Effects of water deprivation on the prevalence of gastrointestinal parasites in Nguni goats

---

by

Sithembile Zenith Ndlela

A dissertation submitted in fulfilment of the requirements for

Master of Science in Agriculture (Animal Science)

Discipline of Animal and Poultry Science

College of Agriculture, Engineering and Science

School of Agricultural, Earth and Environmental Sciences

University of KwaZulu-Natal

Pietermaritzburg, South Africa

UNIVERSITY OF KWAZULU-NATAL

2016

Supervisor: Prof M. Chimonyo

DECLARATION

I, Sithembile Zenith Ndlela, declare that this dissertation has not been submitted to any University and that it is my original work conducted under the supervision of Prof M. Chimonyo. All assistance towards the production of this dissertation and all references contained therein has been fully acknowledged

Sithembile Zenith Ndlela **Date**

Approved as to style and content by:

Prof M. Chimonyo **Date**

Supervisor

ABSTRACT

The broad objective of the study was to determine the effects of water deprivation on prevalence of gastrointestinal parasites in Nguni goats. A cross-sectional survey was conducted on 285 farmers that kept goats from KwaNongoma in Zululand district in South Africa. Data collected included household demographics, goat production constraints, extent of water scarcity, disease challenges and prevalence of gastrointestinal parasites. Varying periods of water deprivation (0, 24 and 48 hours) on water intake, feed intake, body weight, body condition score, FAMACHA, faecal egg counts and faecal larval counts were determined.

Government grant was the main source of income for households experiencing no water shortages (60 %) and those experiencing water shortages (65 %). All households kept goats for traditional ceremonies. The mean goat flock sizes were not significantly different ($P > 0.05$) between households that did not face water shortages (14.7 ± 1.25) and households that experienced water shortages (13.2 ± 1.23). Goats in households experiencing water shortages were 11.0 times more likely to experience water scarcity than goats from households facing no water shortages ($P < 0.05$). Coccidia and roundworms were the most prevalent parasites in goats from households experiencing water shortages.

From the experiment, daily water intake (DWI) was the same in goats deprived of water for 0 (control) and 24 and 48 hours ($P > 0.05$). The daily feed intake (DFI) and the DWI: DFI ratio deprived of water for 0 and 24 hours was similar ($P > 0.05$). The FEC was the same in goats deprived of water for 0 and 24 hours ($P > 0.05$). Faecal egg counts (FEC) were highest in goats deprived of water for 48 hours ($P < 0.01$). Faecal larval counts (FLC) for goats deprived of water for 48 hours were almost double the counts from goats deprived for 24 hours. This implied that parasite infestation was strongly related to water intake. Correlation between water deprivation period with DFI, DWI: DFI ratio and BCS were negative ($P < 0.05$). The FAMACHA scores increased as the water deprivation period was increased. The FAMACHA correlated positively with FEC and FLC ($P < 0.01$) and negatively with BWT. There was a negative correlation between water deprivation period and BWT ($P < 0.01$). Pearson's correlation coefficients between FEC with water deprivation period were positive ($P < 0.01$), and negative with BWT ($P < 0.01$) and BCS ($P < 0.05$). There was a positive correlation between FLC and water deprivation period ($P < 0.01$), whereas a negative correlation with DFI ($P < 0.05$). It was concluded that coccidiosis and gastrointestinal parasites were major constraints to goat productivity and were severe in households that experienced water shortages. The increased periods of water deprivation compromised goat productivity, therefore, water deprivation periods can be set to 24 hours for Nguni goats.

Keywords: Goat productivity; Nguni goats; roundworms; water scarcity

ACKNOWLEDGEMENTS

I sincerely thank my supervisor Professor Michael Chimonyo for his patience, guidance and mentorship towards this dissertation. Without your constructive criticism, this dissertation would not exist without tears that prompted one to work harder.

I gratefully acknowledge the University of KwaZulu-Natal for financial support through fee remission. I like to acknowledge my fellow post graduates from the Discipline of Animal and Poultry Science, particularly Dr Titus Zindove 'Tito, my tight man' for his tireless assistance in the third chapter of this thesis, Dr Thando Mpendulo 'Ingonyama' for sharing ideas and helping with data collection including data analysis on those sleepless nights. I also thank Zwelethu Mdletshe 'Umphathi', Vusumuzi Mkwanazi 'Veloh', Mehluli Moyo 'Chief', Xolile Gudiso 'Mfundisi', as well as 3rd and 4th year students, for dedicating their cold early mornings helping with data collection; your hard work and support is greatly appreciated Animal Scientists. I am grateful to Ukulinga Farm staff: Mr Sam Khumalo and Mr Mesheck Dlamini for all their help at the farm during the trial. I also thank my fellow postgraduate students: Mupenzi Mutimura and Nourou Adbou for their support and encouragement, not forgetting Ayobami Adeyemo for his jokes that kept us going throughout the journey.

To all my friends, especially Pam Mngadi, Zama Mbulawa, Swazi Magwaza, Elihle Zuma (helping with lab work at nights and on weekends) and Tezi Nala; thank you for your prayers, support and encouragement during the course of the degree. From the depth of my heart, I would like to thank my family for their prayers and always believing in me as my name articulates 'Sithembile', without you this dissertation would not have been a dream that has come true.

Lastly, To God my Father, who is everything to me (El shaddai): Ngiyabonga, angazi wawubonani kimi Nkosi ukuba ungithande kangaka.

With man this is impossible, but with God all things are possible "Matthew 19:26"

DEDICATION

I dedicate this dissertation to my precious family: Gugu and Mshiyeni (mom & dad), Londiwe, Silindile, Siphelele, Siphamandla, Sihalaliso, Sinethemba, Wandiswa and Senamile. Without you guys 'Bo Mzala', I would not have made it. I appreciate your love, support and understanding throughout the journey of my life, even when I was robbing you of quality time to spend with the family. It is unfortunate that my grandmother, uGogoe uMaMsiya uMtubatsi, could not live long enough to taste the fruits of her labour.

"For I know the plans I have for you, declares the Lord. Plans to prosper you and not to harm you, plans to give you hope and a future. Jeremiah 29: 11"

LIST OF ABBREVIATIONS

DWI	Daily water intake
DFI	Daily feed intake
DWI: DFI ratio	Ratio of daily water intake to daily feed intake
BWT	Body weight
BCS	Body condition scores
FAMACHA	Faffa Malan chart
FEC	Faecal egg count
FLC	Faecal larval count

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: General Introduction

1.1 Background

The sub-Sahara is a water scarce region (Schoeman and Visser, 1995). The International Water Management Institute assessment projected that by 2023, 33 % of the sub-Saharan population will live in areas of absolute water scarcity (IWMI, 2000) and, thus increasing competition for water. As a result of water scarcity, drinking water will become limiting to livestock production (Hadjigeorgiou *et al.*, 2000; Casamassima *et al.*, 2008). This is because global climate is changing, and it impacts on temperatures and rainfall patterns (Dzama, 2016).

Agriculture is highly affected by climate, as it depends on it. Agriculture contributes about 38 % of GDP in the economy of the Southern Africa (Dzama, 2016). Sixty-two percent of poor people in the sub-Saharan region live in rural areas. Due to declines in agricultural activities, the rural sectors of sub-Saharan Africa are stricken by extreme poverty estimated to account for approximately 90 % of total poverty, with about 80 % still depending on agriculture for their livelihood (FAO, 2008). As three-quarters of livestock population are kept by resource-poor farmers in communal production systems (Dzama, 2016), goats could be used as a gateway out of poverty (Hussain *et al.*, 2003) due to their wide distribution and ownership by the resource-poor farmers. Goats are the main source of income for farmers living in arid and semi-arid regions (Ben Salem, 2010). These goats are important multifunctional animals contributing to nutrition and food security, financial security, stability at households for survival of the poor in rural areas (Devendra, 2013).

Goats can withstand drought and water scarcity better than other livestock (Singh *et al.*, 2013). Indigenous goats in Sub-Saharan Africa are adapted to harsh conditions of the extensive production systems they are reared under (Webb and Mamabolo, 2004). Indigenous goats are able to utilise low quality feed and cover large grazing areas in search of feed and water (Silanikove, 2000). They are also efficient users of water and can thrive water shortages (Qinisa *et al.*, 2011; Al-Ramamneh *et al.*, 2012; Abioja *et al.*, 2014). Goats have the capacity to balance their water economy at a lower level than their normal water intake (Kaliber *et al.*, 2015). The greater tolerance to water loss is mainly attributed to the rumen acting as a water reservoir (Silanikove, 2000).

Water scarcity causes stress in goats that may lead to reduced immunity, escalating diseases and gastrointestinal parasite infections (Rhind *et al.*, 2009). Gastrointestinal parasites are identified as one of the major challenges that communal goat production systems are facing (Rumosa Gwaze *et al.*, 2009; Owhoeli *et al.*, 2014; Kunene *et al.*, 2015). Studies have been conducted to determine the effects of water scarcity on physiological responses in indigenous goats (Qinisa *et al*., 2011; Al-Ramamneh *et al.*, 2012; Abioja *et al*., 2014). The effects of water scarcity on the prevalence of gastrointestinal parasites in goats are not well understood. With a global increase in water scarcity and competition amongst livestock and humans, it is important to determine how water scarcity affects the nutritional and health status of goats. Against this background, it was important to assess the effects of water deprivation on the prevalence of gastrointestinal parasite loads.

