic and phenotypic characterisation data to argue exploitation opportunities and the need for conservation of Zulu sheep. Objectives were to (i) provide preliminary genetic diversity data for Zulu sheep and (ii) link this data to some existing linear body measurement (phenotypic) data.

5.4 Materials and Methods

5.4.1 Blood samples and location of populations

Blood samples (5-10 ml) were collected from jugular vein into EDTA containing tubes. Zulu sheep were from the three populations (Figure 5.1): Makhathini Research Station (27°38’15; 32°10’E; 16 individuals), University of Zululand (UNIZULU: 28°51’S;31°51’E; 19 individuals) and KwaMthethwa community (28°37’S; 31°55’E; 19 individuals). The Zulu goats (2 individuals) were from the Owen Sithole Agricultural College farm (27°38’S; 31°56’E). The Merino sheep (3 individuals) were reared at a farm at Melmoth (28°58’S; 31°40’ E).

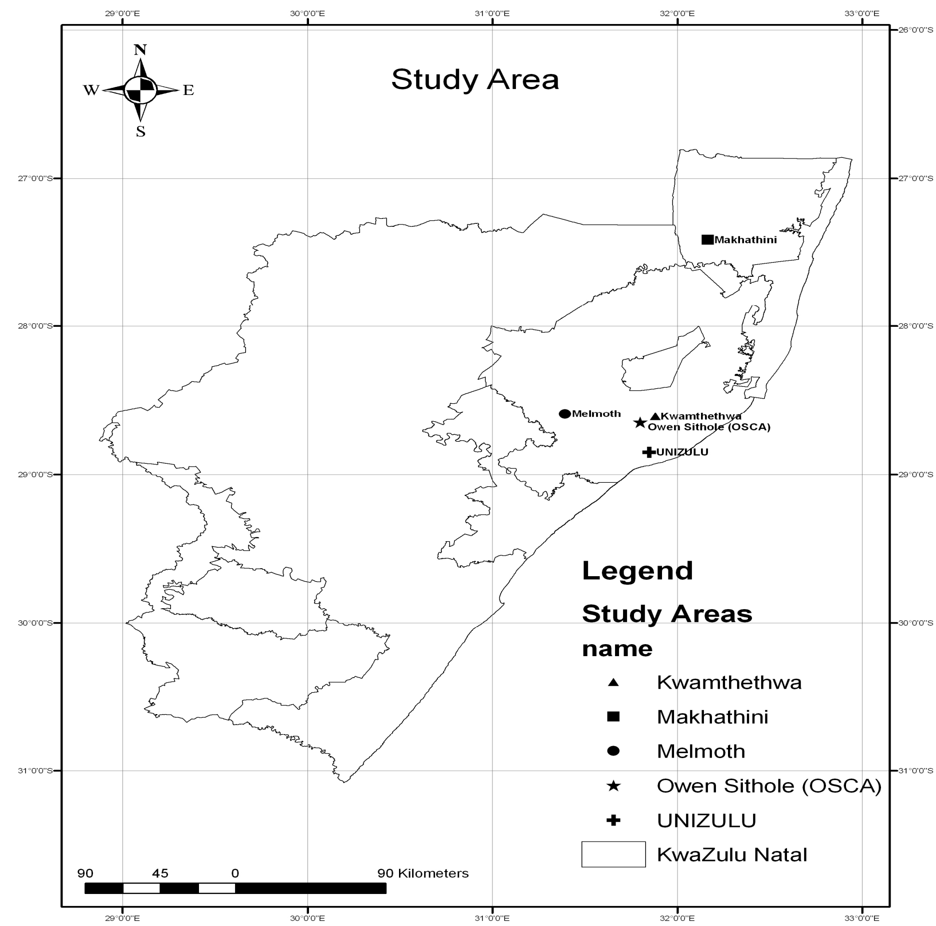

Figure 5.1 Geographical locations of the sampled sheep and goat populations in the areas of Kwazulu-Natal (South Africa).

5.4.2 DNA isolation and RAPD-PCR analysis

DNA was extracted from 100µl of blood using a modified procedure of Sharma *et al.* (2000) and RAPD-PCR amplifications performed using the procedure of Williams *et al.* (1990). Primers were supplied by Operon technologies (Cologne, Germany), and the PCR reagents by Fermentas (US). Twenty one random oligonucleotide primers were screened. RAPD-PCR amplifications were carried in a 25µl reaction mixture containing 12.5µl of 2XPCR master mix (0.05U/µl Taq polymerase, 4mM $MgCl_2$, and 0.4mm dNTPs; Fermentas, US), 50pmole primer, 100ng DNA and additional 2U of *Taq* DNA polymerase (Fermentas, US) and 4mM of $MgCl_2$ (Fermentas, US). The PCR reaction consisted of an initial denaturing step at 95°C for 300 seconds, followed by annealing at 36°C for 30 seconds. This was followed by 35 cycles of amplification at 95^{o}C for 30 seconds, annealing at 36°C and extension at 72°C for 60 seconds. A final extension at 72°C for 300 seconds was also included. PCRs were conducted in a Hybaid OMN E- thermal cycler (Hybaid, UK). Amplified segments were resolved on 1.5% ($^{w}/_{v}$) agarose gels stained with ethidium bromide.

Images were captured using a Gene Genius bio-imager and GeneSnap software (SynGene, UK). A 100bp DNA ladder (O'RangeRuler, 100bp Fermentas, US) was used as molecular size marker.

5.4.3 Statistical analysis

RAPD-PCR profiles were compared and analysed using GeneTools (version 3.00.22) software (SynGene, UK). Presence, absence and intensity of band data were obtained, exported to Microsoft Excel (Microsoft Office, 2003) and used to generate a data matrix. The data matrix was analysed using Minitab software (1998). Unweighted pair group method with arithmetic mean (UPGMA) and complete linkage algorithms were used to analyze the similarity matrix data. Relationships between the various profiles were expressed as dendrograms.

5.4.4 Phenotypic measurements

Data on linear body measurements of Zulu sheep populations were first published in Kunene *et al.* (2007). The data used in this article were extracted from the mentioned article.