1.2 Justification

Understanding parasite infection in the face of water shortages makes livestock producers predict goat performance and veterinary costs. For example, farmers will know how frequently they need to drench their goats in order to minimise gastrointestinal parasite loads. Information generated by this research will assist in designing appropriate strategies and approaches to minimize parasite loads under conditions of water limitations. A reduction in gastrointestinal parasites is likely to increase goat productivity and health, and in turn reduce the development of anthelmintic resistance in gastrointestinal parasites. The reduction in over-use of antihelmintics reduces chevon contamination, and consumers will benefit through consumption of safe chevon. More importantly, it is crucial to conduct on-farm research, to understand challenges that farmers face and therefore, devise strategies that will address their needs, in collaboration with farmers, with a hope that farmers would easily adopt them.

The current study is expected to benefit farmers, extension officers, researchers, non-governmental organisations (NGO) and consumers. Policy-makers and farmers should know the amount and frequency with which water should be supplied to goats to ensure that the health status of goats is not compromised. Extension officers and NGO's will be able to extract information from the study and distribute to farmers. Researchers use the information as a build-up on further research on climate change and its impact on goat health. Therefore, improving goat productivity and health through efficient water utilization is beneficial to the environment and livelihoods, since Nguni goats have the potential to counteract the global crisis on water scarcity.

1.3 Objectives

The broad objective of the study was to determine the effects of water deprivation on the prevalence of gastrointestinal parasites in Nguni goats. The specific objectives were to:

1. Explore farmer perceptions on importance of gastrointestinal parasites in Nguni goats, and
2. Determine the influence of water deprivation on gastrointestinal parasite loads in Nguni goats.

1.4 Hypotheses

1. Farmer perceptions on importance of gastrointestinal parasites prevalence in Nguni goats differ between households that experience water shortages and those not experiencing water shortages, and
2. Varying water deprivation levels influence the prevalence of gastrointestinal parasites in Nguni goats.

1.5 References

Abioja MO, Asinowo OA, Abiona JA and Sodipe OG (2014). Water balance and some blood parameters in water-restricted goats during hot-dry season. *Journal of Animal Science* 47 (3): 149-156.

Al-Ramamneh D, Riek A and Gerken M (2012). Effect of water restriction on drinking behaviour and water intake in German black-head mutton and Boer goat. *Animal: The Animal consortium 2011* 6 (1): 173-178.

Ben Salem H (2010). Nutritional management to improve sheep and goat performances in semiarid regions. *Revista Brasileira de Zootecnia* 9: 337-347.

Casamassima D, Pizzo R, Palazzo M, Alessandro AGD and Martemucci G (2008). Effect of water restriction on productive performance and blood parameters in comisana sheep reared under intensive condition. *Small Ruminant Research* 78: 169-175.

Devendra C (2013). Investments on Pro-Poor Development Projects on goats: ensuring success for improved livelihoods. *Asian-Australasian Journal of Animal Sciences* 26 (1): 1-18.

Dzama K (2016). Is the livestock sector in Southern Africa prepared for climate change? *South African Institute of International Affairs Policy Briefing* 153: 1-4.

FAO (2008). Mapping poverty, water and agriculture in sub-Saharan Africa. *Interventions for improving livelihoods is sub-Saharan Africa*: 17-40.

Hadjigeorgiou I, Dardamani K, Goulas C and Zervas G (2000). The effect of water availability on feed intake and digestion in sheep. *Small Ruminant Research* 37: 147-150.

Hussain SO, Al-Janabi AS, Asofi MK, AL-Badry KL (2003). Seasonal changes in serum enzymes of male goats. *Iraqi Journal of Veterinary Science* 17: 1-5.

IWMI, 2000. World water supply and demand: 1995-2025. In: Rijsberman, FR (Ed.). *World Water Scenario Analyses*. World Water Council, Marseille, France.

Kaliber M, Koluman N and Silanikove N (2015). Physiological and behaviour basis for the successful adaptation of goats to severe water restriction under hot environment. *Animal*. http://www.researchgate.net/publication/277175966.

Kunene WN, Fon FN and Qwabe CSZ (2015). Management of Nguni goats to control gastrointestinal parasites and anthelmintic resistance at KwaMthethwa and Owen Sitole College of Agriculture area. *African Journal of Agricultural Research* 10 (11): 1197-1202.

Owhoeli O, Elele K and Gboeloh LB (2014). Prevalence of gastrointestinal helminths in exotic and indigenous goats slaughtered in selected abattoirs in Port Harcourt, South-South, Nigeria. *Chinese Journal of Biology* 2014: 1-8.

Qinisa MM, Boomker EA and Mokoboki HK (2011). Physiological responses of water-restricted Tswana and Boer goats. *Life Science Journal* 8 (S2): 106-111.

Rhind SM, Reid HW and McMillen SR (2009). Effects of pulsed or continuous infusion of cortisol on immune function in sheep. *Domestic Animal Endocrinology* 16: 1-9.

Rumosa Gwaze F, Chimonyo M and Dzama K (2009). Prevalence and loads of gastrointestinal parasites of goats in the communal areas of the Eastern Cape Province of South Africa. *Small Ruminant Research* 84: 132-134.

Schoeman SJ and Visser JA (1995). Water intake and consumption in sheep differing in growth potential and adaptability. *South African Journal of Animal Science* 25(2): 75-79.

Silanikove N (2000). The physiological basis of adaptation in goats to harsh environments. *Small Ruminants Research* 35: 181-193.

Singh V, Varshney P, Dash SK and Lal HP (2013). Prevalence of gastrointestinal parasites in sheep and goats in and around Mathura, India. *Veterinary World* 6 (5): 260-262.

Webb EC and Mamabolo MJ (2004). Production and reproduction characteristic of South African indigenous goats in communal farming systems. *South African Journal of Animal Science* 34 (1): 236-239.

CHAPTER 2: Literature review

2.1 Introduction

The world's goat population is estimated to be 1 billion, with 351 million being in Africa and about 6 million are produced in South Africa (FAOSTAT, 2013). Goats are a source of household income and wellbeing, and constitute a major source of proteins for humans in tropical and subtropical regions (Bakunzi *et al.,* 2013). Moreover, goats provide milk, skins, mohair, cashmere and manure (Haenlein and Ramirez, 2007). Goats play a role in traditional ceremonies and are also used to control bush encroachment in velds (Saico and Abul, 2007; Simela and Merkel, 2008).

Climate change is a global challenge that has adverse effects on livestock production, especially in developing countries of the Sub-Saharan Africa (Rust and Rust, 2013). The impact of climate change increases the vulnerability of livestock and exacerbates existing challenges that affect goat production systems (Gill and Smith, 2008). Reducing the impact of climate change, therefore, calls for selection of breeds that are robust, and tolerant to diseases and parasites (Rust and Rust, 2013). Goats display numerous advantages such as adaptability to feed shortages, severe cold or hot climates, water scarcity and are tolerance to endemic diseases (Silanikove*,* 2000). The readiness and adaptation of goats to the impacts of climate change, particularly increasing parasite prevalence, need to be clearly understood. Therefore, this review discusses goat production systems, measures of assessing nutritional status and parasite prevalence in goats and goat production constraints. The possible effects of water deprivation on parasite prevalence in goats are also highlighted.

2.2 Overview of goat production systems

The Southern African region consists of a variety of goat breeds reared in different production systems. These include goats such as Nguni, Tswana, Matabele, Mashona, Malawi and Landim (Rumosa Gwaze *et al.*, 2009a). Goats are produced under intensive, semi-intensive and extensive production systems. All these systems are faced with a challenge of water scarcity.

2.2.1 Intensive production system

Intensive system involves the confinement of fast-growing and or highly productive breeds of goats. The production process is modified to increase output per animal per unit of land. For example, in Saanen goats used for milk production, an additional protein and energy supplementation are provided to maintain goat performance, and the production output is measured in terms of the amount of milk produced per unit of land (Herrera *et al.*, 2011). Fattening of goats occurs under intensive production systems, to attain early market weight and condition (Aktaş *et al.*, 2015). Goats kept under this system have *ad libitum* access to feed and water.

2.2.2 Semi-intensive production system

Under the semi-intensive system, goats are put on small pieces of land to meet market demands, and have no access to communal pastures (Herrera *et al.*, 2011). Goats are allowed to browse but also stall fed to complement browsing. They are also provided with protein and energy supplement. Goats have *ad libitum* access to water. The semi-intensive system is normally used for smallholder farming projects, where stakeholders enforce a controlled management system that produces desired results. For example, fattening of does and kids that are kept on pastures and only housed at night. The goats destined for slaughter are then confined for about 60 days prior to slaughter (Aktaş *et al.*, 2015).

Semi-intensive and intensive systems require a high standard of expertise when it comes to feeding, breeding, housing and health management. Production costs are, therefore, high. Communal production systems are characterised by minimal resources in terms of low income, capital, poor food security and land (de Sherbinin *et al.*, 2008); therefore, do not subscribe to these systems, as indigenous goats such as Nguni goats are mostly owned by resource-poor communal farmers (Lehloenya *et al.*, 2005; Mamabolo and Webb, 2005).

2.2.3 Extensive production system

Under extensive system, goats graze on communal land where they compete for feed and water. Extensive goat production under the traditional communal grazing system is widely practiced in the semi-arid regions of Africa (Rumosa Gwaze *et al.*, 2009a). Communal production systems are highly vulnerable to climate variability and extremes, as animals are more exposed to the elements and depend on natural waters and pastures for nutrition (Thornton *et al.*, 2007). The extensive production system is characterized by low inputs, poor husbandry systems, poor range management, forage fluctuations and low productivity (Papachristou *et al.,* 2005; Ben Salem and Smith, 2008). Water supply for livestock depends on natural rainfall. The lack of improvement of goat productivity in communal production systems could be due to neglect by veterinarians, extension officers, livestock officers, researchers and other stakeholders (de Vries, 2008) and poor access to conventional knowledge and information (Boyazoglu *et al*, 2005).

Since goats are produced across a diversity of systems, farmers are able to adopt systems that suit them and their environment, taking into account challenges such as water scarcity. It is, therefore, essential to understand adaptation strategies of goats to deal with water challenges at are facing the goat industry. Nguni goats are the predominant genotype used in extensive production systems in South Africa (Rumosa Gwaze *et al.*, 2009a).

2.3 Characteristics of Nguni goats

In Southern Africa, goat production suffers at the hands of adverse climatic and nutritional conditions. As a result, indigenous goats are preferred by most goat producers under extensive conditions due to their hardiness and good mothering ability (Barry and Godke, 2001). The Nguni breed, for example, increased over the last decade in South Africa, due to its adaptability and low management requirements (Rumosa Gwaze *et al.*, 2009a). Goats have invaluable genes for adaptation to different environments in Southern Africa, for example, early attainment of maturity and low requirement for input (Olivier, 2002), hardiness (Kouakou *et al.*, 2008) and high prolificacy (Simela and Merkel, 2008). The Nguni breed is mostly kept because of its adaptability and tolerance to heat stress, water stress, utilization of limited and often poor quality fodder, and natural resistance to many tropical diseases and parasites found in Africa (NAMC, 2005).

Nguni goats are usually raised in an extensive production system like other indigenous goats in semi-arid areas of Africa (Rumosa Gwaze *et al.*, 2009a). Nguni goats are more common in communal production systems of South Africa (Sebei *et al.*, 2004). They can walk long distances searching for feed and water (Preston and Murgueitio, 1992). These Nguni goats have adapted mechanisms, for example, limiting dry matter intake, that benefit them in enduring water deficiency even during periods of droughts, better than any other livestock (Ben Salem, 2010). Nguni goats can tolerate endemic diseases such as pasteurella and pulpy kidney (Webb and Mamabolo, 2004), heartwater (Donkin *et al.*, 2015), tick infestation (Gopalraj *et al.*, 2014) and haemonchosis (Marume *et al.*, 2011). Although Nguni goats are susceptible to gastrointestinal parasites and other diseases, largely because of their exposure to the environment, they have developed high degrees of tolerance and immunity against them (Rumosa Gwaze *et al.*, 2009b; Kunene *et al.*, 2015).

Table 2.1 summarises the characteristics of Nguni goats. Nguni goats are not regarded as meat or milk goats due to their small to medium body frames and low milk production (Mmbengwa *et al*., 2013). They are dual-purpose animals. They are prolific and breed throughout the year (Webb and Mamabolo, 2004). They reach puberty at 6 to 7 months of age, and first kid from when they are a year and five to six months old (Mamabolo and Webb, 2005). Gestation period for does bearing multiple kids is shorter (between 142.7 ± 2.1 to 148.8 ± 1.0 days) than those bearing singles (150.0 ± 0.9 days), which could be explained by the lack of uterine space due to increased total litter weight which induces stress and leads to earlier kidding (Webb and Mamabolo, 2004). Higher litter size and birth weight could be achieved through good management (Table 2.1). The higher litter size results in lower birth weight (Lehloenya *et al.*, 2005).

Despite the adaptability of Nguni goats, their productivity in communal production systems is low. This could be attributed to poor management, which leads to the reduction of conception rate and an increase of mortality rate for both adult goats and kids (Sebei *et al.*, 2004; Lehloenya *et al*., 2005). Nguni goats have a potential to perform better under improved management systems (Masika *et al.*, 1998; Lehloenya *et al.*, 2005). The hardiness of Nguni goats could make them the ideal breed in the face of climate change. Interactions between goat production challenges and effects of climate change such as feed and water shortages can challenge the hardiness of Nguni goats (Abebe *et al.*, 2010; Kunene *et al.*, 2015). It entails, therefore, that productivity of goats in communal production systems should be improved, especially in dry

Table 2.1: Characteristics of Nguni goats

	Description	Source
Body structure	Small to medium frame	Snyman (2014)
Coat colour	Multi-coloured	Snyman (2014)
Coat texture	Short and glossy	Snyman (2014)
Litter size	2.0 ± 0.2	Lehloenya *et al.* (2005)
Average gestation period (days)	149.1 ± 0.8	Lehloenya *et al.* (2005)
Mean birth weight (kg)	2.7 ± 0.5	Lehloenya *et al.* (2005)
Age at first kidding (months)	17 to 18	Webb and Mamabolo (2004)
Breeding season	Polyestrous	Mamabolo and Webb (2005)

season and drought when water is scarce, which impacts on forage growth. It is important to understand measures of goat productivity, for comparative purposes and to align development strategies.

2.4 Measures of assessing nutritional status and gastrointestinal parasite loads in Nguni goats

The performance of Nguni goats under extensive systems can be assessed in terms of body weight changes, body condition scores, parasite loads and diseases.

2.4.1 Body weight changes in Nguni goats

The use of body weight and body condition score to determine the nutrition and health status of goats was reviewed by Yilmaz *et al.* (2014). Body weight reflects the amount of muscle accumulated by an animal. Body weight is affected by the level of nutrition (Uddin *et al.*, 2014). Goats show lower body weight gain during the dry season where feed is restricted and of low quality (Texeira *et al.*, 2006). The reduced body weight gain is attributed to the shortage of water during the dry season, which reduces fodder availability. Body weight is also affected by higher faecal egg and larval counts, as parasitism causes inappetence; thereby changing the utilization of feed and metabolism (Marume *et al.*, 2011). These effects are more pronounced during the periods of feed and water scarcity (Githigia *et al.*, 2001). Body weight gain has been correlated with body condition scoring in assessing nutritional and health status of goats (Nsoso *et al*., 2003; Rumosa Gwaze *et al*., 2010; Yilmaz *et al*., 2014).

2.4.2 Body condition scoring

Body condition score indicates animal body fat reserves (Sanson *et al.*, 1993). Details of the body condition scoring are given in Table 2.2, ranging from 1 (emaciated) to 5 (obese). Body condition scoring is done by assessing the amount of fat covering the spine in the loin area,

Table 2.2: Body condition score description for goats

Body condition score	Description
1 (emaciated)	Backbone and ribs highly visible and hollow flank. Prominent and sharp distinct gaps between each spinous processes of the lumbar vertebrae. Deep cavity around tailhead.
2 (thin)	Backbone and ribs slightly visible with small fat cover. Prominent, smooth individual spinous processes of the lumbar vertebrae. Loin muscle moderate. Shallow cavity lined with fatty tissue at tailhead.
3 (good condition)	Backbone not prominent. Ribs barely visible, covered by fats and intercostal spaces detected with firm pressure. Slightly prominent, smooth rounded spinous processes of the lumbar vertebrae. Loin muscle slightly full. No cavity around tailhead.
4 (fatty)	Backbone and ribs not visible. Spinous processes of lumbar vertebrae wrapped in thick layer of fat and muscle, and form a continuous line. Loin muscle full. Fatty tissues visible around tailhead.
5 (obese)	Backbone, ribs and tailhead buried in excessive fatty tissue. Loin muscle very full.

Sources: Gerhart *et al*. (1996); Marume *et al*. (2011)

ribs, tail head and fat pad at the sternum. Body condition scoring is easy to apply and could be adopted by farmers including those in communal production systems, to estimate body energy reserves in goats. Body condition scoring is a useful management tool for making decisions with regards to nutritional needs of goats. Heavy parasite load leads to reduction in body condition (Marume *et al.*, 2011). The relationship that exists between body condition with body weight, faecal egg count, larval count and water intake is important in assessing the nutritional and health status of goats.

2.4.3 Faecal egg count and larval culture

Faecal egg counting is the most common method for detection of gastrointestinal parasite burden in livestock. Egg counting provides a diagnostic value, but is not specific to species, as eggs are grouped according to size, shape, and structure. For example, *Strongyles* are eggs from roundworms which could be *Haemonchus* and *Trichostrongylus* species (Sissay *et al.*, 2006). For that reason, it is necessary to culture eggs to yield their third-stage larvae (L_3) which can easily be identified morphologically using a light microscope. The morphology of infective larvae (L_3) differs, and their identification permits a specific diagnosis to gastrointestinal parasites due to their large differences in pathogenicity (Van Wyk and Mayhew, 2013).

High faecal egg counts affect the utilization of feed and induce the loss of protein from the gastrointestinal tract (Rumosa Gwaze *et al.*, 2009b). Changes in body condition, reduced growth rate, gradual emaciation and disease susceptibility of an animal can be a clear indication of this effect (Abebe *et al.*, 2010; Marume *et al.*, 2011).