5.5 Results

Originally 21 RAPD primers from Operon were screened. Six primers listed in Table 5.1 below (OPA 1, OPA 10, OPA 16, OPA 18, OPB 1 and OPB 17) gave clear polymorphic bands that were reproducible under similar conditions. Control reactions that did not have either primer or template DNA did not show any amplification products. For the 52 Zulu sheep, 3 Merino and 2 Zulu goat representatives, a total of 2744 scorable bands were amplified. Of these 1262 (~46.0%) were polymorphic. Each band was assumed to correspond to one locus. The banding profiles, total number of bands as well as number of polymorphic bands were primer dependant. The number of amplified loci per individual varied from 4-9, with a size range varying from 0.22 to 2.00 kb (Table 5.1). Such size ranges of RAPD bands were also observed in previous studies (Ali, 2003; Kumar *et al.*, 2003; Devrim *et al.*, 2007; Elmaci *et al.*, 2007).

Table 5.1 List of RAPD primers used in determining genetic similarity within and among three Zulu sheep populations. (C = cytosine; G = guanine; kb = kilobase)

No	Primer	Sequence 5'-3'	C+G %	Total number of scored bands	Polymorphic Bands	Bands size range (kb)
1	OPA 01	CAG GCC CTT C	70	436	94	0.24 – 0.90
2	OPA 10	GTG ATC GCA G	60	581	296	0.24 - 1.24
3	OPA 16	AGC CAG CGA A	60	310	139	0.22 - 1.30
4	OPA 18	AGG TGA CCG T	60	577	349	0.28 - 1.20
5	OPB 01	GTT TCG CTC C	60	411	240	0.34 - 2.00
6	OPB 17	AGG GAA CGA G	60	429	144	0.30 - 1.30
		Total		**2744**	**1262**	

Figures 5.2 and 5.3 are examples gels that were analysed. It shows the range of bands as well as differences and similarities. Figure 5.2 shows RAPD profiles of the Zulu sheep, Merino and Zulu goats that were obtained using the primers OPA 10 and OPA 16. From this figure it is evident that the goat profiles were different from the

sheep profiles. On the other hand, the Merino profiles were similar to the Zulu sheep ones. In the profiles some species specific bands were observed while others were common to both sheep and goats (Figure 5.2).

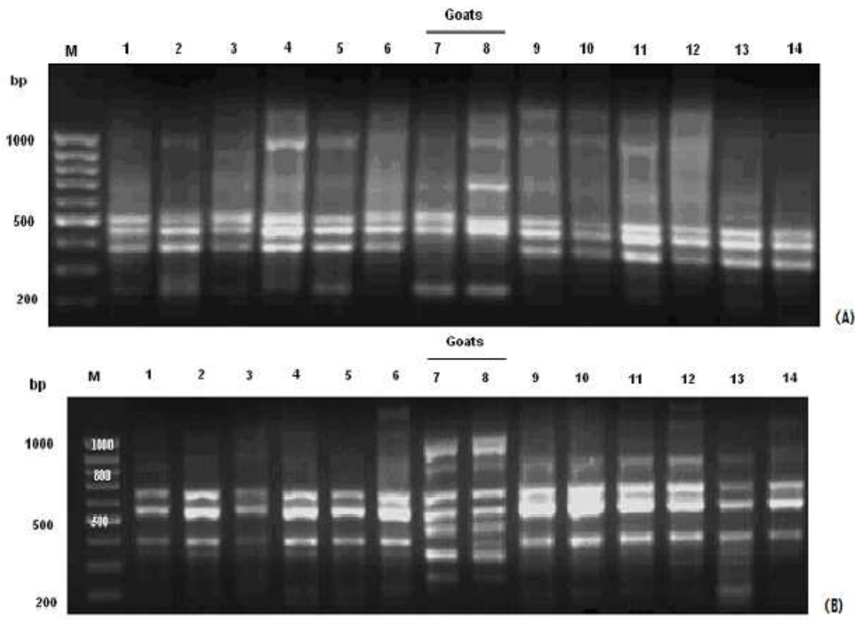

Figure 5.2 RAPD profiles generated from Zulu sheep DNA using primers OPA 10 (A) and OPA 16 (B). Lanes 1-3 represents Merinos, lanes 4-6 Zulu sheep from KwaMthethwa, lanes 7-8 Zulu goats, lanes 9-12 Zulu sheep from UNIZULU and lanes 13-14 Zulu sheep from Makhathini. Lane M represents the molecular size marker (O'RangeRuler, 100bp Fermentas, US).

Figure 5.3 shows the RAPD profiles generated by primers OPA 01, OPA 18, OPB 1 and OPB 17. Several polymorphic bands are visible in particular profiles of OPA 18 and OPB 01. Size distribution data for all these profiles are summarized in Table 5.1. Present/absent and intensity data were used to construct a similarity matrix that was subjected to UPGMA as well as complete linkage analyses. Resultant dendrograms are depicted in Figure 5.4.

Dendrograms in Figure 5.4 shows that Zulu goats and Merinos form out-groups to the Zulu sheep representatives. Although these dendrograms were based on two different algorithms their topology regarding the relationships between the Zulu sheep populations on the one hand and the out-group on the other, is the same.

However, a conflict exists between the relationship of the UNIZULU population to the other two populations as depicted by the UPGMA and the complete linkage dendrograms (Figure 5.4). According to the UPGMA dendrogram the UNIZULU population is more closely related to the KwaMthethwa population. This makes sense because the UNIZULU population was founded in 1995 with individuals from the KwaMthethwa population (Mr. Du Toit, 2006, farm manager University of Zululand, personal communication). This relationship was also demonstrated when a smaller number of Zulu sheep representatives (27) were used for RAPDs analysis and the data were analysed using complete linkage (Kunene *et al.*, 2008).