2.4.4 FAMACHA

The FAffa MAlan CHArt (FAMACHA) technique is a diagnostic on-farm system that estimates the level of infection by *Haemonchus contortus* through assessing anaemia in the mucous membranes of goats. It is used to identify goats that need to be dosed with anthelmintics. It reduces the abuse of these anthelmintics since not all goats in the flock may require treatment. The lower eyelid mucous membrane of each goat is examined and compared to a laminated chart showing five colour classifications. The description of the FAMACHA scores is shown in Table 2.3. *Haemonchus contortus* sucks large amounts of blood, which reduces the volume of erythrocytes (Kaplan *et al*., 2004). Gastrointestinal parasite infestation has a high contribution to anaemia (Vatta *et al.,* 2001; Van Wyk *et al*., 2006). There is a positive correlation between the worm burden of *Haemonchus contortus* and FAMACHA scores (Kaplan *et al.*, 2004; Sri Jeyakumar, 2007; Marshall *et al.*, 2012)). A negative correlation between body condition scores and FAMACHA was reported by Yilmaz *et al.* (2014).

The limitation of the FAMACHA technique is that it does not work well in goats that are poorly fed, as compared to when nutrition is of high quality and quantity. Therefore, early diagnosis of poor nutrition is necessary to eradicate false diagnosis of diseases using FAMACHA. Another limitation of the FAMACHA technique is that animals that are resilient to *Haemonchus* species show no signs of anaemia but continue depositing gastrointestinal parasite eggs to the environment, infecting other animals in the flock that are not resilient. The FAMACHA technique should, thus, be coupled with faecal egg counting and larval culture, for accurate diagnosis and control of infections. Although Nguni goats are regarded as tolerant and resilient, the challenges faced by goat farmers are complex.

2.5 Constraints to goat production

Communal goat production systems are faced with different challenges that vary according to the geographical location, climatic conditions, breed and management practices. These include

Table 2.3: FAMACHA scoring used to assess levels of anaemia in goats

Clinical category	Colour classification	Treatment recommendation
1	Red	Optimal (non-anaemic): no treatment
2	Red - pink	Acceptable: no treatment
3	Pink	Borderline (mild-anaemic): may or may not require treatment
4	Pink - white	Dangerous (anaemic): require treatment
5	White	Fatal (severely anaemic): require treatment

Sources: Malan *et al.* (2001); Kaplan *et al.* (2004)

lack of good animal husbandry practices and poor veterinary services (Slayi *et al.,* 2014). The major constraints are water and feed shortages, and high prevalence of gastrointestinal parasites (Ben Salem and Smith, 2008; Mutibvu *et al*., 2012; Solomon *et al.*, 2014).

2.5.1 Water shortages

Water is the most important component of the diet and is consumed more than other nutrients (Mustafa *et al.*, 2010). Water is essential for the adjustment of body temperature, growth, reproduction and lactation mechanisms, digestion patterns, metabolism of energy and nutrients, nutrients and metabolite exchanges, and excretion of waste products (Ben Salem, 2010). For example, during dehydration, the physiological changes that take place may alter the disposition of drugs administered due to reduced distribution of drugs in tissues, thereby reducing the efficiency of treatments and health status (Abdelatif *et al.*, 2010).

Water scarcity affects the availability of drinking water and the type of vegetation available for goats (Qinisa *et al.*, 2011). When goats are subjected to water restriction, they minimise water losses via urine and faeces (Mirkena *et al.*, 2010). The first physical response to water restriction is the reduction of voluntary feed intake (Abioja *et al.,* 2010). There is a positive correlation between feed and water intake (Silanikove, 2000; Ben Salem and Smith, 2008; Maloiy *et al.*, 2008). Therefore, adequate provision of water to meet the requirement of a goat improves dry matter intake.

Goats are able to utilize their body water more efficiently to maintain dry matter intake during water scarcity periods (Ben Salem, 2010). Goats also have the capability to tolerate dehydration (Misra and Singh, 2002; Alamer, 2006). The response of Nguni goats to water stress is, however, not clearly understood. The extent to which water shortage exacerbates the effects of gastrointestinal parasites is also not clear. It is, therefore, necessary to understand the interaction between water shortage and gastrointestinal parasite prevalence in goats.

There has been a gradual change of climate over the last decade, which could be attributed to global warming (FAO, 2005). Water demand has increased severely over the last century mainly due to climate change and increased human and animal population (FAO, 2013). Erratic rainfall in arid and semiarid regions also contributes to critical water shortages (Ben Salem, 2010). Low rainfall affects water and feed availability (Abdelatif *et al.*, 2010). As a result, drinking water is often limited in goats grazing in marginal areas.

Stressful conditions such as prolonged heat and intermittent droughts have an influence on water and energy metabolism in goats. The imbalances in water and energy metabolism influence the health and productivity of goats (Abdelatif *et al.*, 2010). Indigenous goats reared in semi-arid areas have, however, developed a physiological mechanism that enables them to survive and reproduce efficiently in these areas (Maloiy *et al.*, 2008). For example, Saudi Arabia and Ethiopian Somali goats have been reported to withstand water deprivation for up to three days (Alamer, 2006; Mengistu *et al.*, 2007).

Although indigenous goats have the capacity to tolerate water stress for prolonged periods, goats are subjected to severe dehydration during the dry season (Alamer, 2006). Water points are dispersed during the dry season, obliging goats to walk long distances for days, away from grazing areas, without drinking water (Silanikove, 2000). There is, therefore, a need to explore the response of indigenous goats found in the Southern Africa to water deprivation. This will help understand the extent of adaptability of Nguni goats, as there is no data available on how long Nguni goats could withstand water deprivation.

2.5.2 Feed shortages

Rainfall is the major determinant of forage production. Plants grow on the upper layer of soil, therefore depend on patterns of rainfall (Ben Salem and Smith, 2008). This restricts the availability of natural pasture as a feed source to the wet season, although limited supplies of pastures are available during the dry season along river banks and unusual patches of land. The nutritive quality of pastures varies with areas, seasons and growing stages. The nutritive value of pastures varies due to seasonality of rainfall and periodic drought events (Mahala *et al*., 2009).

During the dry season, forage supply is limited and the little that is available is fibrous and low in proteins (Ben Salem and Smith, 2008). Low protein concentration is the major limiting factor in animal production from natural pastures. The low protein content causes low digestibility and feed intake thus also causing deficiency of energy. Although there is a decline in protein content, the nutritive value is more pronounced in sour veld than sweet veld areas. In sweet veld areas the decline in grazing quality during the dry season is enhanced by the presence of browse species that maintain their high protein levels even during dry seasons. However, in wet season, forage is of high quality (Botsime, 2006). To sustain goat production, dietary supplementation is necessary to increase productivity of goats. Dietary supplementation would also help mitigate the pathogenic effects of infection by gastrointestinal parasites, especially in low-input systems.

2.5.3 High prevalence of gastrointestinal parasites

Gastrointestinal parasites are organisms that can infect the gastrointestinal tract of a host animal. These parasites cause a disease when present in high numbers or when an animal is weakened by another disease or poor nutrition. The damage to the goat occurs when parasites attach to the lining of the gastrointestinal tract and ingest blood, and when parasites live in the lumen and ingest feed nutrients before the animal can digest them. This can result in impaired ability of the animal to absorb nutrients, causing weight loss and poor body condition, low growth rates, low milk production, poor hair coat or growth of fleece, diarrhoea, anaemia, dehydration, general weakness and, eventually, death (Valentine *et al*., 2007; Singh *et al.*, 2013; Villarroel, 2013).

Gastrointestinal parasites are a major constraint in goats reared in communal production systems and are endemic in regions of Southern Africa (Githiori *et al.,* 2006; Marume *et al.,* 2011). Sebei *et al*. (2004) and Debele *et al.* (2013) identified gastrointestinal parasites as one of the major causes of kid mortality under communal farming systems. Weaned kids are more susceptible to gastrointestinal parasite infection due to weaker immune response systems (Sebei *et al.*, 2004; Slayi *et al.*, 2014). Furthermore, Kunene *et al*. (2015) observed that does are more susceptible to gastrointestinal infection during pregnancy and peri-parturient period. Khan *et al.* (2010) attributed such cause of susceptibility to weaker immune system and stress. Susceptibility to gastrointestinal parasites is also increased by overgrazing, dense stocking rates, and inadequate nutrition, mainly protein intake (Paddock, 2011).

The most common gastrointestinal parasites in the Southern Africa are the Trichostrongyle group (*Haemonchus, Trichostrongylus, Ostertagia, and Cooperia*) and *Oesophagostomum*, as shown in Table 2.4. *Haemonchus* is the most highly pathogenic of the blood suckers and infections with large numbers of this parasite often results in severe anaemia in goats in the sub-Saharan region (Singh *et al.*, 2013). This is attributed to the fact that the hot wet conditions favour *Haemonchus* larval development and they reproduces quickly (Maphosa *et al.*, 2010). *Haemonchus* adapts well to even harsh conditions. The third-stage (L_3) larvae of *Haemonchus* can survive up to six months on pasture and become metabolically inactive in cool dry season.