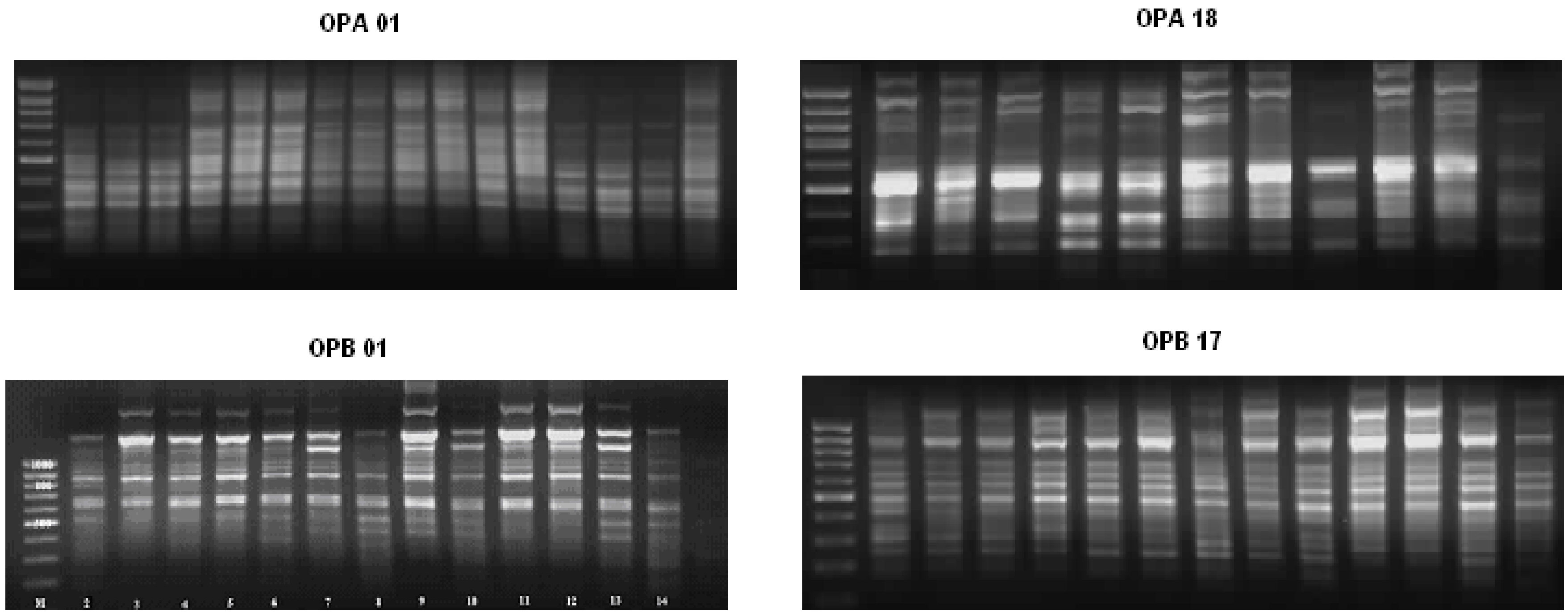

Figure 5.3 RAPD fingerprints generated from Zulu sheep DNA using primers OPA 01, OPA18, OPB 01 and OPB 17. Only Zulu sheep representatives are shown. The first lane in each of the profiles represents the molecular size marker (O'RangeRuler, 100bp Fermentas,US).

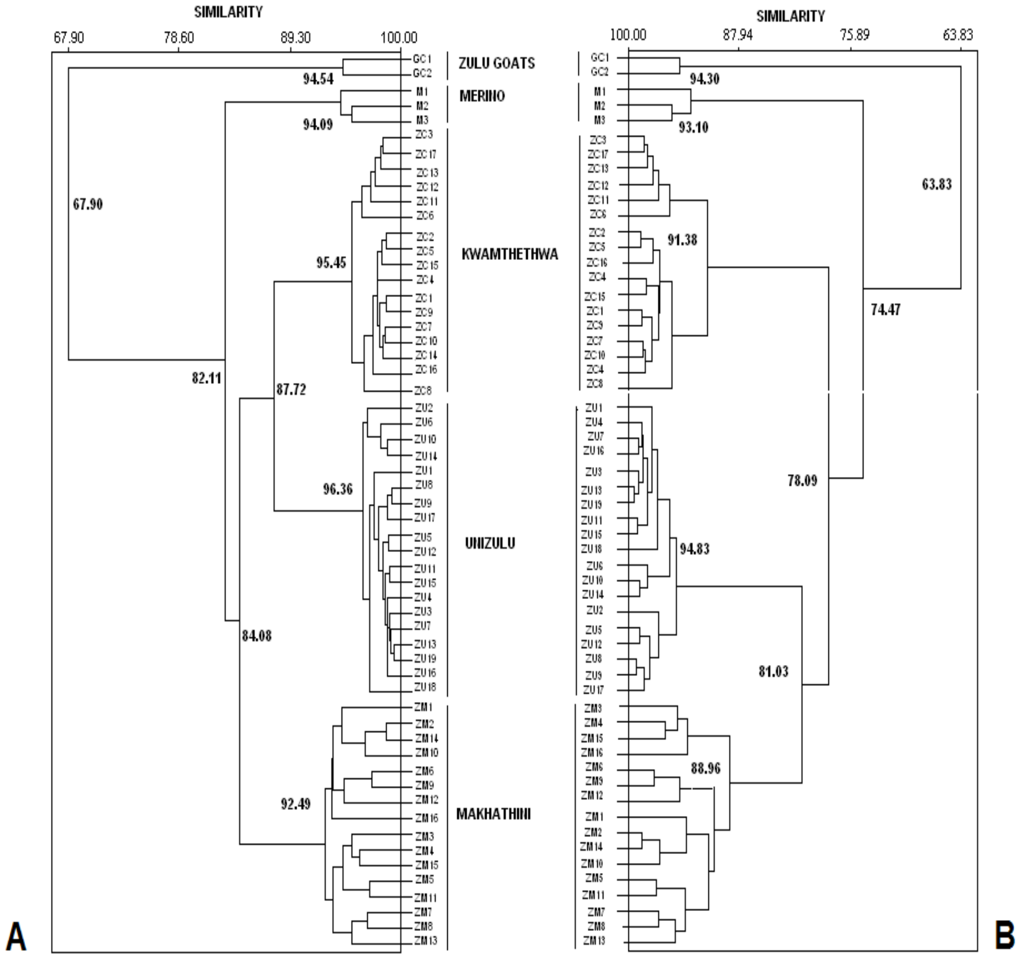

Figure 5.4 Dendrograms showing relationship of Zulu sheep populations. Dendrogram A is based on the UPGMA algorithm and dendrogram B based on the complete linkage algorithm. ZC represents the KwaMthethwa population, ZU the UNIZULU population and ZM the Makhathini population. The code GC represents Zulu goats and M merinos. Percentage similarities for the various clusters are also indicted.

The complete linkage algorithm is a more robust algorithm than the UPGMA. For the data set in the present study it (complete linkage) indicates a closer relationship between the UNIZULU and the Makhathini populations. This relationship was unexpected. However, to test this observation linear body measurement data from Kunene *et al.* (2007) were subjected to UPGMA and complete linkage analyses. Figure 5.5 is the complete linkage dendrogram and it demonstrates that UNIZULU and Makhathini populations are closer related to each other than to the KwaMthethwa populations. This observation needs further investigation since it could have implications when conservation, population management and breeding decisions are to be made. Furthermore, what is evident in

Figure 5.5 is that in all three population clusters, three characters (hearth girth, live weight and wither height) formed a sub-cluster and the character for ear length formed a separate branch to this cluster.

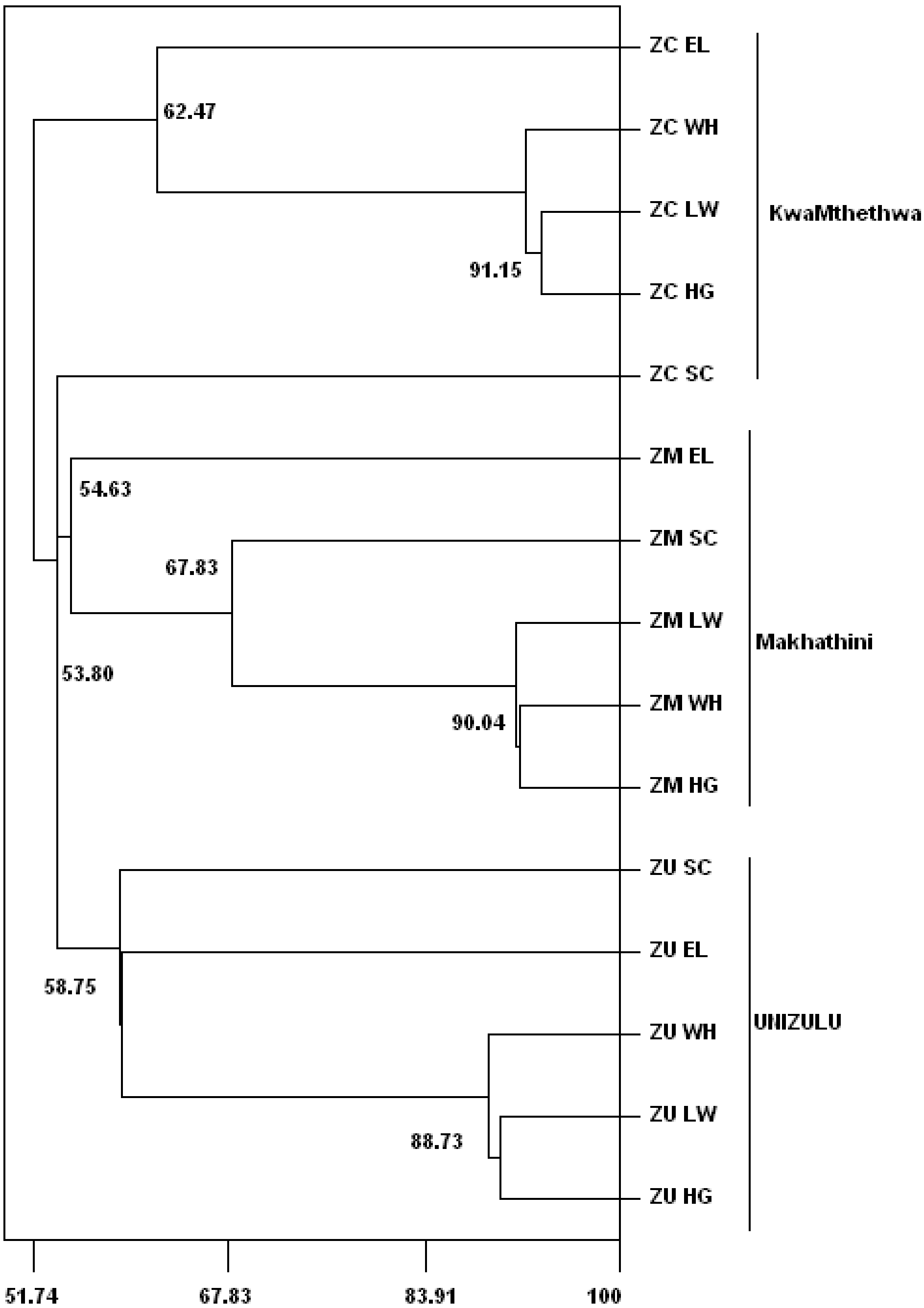

Figure 5.5 Dendrogram showing clusters based on linear body measurements of Zulu sheep in the three populations. ZC represents the KwaMthethwa population, ZU the UNIZULU population and ZM the Makhathini population. The five parameters that were measured include heart girth (HG), wither height (WH), live weight (LW), scrotum circumference (SC) and ear length (EL).