Table 2.4: Common gastrointestinal parasites affecting goats in the Southern Africa

Country	Gastrointestinal parasites	Source
South Africa	*Haemonchus, Trichostrongylus*	Tsotetsi *et al*. (2013) Rumosa Gwaze *et al.* (2009b)
Botswana	*Haemonchus, Ostertagia, Trichostrongylus, Oesophagostomum*	Ramabu *et al*. (2015)
Namibia	*Haemonchus*	Kumba *et al.* (2003)
Zimbabwe	*Haemonchus, Cooperia, Trichostrongylus*	Chikwanda *et al.* (2013)
Tanzania	*Haemonchus, Trichostrongylus*	Mhoma *et al.* (2011)

These larvae emerge and become metabolically active in summer or wet season.

Gastrointestinal parasites of economic importance in Southern Africa, which are Trichostrongyles and *Oesophagostomum*, have direct life cycles with no intermediate host to complete their life cycle (Sissay, 2006). The direct life cycle is presented in Figure 2.1. The goat ingests the L_3 larvae while grazing, which mature into adult worm, mate in the host, and females lay eggs that are passed out in the faeces. Outside the host, eggs hatch into first-stage larvae (L_1), which then moult into second-stage larvae (L_2), and then to third-stage larvae (L_3). The infective larvae (L_3) migrate out of faeces onto the surrounding forage where they can be consumed during grazing, thus completing the cycle (Hepworth *et al*., 2006). The time for development from egg to an infective larva can be as short as 7-10 days in warm weather, or under optimal conditions of warm temperature and high humidity (Zajac, 2006).

The development process may be prolonged in cooler temperatures. Therefore, transmission and continuous contamination of pastures can be rapid. The L_3 larvae in next few days penetrate the mucous membrane (for example, in the case of *Haemonchus* and *Trichostrongylus*) and moult to the fourth stage (L_4), then emerge into young adult stage (L_5) (Hepworth *et al*., 2006). The L_4 stage is critical for blood suckers like *Haemonchus* because animals get infected with large numbers of larvae, therefore, may suffer from anaemia before parasite eggs can be detected in the animal's faeces. Trichostrongyles mostly mature and start producing eggs at about three weeks after infection, whereas *Oesophagostomum* requires about six weeks (Zajac, 2006).

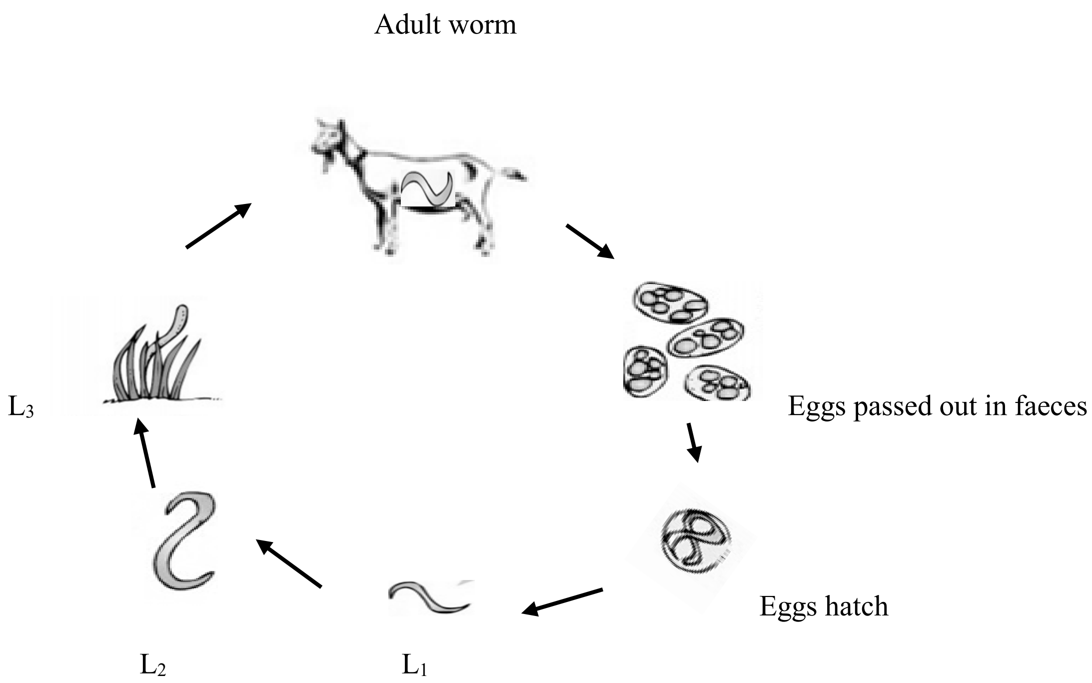

Figure 2.1: Life cycle of gastrointestinal parasite in goats

L_1: First-stage larvae in faeces

L_2: Second-stage larvae in faeces

L_3: Third-stage (infective) larvae migrate onto grass

https://www.farmanimalhealth.co.uk/sheep-worms

The effects of gastrointestinal parasites are more prominent during periods of feed shortage and are reduced during periods of feed availability. This is attributed to shortage of water and poor quality of forage (Githigia *et al.*, 2001). The prevalence of gastrointestinal parasite infestation is a huge challenge in communal production systems in the sub-Saharan region due to inadequate nutritional resources. Low nutrition consequently compromises the natural immunity of goats and make them susceptible to gastrointestinal parasites (Perry *et al.,* 2002).

The presence of gastrointestinal parasites in goats interrupts protein metabolism and reduces absorption and retention of minerals, thus, decreases growth performance (Ben Salem, 2010). Gastrointestinal parasites suck blood and decrease the concentration of total blood protein through internal bleeding. Protein metabolism is also affected by body hydration, which is important in maintaining the normal plasma volume. This volume is maintained by the osmotic pressure of the plasma proteins. Since the blood stream is regarded as the immediate source of water loss, it is, therefore, essential to control gastrointestinal parasite infestation. Improving the immune system of goats to increase resilience to gastrointestinal parasites could be the solution (Moyo *et al.,* 2013).

One of the strategies that could be used to improve the immune response is the protein and energy supplementation, thereby improving resilience against parasitic infections (Rastogi *et al.*, 2009; Xhomfulana *et al.*, 2009). Marume *et al.* (2011) reported that dietary protein supplementation suppresses the egg output from gastrointestinal worms. Similarly, Hoste *et al.* (2008) reported that protein supplementation reduces gastrointestinal parasites loads. Goats that are well-nourished are better able to withstand the effects of gastrointestinal parasite infection than those on a low plane of nutrition (Hoste *et al.*, 2008; Arsenos *et al.*, 2009). However, even in the availability of all other nutrients in required proportions, stress due to lack of water compromises the immunity of goats (Kruger, 2015). Therefore, it is necessary that protein and energy supplementation to improve resilience and or resistance against parasitic infections should be coupled with adequate water supply.

Although Nguni goats are more adaptable to gastrointestinal parasite infections due to the physiological mechanism developed over the years of natural exposure, it remains the main challenge in goat production (Marume *et al.*, 2011). This could be because their immunity is compromised by water deprivation for longer periods of time. Studies have shown that protein and energy supplementation to Nguni goats help improve resilience to gastrointestinal parasites, however, there is dearth of information on the effects of water shortage on the resilience of Nguni goats to gastrointestinal parasites.

2.6 Effects of water deprivation on Nguni goats

Dehydration causes a decrease in body fluid and an increase in plasma osmolarity (Abdelatif *et al.*, 2010). Heat stress and diseases including gastrointestinal infestation increases loss of body fluid through sweating and panting, diarrhoea, internal bleeding or blood loss. When loss of body fluid reaches a critical stage, it can become a threat to thermoregulation and cardiovascular function, and weakens the immune system of an animal.

Goats have the ability to survive water restrictions up to two days without causing stress to the animal (Alamer, 2009). Li *et al.* (1999) demonstrated that water deprivation in combination with physiological stress resulted in an increase in blood cortisol levels in lactating animals. Elevated concentrations of cortisol in goats is an indication of stress, regardless of the cause. Kruger (2015) also indicated that goats subjected to stress resulted in an increase in cortisol levels. The major consequence of cortisol concentration increase is that it compromises successful reproduction (Fatet *et al.*, 2011), production (Veerasamy *et al.*, 2010) and increases susceptibility to diseases due to compromised immunity (Hosamani *et al.*, 2009). Rhind *et al.* (2009) demonstrated that stressed animals mount a less effective response to pathogen challenges than unstressed animals, suggesting that the increase of cortisol level not only indicates stress but also suppresses the immune system.

Correlation between stress and immune suppression is a major cause of goats' susceptibility to diseases (Kruger, 2015). When an animals' immunity is compromised due to stress, the resistance and or resilience to infection decreases to such an extent that the animal succumbs to the disease (Henton, 2009). This reflects that water deprivation can increase stress in goats, and therefore, with a compromised immunity, gastrointestinal parasites could take advantage and multiply in the gastrointestinal tract. The influence of water stress on gastrointestinal parasite loads in not fully understood.

2.7 Summary

The productivity of goats is influenced by several factors such as water, nutrition and gastrointestinal parasites. Water challenge is a major threat to the livestock industry since shortage of water is expected to rise due to climate change and an increasing demand by humans and agricultural activities. Water deprivation, feed shortage and gastrointestinal parasite burden are stress factors that can reduce goat productivity. The objective of the study was to determine the influence of water deprivation and gastrointestinal parasites on growth performance, nutritional and health status of Nguni goats.