When the percentage similarities for the various populations were taken at the point where the ear length and the three mentioned characters (hearth girth, live weight and wither height) branched (Figure 5.5), it was observed that percentage similarities were smaller in Makhathini (54.63%) and UNIZULU (58.75%) populations compared to the KwaMthethwa (62.47%) population. However, when one considers clusters based on only the hearth girth, live weight and wither height, then it emerges that the intra-population similarities of all three populations are close, ranging from 88.73% to 91.15%. In these population clusters, scrotum circumference, a male characteristic, formed a separate branch in UNIZULU and KwaMthethwa populations (Figure 5.5)

Table 5.2 also show mean linear body measurements extracted from the data of Kunene *et al.* (2007). In this table it is illustrated that, among the three Zulu sheep populations, there were variations in linear body measurements. Various phenotypic body measurements were significantly higher in the Makhathini population compared to the other two populations. UNIZULU population had significantly lower values for live weight, heart girth, wither height and scrotum circumference measurements when compared to KwaMthethwa and Makhathini populations.

Furthermore, genetic similarity is also consistently higher in the UNIZULU population compared to the KwaMthethwa and Makhathini populations. Genetic similarity in the Makhathini population was the lowest (Table 5.2).

Table 5.2 A summary of linear body measurements and genetic similarity data among the three Zulu sheep populations. Linear body measurements (live weight, heart girth, wither height and scrotum circumference) are least-square means and ear length are percentage observed. These values were adapted from Kunene *et al.* (2007).

	UNIZULU	KwaMthethwa	Makhathini
Live weight	$22.76^{a} \pm 0.44$ N=843	$28.54^{b} \pm 0.50$ N=874	$34.28^{c} \pm 0.44$ N=652
Heart girth	$68.67^{a} \pm 0.50$ N=843	$72.58^{b} \pm 0.57$ N=874	$75.48^{c} \pm 0.51$ N=652
Wither height	$58.04^{a} \pm 0.34$ N=843	$59.84^{b} \pm 0.42$ N=874	$64.58^{c} \pm 0.42$ N=652
Scrotum circumference	$22.11^{a} \pm 0.54$ N=156	$23.32^{b} \pm 0.59$ N=186	$27.35^{b} \pm 0.58$ N=181
[d]Ear length size	N=86	N=89	N=253
% Ear buds	11.63	2.25	7.12
% Small	15.12	10.11	13.83
% Medium	30.23	23.60	27.67
% Large	43.02	64.05	51.38
[e]Complete linkage % phenotypic similarity	88.73	91.15	90.04
[f]Complete linkage % phenotypic similarity	58.75	62.47	54.63
UPGMA % genetic similarity	96.36	95.45	92.49
Complete linkage % genetic similarity	94.83	91.38	88.96

[a,b,c] row means with common superscript do not differ significantly (P>0.05). See Kunene *et al.* (2007) for details.
[d]Small (3> <6 cm); medium (6> <9cm); large (9> up to 14 cm)
[e]based on heart girth, live weight and wither height only.
[f]based on heart girth, live weight, wither height, ear length and scrotum circumference

5.5 Discussion

In this study genetic diversity data, based on RAPD profiles, were presented for three Zulu sheep populations. Two of these were populations at commercial and research stations and one a population from a community (KwaMthethwa). The populations were exposed to different environmental and feeding conditions (Kunene *et al.*, 2007). From the results it was evident that the genetic diversity within the UNIZULU population was less than the KwaMthethwa and Makhathini populations. However, cluster analysis (complete linkage analysis) of the genetic data demonstrated a close relationship between the UNIZULU and Makhathini populations. These populations are both at research stations. What was further evident among the three populations was that genetic similarity was the lowest in the Makhathini population and the greatest in the UNIZULU population. Previous studies that used DNA profiling to study sheep genetics were concerned with phylogenetic relationships of sheep (Appa Rao *et al.*, 1996) and the relationship of sheep breeds in various parts of the world (Kantanen *et al.*, 1995; Appa Rao *et al.*, 1996; Ali, 2003; Kumar *et al.*, 2003; Devrim *et al.*, 2007; Elmaci *et al.*, 2007; Mariante *et al.*, 2009). Kantanen *et al.* (1995) was concerned with the application of RAPD analysis to cattle and sheep breeds. In their study Appa Rao *et al.* (1996) were interested in finding genetic markers in farm animals. They demonstrated a similarity coefficient between indigenous Indian goats and sheep to be 0.34. In our study the similarity index between Zulu sheep and goats could be extrapolated to 0.36 based on complete linkage analysis. This latter value was based on the genome of only 2 Zulu goat representatives and should be treated with caution.

Ali (2003) worked on genetic relationship of Egyptian sheep breeds, Kumar *et al.* (2003) with Indian sheep breeds and Devrim *et al.* (2007) as well as Elmaci *et al.* (2007) with Turkish ones. RAPD analysis was useful in all these studies detecting inter- and intra breed variations. Furthermore, Mariante *et al.* (2009) in a review mentioned how RAPD and microsatellite data was included in the genetic database of unique Brazilian domestic species and how such data were used for conservation decisions. Our study was concerned with inter- and intra population genetic diversity of Zulu sheep. In this case RAPDs was also a useful technique. An extensive literature survey indicate that this and a linked study (Kunene *et al.*, 2008) is the first in which RAPD data were used to characterise Zulu sheep populations. Several recent studies considered only microsatellite markers for sheep genetic diversity studies (Dalvit *et al.*, 2008; Gizaw, 2008; Mariante *et al.*, 2009). This is inline with the international society of animal genetics (http://www.fao.org/dad-is). Future population genetics studies of Zulu sheep should thus consider using microsatellites, provided that infrastructure or relevant partnerships and funding are available.

Genetic and phenotypic diversity data demonstrated similarities and differences between Zulu sheep populations. In this study it was demonstrated that the genetic diversity and selected phenotypic data could be sensibly linked. The morphological data used here were linear body measurements for selected characters (live weight, heart girth, wither height, scrotum circumference and ear length; data extracted from Kunene *et al.*, 2007). There was a close relationship between the first three characteristics for each population. The intra-population diversity for each of the three populations was similar. Some of these characteristics were used in previous studies to characterise indigenous sheep breeds (Gizaw *et al.*, 2007, 2008). Gizaw *et al.* (2007) used ear length, withers height and chest girth amongst other linear body measurements to characterise indigenous sheep of Ethiopia. They also combined the morphological data with genetic data. Their results for the two data sets show dendrograms that were similar in topology but not identical. Furthermore, they could deduce population structure from the genetic data and demonstrated that a high within population diversity existed. This was congruent with phenotypic characteristics that were highly diverse (Gizaw *et al.*, 2007). Kunene *et al.* (2007) demonstrated diverse morphological characteristics of Zulu sheep. Kruger (2001) argued that the great phenotypic variation of the Zulu sheep is potentially due to the broad ancestral genetic pool of this breed. Considering the data of Gizaw *et al.* (2007), it is thus highly likely that the genetic diversity between various Zulu sheep populations could be high. In our study only three populations were included. Further studies should include greater numbers of representatives as well as greater numbers of populations.

In a 2008 study Gizaw *et al.* also used various linear body measurements to test parameters that are correlated with selection for live weight. Here they established that chest girth, wither height and body length were measurements that correlated with selection for improved live weight. These studies demonstrated the enormous application potential of linear body measurements for characterisation of indigenous sheep breeds, but also the breed improvement potential. Linear body measurements obtained within a previous study (Kunene *et al.*, 2007) and linking this to genetic diversity data is thus a useful approach and first step in providing arguments towards considering steps to conserve Zulu sheep as a breed.

There may also be some other linear body measurement data that could also be included in future studies of Zulu sheep characterisation. Nsoso *et al.* (2004) also used body measurements and other phenotypic characteristics to characterise Tswana sheep breeds. Various linear body measurements were also used to characterise Burkina Faso sheep (Traoré *et al.*, 2008). These measurements included ear length, wither height and several other characteristics. The linear body measurements (phenotypic) data used in the present study may thus be supplemented with other phenotypic characteristics such as those used by Nsoso *et al.* (2004), Gizaw *et al.* (2007) and Traoré *et al.* (2008).

Evidence from recent literature is strongly suggesting the use of combined data sets for sheep conservation decisions (Galal *et al.*, 2008; Gizaw, 2008; Mariante *et al.*, 2009; Traoré *et al.*, 2008). The studies of Gizaw (2008) is an excellent example of how various aspects of data sets (phenotypic and genetic) could be used to answer specific questions regarding utilization and conservation of sheep breeds. Such a database (including genetic and morphological data) would be important for decision making regarding the conservation status and future breeding programmes for optimal utilization of Zulu sheep.

Our future is intricately, intertwined with our ability to produce food from domestic animals including small ruminants such as sheep. We have full control over their reproduction and may devise strategies to select for desirable traits. Characterisation of such populations is thus critically important. Knowledge about the characteristics provides the opportunity to develop and implement strategies to protect existing indigenous sheep breeds and populations on the one hand, and promoting effective utilization on the other. It has been demonstrated that data from such characterisation databases could be used in subsistence farming scenarios (Gizaw, 2008).

In general, based on numbers, sheep may presently not be considered endangered. However, many of the indigenous breeds are highly endangered (Taberlet *et al.*, 2008). The conservation status of Zulu sheep is undetermined. This is due to extremely little characterisation data available for this sheep breed. A previous study (Buduram, 2004) has shown close genetic relationship between this breed and Swazi sheep. However, the genetic relationship of these two breeds to the other recognized Nguni sheep breed (the Pedi sheep; Kruger, 2001) was very distant (Buduram, 2004). It could be that, due to geographic separation, genetic selection over the past 200 years was sufficient to render two main sub-breeds among the Nguni sheep breeds (Pedi on the one hand and Zulu and Swazi sheep on the other). Sufficient genetic and morphological data could be useful to establish such relationships. Future studies of Zulu sheep should thus include the other members of the Nguni sheep. A database that includes morphological and genetic data is urgently needed for Nguni sheep in general, but Zulu sheep in particular. It is hereby also suggested that the UNIZULU population and the University of Zululand (Department of Agriculture) be the reference population and custodian, respectively, of such a database. Such a programme should consider advocating for subsidies to farmers that contribute to conservation of this genetic resource (Taberlet *et al.*, 2008).

In conclusion, results presented here demonstrated that RAPD analysis could be used to demonstrate genetic diversity between and within Zulu sheep populations. It was also demonstrated that the genetic diversity and selected phenotypic data for the Zulu sheep breed could be sensibly linked. Such data is important for developing a database for this sheep breed and its close relatives. However, more populations should be sampled and data from other genetic - and morphological markers as well as production characteristics need to be included to complement the data from the present study.

CHAPTER 6

GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

6.1 General discussion

Zulu sheep are the indigenous Nguni sheep of Zululand and are found in the rural areas of KwaZulu–Natal. They are used by the rural farmers as a source of food and cash and are believed to have adapted to the harsh conditions of these areas. There is scanty information available about the characteristics of this breed and there is a concern about the declining numbers (Kruger, 2001). Characterisation of this breed would be the first step for designing appropriate management and conservation programmes for the Zulu sheep. The aim of this study was to characterise Zulu (Nguni) sheep for purposes of utilization, improvement and conservation. Objectives were:

(i) to investigate the utilization of Zulu sheep and the socio-economics of keeping them;

(ii) quantify some morphological characteristics among three Zulu sheep populations using six morphological characteristics;

(iii) estimate a body weight prediction equation for Zulu sheep using heart girth and wither height, and

(iv) to assess the genetic variation between and within the three populations using random amplified polymorphic DNA markers.

Data from these studies can now be used as a baseline and lessons learnt utilized to devise strategies for maximum utilization and conservation of this breed.