2.8 References

Abdelatif AM, Elsayed SA and Hassan YM (2010). Effect of state of hydration on body weight, blood constituents and urine excretion in Nubian goats (*Capra hircus*). *World Journal of Agricultural Sciences* 6: 178-188.

Abebe R Gebreyohannes M, Mekuria S, Abunna F and Regassa A (2010). Gastrointestinal nematode infections in small ruminants under the traditional husbandry system during the dry season in southern Ethiopia. *Tropical Animal Health and Production* 42: 1111-1117.

Abioja MO, Osinowo OA, Adebambo OA, Bello NJ and Abiona JA (2010). Water restriction in goats during hot-dry season in the humid tropics: feed intake and weight gain. *Archivos de Zootecnia* 59 (2): 195-203.

Ahmed Muna MM and Nour HS (1997). Legume hays as a supplement for dairy goats during the dry season. *Small Ruminant Research* 26: 189-192.

Aktaş AH, Gök B, Ateş S, Tekin ME, Halici I, Baş H, Erduran H and Kassam S (2015). Fattening performance and carcass characteristics of Turkish Indigenous Hair and Honamli goat male kids. *Turkish Journal of Veterinary and Animal Sciences* 39: 643-653.

Alamer M (2006). Physiological responses of Saudi Arabia indigenous goats to water deprivation. *Small Ruminant Research* 63: 100-109.

Arsenos G, Fortomaris P, Papadopoulos E, Sotiraki S, Stamataris C and Zygoyiannis D (2009). Growth and meat quality of kids of indigenous Greek goats (*Capra prisca*) as influenced by dietary protein and gastrointestinal nematode challenge. *Meat Science* 82: 317-323.

Bakunzi FR, Motsei LE, Nyirenda M, Ndou RV and Mwanza M (2013). The effects of strategic anthelmintic treatments on goat performance under extensive management in the semi-arid area of South Africa. *Life Science Journal* 10 (2): 1195-1197.

Barry DN and Godke RA (2001). The Boer goat: The potential for cross breeding. Louisiana State University, Baton Rouge, USA. dnafrica@worldonline.co.za.

Ben Salem H and Smith T (2008). Feeding strategies to increase small ruminant production in dry environments. *Small Ruminant Research* 77: 174-194.

Ben Salem H (2010). Nutritional management to improve sheep and goat performances in semiarid regions. *Revista Brasileira de Zootecnia* 39: 337-347.

Botsime BD (2006). Influence of agro-ecological region on selected anthropometrical measurements of Nguni cattle in South Africa, MSc thesis, University of Pretoria, Pretoria, South Africa.

Boyazoglu J, Hatziminaoglou Y and Morand-Fehr P (2005). The role of the goat in the society: Past, present and perspective for the future. *Small Ruminant Research* 60: 13-23.

Chikwanda AT, Mutisi C, Sibanda S, Makuza SM, Kusina NT and Chikwanda D (2013). The effect of housing and anthelmintic treatment of pre-weaning kid death rate and infestation with gastrointestinal helminthes. *Applied Animal Husbandry and Rural Development* 6: 32-35. www.sasas.co.za/aahrd.

Debele G, Duguma M, Hundessa F, Messele F, Kebede T and Negash M (2013). Study on major causes of kid mortality in Adami tulu Jido Kombolcha District of Oromia, Ethiopia. *Agriculture and Biology Journal of North America* 4 (2): 110-115.

de Sherbinin A, Van Wey LK, McSweeney K, Aggarwal R, Barbieri A, Henry S, Hunter LM, Twine W and Walker R (2008). Rural household demographics, livelihoods and the environment. *Global Environmental Change* 18 (1): 38-53.

de Vries J (2008). Goats for the poor: some keys to successful promotion of goat production among the poor. *Small Ruminant Research* 77: 221-224.

Donkin EF, Stewart CG, MacGregor RG, Els HC and Boyazoglu PA (2015). Resistance of indigenous and crossbred goats to heartwater (Cowdria Ruminantium). Faculty of Veterinary Science, Medunsa, South Africa. https://www.researchgate.net/publication/275647613. Retrieved on 30 June 2016.

FAO (2005). Water reports. Aquastat. *Survey Journal*: 1-89.

FAO (2013). Sustainability dimensions. http://www.fao.org/docrep/018/i3107e/i3107e04.pdf.

FAOSTAT (2013). Food and Agriculture Organisation of the United Nations Statistical database. http://faostat.fao.org/site/573/DesktopDefault.aspx?PageID=573#ancor. Accessed April 15, 2016.

Fatet A, Pellicer -Rubio MT and Leboeuf B (2011). Special issue: Reproductive cycles of animals: Reproductive cycle of goats. *Animal Reproduction Science* 124: 211-219.

Gerhart KL, White RG, Cameron RD and Russell DE (1996). Estimating fat content of caribou from body condition scores. *The Journal of Wildlife Management* 60 (4): 713-718.

Gill M and Smith P (2008). Mitigating climate change: the role of livestock in agriculture. *Livestock and Global Change Conference Proceeding*. May 2008, Tunisia.

Githigia SM, Thamsborg SM, Munyua WK and Maingi N (2001). Impact of gastrointestinal helminths on production in goats in Kenya. *Small Ruminant Research* 42: 21-29.

Githiori JB, Athanasiadou S and Thamsborg SM (2006). Use of plants in novel approaches for control of gastrointestinal helminths in livestock with emphasis on small ruminants. *Veterinary Parasitology* 139: 337-347.

Gopalraj JBP, Clarke FC, Donkin EF and Govender P (2014). A comparative study of the acquired resistance to the tick species Rhipicephalus Appendiculatus, Rhipicephalus Evertsi and Amblyomma Hebraeum in crossbred (Saanen X South African indigenous goats) goats. *1st International Congress on Environmental, Biotechnology, and Chemistry Engineering IPCBEE* 64: 93-101.

Haenlein GFW and Ramirez RG (2007). Potential mineral deficiency on arid rangelands for small ruminants with special reference to Mexico. *Small Ruminant Research* 68: 35-41.

Henton M (2009). Pasteurella vrektes by lammers. Vra vir Faffa column. Landbou.com online.

Hepworth K, Neary M and Hutchens T (2006). Managing internal parasitism in sheep and goats. West Lafayette, IN: Purdue Univesrity Cooperative Extension Service, 1-10.

Herrera PZ, Bermejo JVD, Henriquez AA, Vallejo MEC and Costa RG (2011). Effects of extensive system versus semi-intensive and intensive systems on growth and carcass quality of dairy kids. *Revista Brasileira de Zootecnia* 40 (11): 2613-2620.

Hosamani M, Scagliarini A, Bhanuprakash V, McInnes and Singh RK (2009). Orf: an update on current research and future perspectives. *Expect Review of Anti Infective Therapy* 7 (7): 879-893.

Hoste H, Torres-Acosta JFJ and Anguilar-Caballero AJ (2008). Nutrition-parasite interactions in goats: Is immunoregulation involved in the control of gastrointestinal nematode? *Parasite Immunology* 30: 79-88.

Kaplan RM, Burke JM, Terrill TH, Miller JE, Getz WR, Mobini S, Valencia E, Williams MJ, Williamson LR, Larsen M and Vatta AF (2004). Validation of the Famacha eye colour chart for detecting clinical anaemia in sheep and goats on farms in the southern United States. *Veterinary Parasitology* 123: 105-120.

Khan MN, Sajid MS, Khan MK, Iqbal Z and Hussain A (2010). Gastrointestinal helminthiasis: prevalence and associated determinants in domestic ruminants of district Toba Tek Singh, Punjab, Pakistan. *Parasitology Research* 107 (4): 787-794.

Kouakou B, Gazal OS, Terrill TH, Kannan G, Gelaye S and Amoah EA (2008). Digestibility, hormones and blood metabolites in dairy bucks subjected to underfeeding and re-feeding. *Small Ruminant Research* 75: 171-176.

Kruger LP (2015). The effect of environmental factors and husbandry practices on stress in goats. MSc Thesis, University of Pretoria, Pretoria, South Africa.

Kumba FF, Katjivena H, Kauta G and Lutaaya E (2003). Seasonal evolution of faecal egg output by gastrointestinal worms in goats on communal farms in eastern Namibia. *Onderstepoort Journal of Veterinary Research* 70: 265-271.

Kunene KW, Nde FF and Qwabe CSZ (2015). Management of Nguni goats to control gastrointestinal parasites and anthelmintic resistance at KwaMthethwa and Owen Sitole College of Agriculture area. *African Journal of Agricultural Research* 10 (11): 1197-1202.

Lehloenya KC, Greyling JPC and Schwalbach LMJ (2005). Reproductive performance of South African indigenous goats following oestrous synchronization and AI. *Small Ruminant Research* 57: 115-120.

Li BT, Christopherson RJ and Cosgrove RJ (1999). Effect of water restriction and environmental temperatures on metabolic rate and physiological parameters in sheep. *Canadian Journal of Animal Science* 80: 97-104.

Mamabolo MJ and Webb EC (2005). Goat production survey fundamental aspects to model goat production systems in Southern Africa. *Case study Agricultural commission-WITFOR 2005*, South Africa.

Mahala AG, Nsahlai IV, Basha NAD and Mohammed LA (2009). Nutritive evaluation of natural pastures at early and late rainfall season in Kordofan and Butana, Sudan. *Australian Journal of Basic and Applied Sciences* 3 (4): 4327-4332.