A survey conducted among rural farmers (Chapter Two) demonstrated that these farmers use Zulu sheep as a source of protein and for sale when in need of cash. None of the farmers was an emerging entrepreneur. They sold livestock only because of circumstances. Some farmers also reported using sheep for payment of penalties in the tribal courts, but none of the farmers used this species for “Lobola” (marital payments) or other cultural ceremonies. A lower percentage of the farmers owned sheep compared to cattle and goats. There was also no evidence of preference by farmers for keeping one species over the other. However, the number of sheep owned by individual farmers was lower than that of either goats or cattle. This may be reflecting that the numbers of these sheep are declining, as has been reported by Ramsay *et al.* (2000) and Kruger (2001). Farmers have reported various adaptability traits of this breed. These include resistance to diseases, good meat quality and the ability to flourish in the hot and humid climate of KwaZulu-Natal. Sheep are not dipped in these areas due to lack of financial resources. This confirms the observations by the farmers that these animals have a natural resistance or tolerance to ticks and that they can survive on minimal inputs. The farmers explicitly pointed to the lack of sufficient knowledge in animal husbandry as a key hindrance to progress in livestock production. Poor livestock husbandry practices may lead to various productivity problems and even to ultimate death of livestock. Such deaths may also be another reason that farmers do not engage in commercial practices such as consistent selling of their livestock. They highlighted that such a challenge could be minimised if the government could support them by increasing the number of extension officers. The study revealed that farmers in the rural community have developed certain traditional selection criteria as well as some management practices to improve the production of their herds. It was noted that inclusion of indigenous knowledge in subsistence agricultural setting may enhance agricultural production.

Some phenotypic traits such as live weight (LW), wither height (WH), heart girth (HG), colour and the ear length types were used to describe the Zulu sheep (Chapter Three). These sheep are a multi-coloured breed. The dominant colours are brown and a brown-and-white colour combination. Brown or dark brown adult sheep are born as black lambs and the colour gradually changes to brown or dark brown as the lambs grow. Although there were four groups of ear length sizes within a population, the large ear (9 to 14 cm) was the most common among this breed. There was a poor relationship between ear length type and the LW, HG or WH. Zulu sheep have been described by Ramsay *et al*. (2000) as a small to medium breed. The weights for mature Zulu sheep (32 kg and 38 kg for females and males, respectively) are below those of other indigenous sheep breeds such as the Dorper, which were also reported to produce and reproduce even under poor grazing and arid conditions (Dorper SA., http://www.dorpersa.co.za/info characteristics). Cloete and De Villiers

(1987) reported an average weight of 72.3 kg for the mature Dorper ewes and Polachic (2006) reported average weights of 108.0 to 113.4 kg for the mature Dorper rams. Although the LW and LBM of Zulu sheep were seasonally affected, these measurements were similar for summer and autumn and for winter and spring. The differences were small between two seasons, with maximum differences of 2.58 kg, 3.90 cm and 1.52 cm for LW, HG and WH, respectively. One would expect a larger difference between the dry and the wet season since these animals are raised under an extensive management system. Results of a study conducted on forage behaviour of Nguni sheep by Nyamukanza *et al.* (2009) reflected that the Zulu sheep do not lose weight between seasons, because they increase forage time and bite size in the dry season. The combination of such characteristics and those that have been mentioned by the farmers warrant a conservation programme through an improvement scheme which will not only improve the lives of the farmers but maintain the existence of the breed as well. It has been mentioned by Hall (2004) and Taberlet *et al.* (2008) that farmers have abandoned a number of autochthonous breeds because of progressive abandonment of agriculture in marginal areas. Therefore the introduction of Nguni sheep improvement programmes might encourage traditional farmers to become involved in rewarding livestock projects.

The combination of both wither height and heart girth was found to be an excellent predictor of the live weight; the heart girth alone also proved to be a reliable estimator of the LW of Zulu sheep (Chapter Four). Such results have also been observed by Goe *et al.* (2001), Atta *et al.* (2004) and Fajemilehin *et al.* (2008). To increase the carcass yield of this breed a genetic improvement of live weight is required. The participation of the farmers in such a scheme can be adversely affected by the lack of scales (balances) required to measure the live weight. Weighing scales are expensive and farmers in rural communities may not be able to afford them (Hassan and Ciroma, 1990; Slippers *et al.,* 2000; Thiruvenkadan, 2005). Therefore the estimation of live weight from simpler and more easily measurable variables such as WH and HG would be of advantage. Several authors report the successful application of the tape measure records (Hassan and Ciroma, 1990; Fourie *et al.*, 2002; Groesbeck *et al.*, 2002; Odejapo *et al.*, 2007; Fajemilehin, 2008) for WH and HG. This work (Chapter Four) demonstrated that such a tool could be used by the rural farmers to estimate the body weight of the Zulu sheep for purposes of medical treatment and to cost the value of their sheep. Similarly, in young rams, the SC could be used to estimate their LW.

Genetic diversity data are presented in Chapter Five. In this chapter it was demonstrated that one of the populations (Makhathini) had a relatively higher genetic variation compared to the other two (UNIZULU and KwaMthethwa). A high genetic similarity in a population may be attributable to close breeding and small population size (Kantanen *et al*., 1999). Naturally, within each population some individuals were more closely related than others. The inter-population genetic diversity was higher compared to the intra-population diversity. These findings reflect the potential use of the RAPD technique for assessing intra- and interpopulation genetic relationships for the use of selection and breeding. The RAPD technique has been used by Battacharya *et al.* (2003) in estimating the inbreeding coefficient of cattle in India. It has also been successfully used to detect the genetic variation within and among various sheep breeds (Kantanen *et al*. 1995; Ali, 2003; Kumar *et al*., 2003; Paiva *et al*., 2005; Elmaci *et al*., 2007; Dalvit *et al*., 2008). Egito *et al*. (2005) used the RAPD markers for selection of goat individuals for *ex situ* and *in situ* conservation. The present study has also confirmed that RAPD markers can be utilized as a tool which can be used for the selection of Zulu sheep for the purpose of conservation and breeding. When the intrapopulation phenotypic diversity of Zulu sheep was compared, it was consistent with the genetic diversity, i.e. it was lower than the interpopulation diversity. Furthermore, results obtained from the selected phenotypic data could be sensibly linked to the genetic data. A larger phenotypic and genetic diversity between populations may indicate that an improvement may be obtained when selection is done between populations. The use of both phenotypic and genetic data has been recommended by various authors as a requirement for the successful achievement of conservation programmes for sheep (Ali, 2003; Galal *et al*., 2008; Gizaw, 2008). The international society of animal genetics (http://www.fao.org/dad-is) has recommended the use of microsatellite markers. Relevant partnerships and funding are currently being sourced for future genetic studies of Zulu sheep in which microsatellites are evaluated.