Malan FS, Van Wyk JA, Wessels CD (2001). Clinical evaluation of anaemia in sheep: early trials. *Onderstepoort Journal of Veterinary Research* 68: 165-174.

Maloiy GMO, Kanui TI, Towett PK, Wambugu SN, Miaron JO and Wanyoike MM (2008). Effects of dehydration and heat stress on feed intake and dry matter digestibility in East African ruminants. *Comparative Biochemistry and Physiology* 151A: 185.190.

Maphosa V, Masika PJ, Bizimenyera ES and Eloff JN (2010). In-vitro anthelminthic activity of crude aqueous extracts of *Aloe ferox*, *Leonotis leonurus* and *Elephantorrhiza elephantine* against *Haemonchus contortus*. *Tropical Animal Health Production* 42: 301-307.

Marshall R, Gebrelul S, Gray L and Ghebreiyessus Y (2012). Mixed special grazing of cattle and goats on gastrointestinal infections of *Haemonchus Contortus*. *American Journal of Animal and Veterinary Sciences* 7 (2): 61-66.

Marume U, Chimonyo M and Dzama K (2011). A preliminary study on the responses to experimental *Haemonchus contortus* infection in indigenous goat genotypes. *Small Ruminant Research* 95: 70-74.

Masika PJ, Mafu JV, Goqwana MW, Mbuti C and Raats J (1998). A comparison of goat growth performance in a communal and commercial farming system in the Central Eastern Cape Province, South Africa. *In Webb EC and Cronje PB (eds): Research and training strategies for goat production systems in South Africa.* Department of Animal and Wildlife Sciences, University of Pretoria, Pretoria: 34-42.

Mengistu U, Dahlborn K and Olsson K (2007). Effects of intermittent watering on water balance and feed intake in male Ethiopian Somali goats. *Small Ruminant Research* 67: 45-54.

Mhoma JRL, Kanyari PWN and Kagira JM (2011). The prevalence of gastro-intestinal parasites in goats in urban and peri-urban areas of Mwanza city, Tanzania. *Scientia Parasitologica* 12 (4): 191-196.

Misra AK and Singh K (2002). Effect of water deprivation on dry matter intake, nutrient utilization and metabolic water production in goats under semi-arid zone in India. *Small Ruminant Research* 46: 159-165.

Mirkena T, Duguma G, Haile A, Tibbo M, Okeyo AM, Wurzinger M and Sölkner J (2010). Genetics of adaptation in domestic farm animals: A review. *Livestock Science* 132: 1-12.

Mmbengwa VM, Groenewald JA, van Schalkwyk HD and Greyling PJC (2013). Teat perimeters for South African Boer and Nguni goats: Use of these measurements to predict milk production potential and kids' growth. *African Journal of Agricultural Research* 8 (3): 317-324.

Moyo B, Masika PJ and Muchenje V (2013). Effects of supplementing cross-bred Xhosa lop eared goats with *Moringa Oleifera* Lam. on helminth load and corresponding body condition score, packed cell volume. *African Journal of Agricultural Research* 8 (43): 5327-5335.

Mustafa YS, Sulehria AQK, Muneer MA and Munir R (2010). Effect of water restriction on the lymphoid organs and production of broilers. *Biologia* 56 (1 & 2): 63-68.

Mutibvu T, Maburutse BE, Mbiriri DT and Kashangura MT (2012). Constraints and opportunities for increased livestock production in communal areas: A case study of Simbe, Zimbabwe. *Livestock Research for Rural Development* 24: article #165. Retrieved March 28, 2016, from http://www.lrrd.org/lrrd24/9/muti24165.htm.

NAMC (2005). Draft 1: Report on the investigation into the potential for the South African goat industry. *National Agricultural Marketing Council*, March 31.

Nsoso SJ, Aganga AA, Moganetsi BP and Tshwenyane SO (2003). Body weight, body condition score and heart girth in indigenous Tswana goats during the dry and wet seasons in southeast Botswana. *Livestock Research for Rural Development* 15(4). Retrieved May 14, 2014, from http://www.lrrd.org/lrrd15/4/nsos154.htm.

Paddock R (2011). *Haemonchus contortus* in sheep and goats: An insidious killer. *Fall 2011 Newsletter*. http://www.addl.purdue.edu/Newsletter/2011/Fall/Haemonchus.aspx.

Papachristou TG, Luthando ED and Frederick DP (2005). Review article: Foraging ecology of goats and sheep on wooden rangelands. *Small Ruminant Research* 59: 141-156.

Perry BD, Randolph TF, McDermott JJ, Sones KR and Thornton PK (2002). Investing in animal health research to alleviate poverty. *International Livestock Research Institute*, Nairobi, Kenya: 148.

Preston TR and Murgueitio E (1992). Strategy for sustainable livestock production in the tropics. *CONDRIT Ltda*, Cali: 89.

Qinisa MM, Boomker EA and Mokoboki HK (2011). Physiological response of water-restricted Tswana and Boer goats. *Life Science Journal* 8 (S2): 106-111.

Ramabu SS, Dintsi G, Kobe O, Legwale MC, Bika IO, Nthoiwa GP and Sebolai B (2015). Gastro-intestinal nematodes of goats reared under communal small scale farming conditions in Botswana. *Bulletin of Animal Health and Production in Africa* 63 (2).

Rastogi T, Bhutda V, Moon K, Aswar PB and Khadabadi SS (2009). Comparative studies on antihelminth activity of *Moringa oleifera* and *Vitex negundo*. *Asian Journal of Research Chemistry* 2: 181-182.

Rhind SM, Reid HW and McMillen SR (2009). Effects of pulsed or continuous infusion of cortisol on immune function in sheep. *Domestic Animal Endocrinology* 16: 1-9.

Rumosa Gwaze F, Chimonyo M and Dzama K (2009a). Communal goat production in Southern Africa: a review. *Tropical Animal Health and Production* 41: 1157-1168.

Rumosa Gwaze F, Chimonyo M and Dzama K (2009b). Prevalence and loads of gastrointestinal parasites in goats in the communal areas of the Eastern Cape Province in South Africa. *Small Ruminant Research* 84: 132-134.

Rumosa Gwaze F, Chimonyo M and Dzama K (2010). Relationship between nutritionally-related blood metabolites and gastrointestinal parasites in Nguni goats of South Africa. *Asian-Australasian Journal of Animal Sciences* 23 (9): 1190-1197.

Rust JM and Rust T (2013). Climate change and livestock production: A review with emphasis on Africa. *South African Journal of Animal Science* 43 (3): 255-267.

Saico S and Abul S (2007). Socio economic constraints on goat farming in the lowveld of Swaziland. *Journal of Sustainable Development in Africa* 9: 37-49.

Sanson DW, West TR, Tatman WR, Riley ML, Judkins MB and Moss GE (1993). Relationship of body composition of mature ewes with condition score and body weight. *Journal of Animal Science* 71: 1112-1116.

Sebei PJ, McCrindle CME and Webb EC (2004). Factors influencing weaning percentages of indigenous goats on communal grazing. *South African Journal of Animal Science* 34: 130-133.

Silanikove N (2000). The physiological basis of adaptation in goats to harsh environment: a review. *Small Ruminant Research* 35: 181-193.

Simela L and Merkel R (2008). The contribution of chevon from Africa to global meat production. *Meat Science* 80: 101-109.

Singh V, Varshney P, Dash SK and Lal HP (2013). Prevalence of gastrointestinal parasites in sheep and goats in and around Mathura, India. *Veterinary World*: 260-262.

Sissay MM, Asefa A, Uggla A and Waller PJ (2006). Anthelmintic resistance of nematode parasites of small ruminants in eastern Ethiopia: Exploitation of refugia to restore anthelmintic efficacy. *Veterinary Parasitology* 135: 337-346.

Slayi M, Maphosa V, Fayemi OP and Mapfumo L (2014). Farmers' perceptions of goat kid mortality under communal farming in Eastern Cape, South Africa. *Tropical Animal Health and Production* 46 (7): 1209-1215.

Snyman MA (2014). South African goat breeds: Boer goat. *Grootfontein Agricultural Development Institute*. Info pack ref. 2014/002.

Solomon AK, Mwai O, Grum G, Haile A, Rischkowsky A, Solomon G and Dessie T (2014). Review of goat research and development projects in Ethiopia ILRI Project report. Nairobi, Kenya. *International Livestock Research Institute*: 17.

Sri Jeyakumar C (2007). A preliminary report on the use of FAMACHA for haemonchosis in goats in the Eastern Cape Province of South Africa during the late autumn/early winter period. *Journal of the South African Veterinary Association* 78 (2): 90-91.

Teixeira IAMA, Pereira Filho JM, Murray PJ, Resende KT, Ferreira ACD and Fregadolli FL (2006). Water balance in goats subjected to feed restriction. *Small Ruminant Research* 63: 20-27.

Thornton P, Herrero M, Freeman A, Mwai O, Rege E, Jones P and McDermott J (2007). Vulnerability, climate change and livestock – Research opportunities and challenges for poverty alleviation. *SAT eJournal* 4 (1): 1-23.

Tsotetsi AM, Njiro S, Katsande TC, Moyo G, Baloyi F and Mpofu J (2013). Prevalence of gastrointestinal helminths and anthelmintic resistance on small-scale farms in Gauteng Province, South Africa. *Tropical Animal Health and Production* 45: 751-761.