6.2 Conclusions and Recommendations

The information given by the rural community farmers during the survey reflects that these farmers appreciate the value of the Nguni sheep as the breed that has characteristics of disease resistance and physiological adaptation to the hot and humid conditions of KwaZulu-Natal. Farmers are not fully aware of how the breed can be utilized to bring a reliable income but they are interested to learn strategies to improve livestock production. On the basis of this information a Zulu sheep improvement programme for these rural farmers should be considered. The scheme would contribute to improving the livelihoods of the farmers and would also act as a means of conserving the breed. Farmers can be assisted in improving their animal husbandry practices and basic entrepreneurship skills. Improvement and conservation programmes in rural communities could include training that builds on indigenous knowledge concepts as well as appropriate relevant modern technologies. This could enhance the attraction of livestock keeping even to rural youth.

Biological characteristics (yearling and mature weight) of the Zulu sheep imply that their market price may not be as high as that of other sheep breeds which have higher live body weights. However, their adaptation to the local environment and the fact that the input of farmers is minimal makes it more worthwhile compared to the commercial sheep breeds that require extensive inputs. Zulu sheep can survive utilizing only locally available feed resources without major supplements, vaccines and dipping. These animals are prolific under local conditions. This is a very important trait for rural livestock production. A slight improvement in terms of supplements in the dry season might produce considerable changes in the use of simple traits such as live weight and hardiness which needs to be included for the Zulu sheep scheme. Differences in body measurements between the populations could be an advantage for selection. However, the results from the present study indicate that it would be appropriate for the improvement scheme to include a large number of populations to ensure diversity. Traits for hardiness could be included in the breeding objectives.

The RAPD technique can be used for establishing genetic differences within and between the populations. Animals that have a high genetic similarity can be culled and animals from other populations can be brought in to maintain the genetic variation. More genetic studies need to be done on the Zulu sheep breed to investigate how some of the genetics in this breed could be used to improve their production. These results are an account of preliminary research on the genetic structure of the Zulu sheep populations. It will be essential to analyse the microsatellites of more Zulu sheep populations in future studies.

For a Zulu sheep breeding programme in the rural farming system, an open nucleus three-tier system of flocks with three phases - nucleus, sub-nucleus and village flocks - is recommended. A nucleus flock would have to be established within the governmental ranches and only rams could be used in the programme. A combination of phenotypic and genetic characteristics would have to be used for selection between populations. Selection of rams for the station could be based on their 180 day and 365 day weight. However, young rams could be selected based on 80 day weight. Sub-nucleus flocks would be those owned by the participating farmers. Village flocks would be owned by the non-participating farmers. Participating farmers would be expected to conform to the requirements proposed during the planning of the scheme, such as castration of unwanted rams and keeping records. Farmer flocks would include breeding ewes and they would have the option of selling their selected young rams to the nucleus. Such farmers could benefit by using the rams from the nucleus. Some of the best rams from the sub-nucleus flocks could be sold to the village flocks. It would be imperative that government officials, including trained extension workers and the communal farmers, work together from the beginning of the project. To reduce the expense of the weighing scales that would be required by the participating farmers, tables for estimation of live weights of the Zulu sheep could be constructed within age groups using the linear body measurements. Farmers could use only measuring tapes to estimate the weights of their animals.

This study has shown that Zulu sheep are one of the local genetic resources still available in some areas of KwaZulu-Natal. They require minimum inputs and are a source of protein as well as cash for the rural farmers in these areas. There is still a chance for exploitation and maintenance of genetic variation between the populations of this breed. An intervention by Government in conjunction with the livestock owners is required for the design and implementation of an improvement and conservation programme for this breed. *In situ* conservation is generally more successful if benefits are felt at community level.

Finally, it can thus be concluded that the main aim of this study was achieved as formulated. The four objectives that were set for this study were also achieved and presented in Chapters Two, Three, Four and Five.

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APPENDIX A

CONFERENCE PRESENTATIONS

Poster Presentations

1. Kunene, N.W., Bezuidenhout, C.C., Nsahlai, I.V., 2008. Use of random amplified polymorphic DNA (RAPD) markers for detecting genetic similarity between and within Zulu (Nguni) sheep populations. Book of abstracts, pp 28. The10th World Conference on Animal Production, Cape Town, South Africa; 23-27 November, 2008.

2. Kunene, N., Nesamvuni, AE, Fossey, A., 2004. Characterisation of Zulu Sheep. Theme: The Paradigm of Efficiency and Sustainability; Book of Abstracts, pp 200. SASAS- GSSA, Goudini; 28 June- 1 July, 2004.

3. Kunene N., Nesamvuni A.E., Fossey A., 2004. Livestock Farming in some communal areas of Northern Kwazulu Natal. The Theme: The Paradigm of Efficiency and Sustainability; Book of Abstracts, pp 203. SASAS- GSSA, Goudini; 28 June- 1 July, 2004.

4. Kunene N., Nesamvuni, A.E, Fossey, A., 2002. Phenotypic Characterisation of Zulu Sheep on Station. Book of Abstracts, pp 209. GSSA/SASAS Joint Congress, Christiana Aventura, South Africa; May 13-16, 2002.

Podium Presentations

1. Kunene, N., Bezuidenhout, C.C., Nsahlai, I., 2007. Genetic variation among Zulu sheep populations using RAPD markers. Theme: Biotechnology in animal science, Bela Bela, Limpopo; 25 – 27 July, 2007.

2. Kunene, N, Bezuidenhout, C.C., Nesamvuni, E. Nsahlai I., 2007 Research on Zulu sheep. Symposia by South African Society of Animal Science, University of Zululand. Department of Agriculture; 27 June, 2007.

APPENDIX B

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