Uddin MN, Ahmed BS, Rashedunnabi AM, Uddin MMS, Hasan KMM and Abdul BM (2014). Nutritional status of Black Bengal goat in government goat development farm, Sylhet. *Annals of Veterinary and Animal Science*: 97-104.

Valentine BA, Cebra CK and Taylor GH (2007). Fatal gastrointestinal parasitism in goats: 31 cases (2001-2006). *Journal of American Veterinary Medical Association* 231 (7): 1098-1103.

Van Wyk A, Hoste H, Kaplan RM and Besier RB (2006). Targeted selective treatment for worm management – how do we sell rational programs to farmers? *Veterinary Parasitology* 139: 336-346.

Van Wyk JA and Mayhew E (2013). Morphological identification of parasitic nematode infective larvae of small ruminants and cattle: A practical lab guide. *Onderstepoort Journal of Veterinary Research* 80 (1): article #539, 14 pages. http://dx.doi.org/10.4102/ojvr.v80i1.539.

Vatta AF, Letty BA, van der Linde MJ, van Wijk EF, Hansen JW and Krecek RC (2001). Testing for clinical anaemia caused by *Haemonchu*s spp. in goats farmed under resource-poor conditions in South Africa using an eye colour chart developed for sheep. *Veterinary Parasitology* 99: 1-14.

Veerasamy S and Rajendra SS (2010). Effects on melatonin on adrenal cortisol function of Indian goats under thermal stress. *Veterinary Medicine International 2010*: 1-6.

Villarroel A (2013). Internal parasites in sheep and goats. EM95. Oregon State University Extension Service. http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/36666/em9055.pdf

Webb EC and Mamabolo MJ (2004). Production and reproduction characteristic of South African indigenous goats in communal farming systems. *South African Journal of Animal Science* 34 (1): 236-239.

Xhomfulana V, Mapiye C, Chimonyo M and Marufu MC (2009). Supplements containing *Acacia karoo* foliage reduce nematode burdens in Nguni and crossbred cattle. *Animal Production Science* 49: 646-653.

Yilmaz M, Taskin T, Bardakcioglu HE and Di Loria A (2014). Effect of body condition score on some blood parameters for anaemia level in goats. *Veterinarija Ir Zootechnika* 67 (89): 41-46.

Zajac AM (2006). Gastrointestinal nematodes of small ruminants: Life cycle, anthelmintics and diagnosis. Veterinary Clinics: Food Animal Practice 22: 529-541.

CHAPTER 3: Importance of gastrointestinal parasites in Nguni goats in semi-arid areas facing water shortages

Abstract

A survey was conducted to compare the importance of gastrointestinal parasites in households experiencing water shortage and no water shortage under communal production systems in KwaNongoma (Zululand district) in Northern KwaZulu-Natal in South Africa. Two hundred and eighty-five households were interviewed as follows: 142 from the site facing no water shortage and 143 from the site experiencing water shortage. More males (69 % in households with no water shortage and 64% in households with water shortages), than female owned goats. The government grant was the main source of income in households facing no water shortage (60 %) and those with water shortages (65 %). Mean goat flock sizes per household were not significantly different ($P > 0.05$) between the two sites; those with (13.2 ± 1.23) or without (14.7 ± 1.25) water shortages. Farmers in both sites reared goats mainly for traditional ceremonies. Goats in households experiencing water shortage were 10.95 times more likely to experience water scarcity than goats in site with no water shortages ($P < 0.05$). Farmer perceptions demonstrated that diseases and gastrointestinal parasites were the main goat production constraints that farmers in both study sites faced. It was concluded that roundworms were the most important parasites affecting goats in households that experienced water shortages.

Keywords: Gastrointestinal parasites; Nguni goat; perennial rivers; seasonal rivers; water shortage.

3.1 Introduction

Rijberman (2006) reported that water will be a major constraint for agriculture in Africa in the coming decades. Sub-Saharan Africa is experiencing a gradual, yet steady, changes in climate (Griffin, 2012) and is water-scarce (DEA, 2011; Agholor, 2013). Rainfall patterns are shifting, and are a little more variable and unpredictable (Griffin, 2012). There is a significant increase over annual heavy rainfall events in Africa (Groisman *et al.,* 2005), however the intensity of rainfall has decreased resulting in shorter wet season (Nel, 2009). Temperatures have risen significantly over the last 60 years and are expected to continue this rising trend (Griffin, 2012), resulting in an increase in mean maximum temperatures (Easterling *et al.,* 1997). Kruger and Sekele (2013) reported an increased frequency of hot extremes and decreased frequency of cold extremes.

South Africa is amongst countries facing the worst drought in years, resulting in dry conditions that are affecting livestock and crops. The WRC (2016) also highlighted that water resources are drying, and animals are dying due to water and feed shortages, as evidence of drought. Such changes in weather patterns has a huge effect on extensive production systems, as this system relies on natural waters for drinking and crop production. Goats are largely kept by resource-limited farmers and reared under communal production systems which are characterised by low levels of management and meagre productivity (Masika and Mafu, 2004). Water scarcity and high prevalence of diseases are two of the main production constraints that communal production systems in semi-arid areas face (Slayi *et al*., 2014; Al-Khaza'leh *et al.,* 2015). Of the diseases, gastrointestinal parasites are ranked as one of the most important production constraint that is faced by communal farmers owning goats (Rumosa Gwaze *et al.,* 2009; Kunene *et al.,* 2015). Against this background, the objective of the current study was to compare factors influencing gastrointestinal parasite burden in households that face water shortages under resource-limited communal production systems. The hypothesis tested was that gastrointestinal parasites are perceived to be a major challenge in households experiencing water shortages than in households that do not experience water shortages.

3.2 Materials and methods

3.2.1 Description of study site

The current study was conducted at KwaNongoma (27°53'S 31° 38'E), under Nongoma local municipality, Zululand district in the Northern part of KwaZulu-Natal Province, at an altitude of approximately 750 m above sea level. KwaZulu-Natal forms one of the leading provinces in South Africa with the largest distribution of Nguni goats in communal production systems (Botha and Roux, 2008).

Mkhize (2008) described the study site as 65 % with seasonal rivers and 35 % with perennial rivers; with an average annual rainfall of < 600 mm in semi-arid and between 800 and 1000 mm in wetland. The average maximum and minimum temperatures are 29°C and 7.4°C. KwaNongoma is characterised by under-developed water resources, and inadequate supply of water for domestic use in most parts of the area (Mpanza, 1996).

The study region was classified based on water shortages. There were households experiencing water shortage and those not experiencing water shortages. Rivers are the major sources of water for both household and livestock consumption. In households that faced water shortages, rivers had water only during rainy season; whereas in households that did not face water shortages, rivers had water throughout the year (perennial). The seasonal river systems in the area used for drinking by both humans and livestock were Mngeni, Mseba, Entwani, Bululwane, Wela, White-Sizilinda, Entwani, Manzimakhulu River. The perennial river systems used by both humans and livestock were Ivuna, Mona and Black Mfolozi.

The vegetation at KwaNongoma consists of four main types, namely; arid lowveld (dominated by the mixture of Acacia trees, Bushveld trees, leafed perennials and annual grasses such as *Elensine indica, Aristida adcenionis* and *Rhynchelaatrum repeses*); Lowveld (dominated by woody vegetation dominated by *Dichrostachys cinerea, Acacia nigrescence* and *Ziziphus mucronata*); Northern tall grassland (dominated by *Hyparrhenia hirta, Sporobolus pyramidalis* and woody component such as *Acacia sieberana*) and Zululand thornveld (dominated by bushveld species such as *Dichrostachys cinerea* and *Cynodon dactylon* as a grass sward) (Mpanza, 1996; Scogings *et al.*, 2004).

3.2.2 Sampling of households

Households were selected based on the number of Nguni goats owned and the willingness to participate in the study. Farmers who had at least 10 Nguni goats were considered. The snowball sampling technique was used to identify respondents. An estimate of 142 households were interviewed from sites experiencing no water shortages and 143 from sites facing water shortages.

3.2.3 Data collection

A total of 285 households were interviewed in July 2014, consisting of nine villages from households experiencing water shortages and ten villages from households not facing water shortages. Data were acquired through interviews using a pre-tested questionnaire. Questionnaires were administered in the local vernacular IsiZulu by trained enumerators. Enumerators were obtained from KwaNongoma communities. Meetings with local authorities such as chiefs and local headmen were conducted to enable easy access to communities. Local livestock officers, veterinarians, farmer's association and extension officers from the Department of Agriculture were interviewed to help in identifying communities to generate a list of farmers that kept Nguni goats, and to give an overview of water challenges for livestock in the area.

Data were collected on household demographics, the socio-economic status of households, reasons for keeping goats, goat production constraints, disease challenges and prevalence of gastrointestinal parasites (see Appendix 1).

As shown in Table 3.1, the household size was lesser by two members in households experiencing water shortages compared to those facing no water shortages. There were over 60 % males heading households in both areas. Three out of 10 people had no formal education in households with water shortage, 65 % possessed school education, and the remainder had tertiary education; whereas in households with no water shortage, 1 out of 5 had no formal education, 71 % possessed school education, and the remainder had tertiary education. Over 60 % of household income came from the government old-age pensions and children social grants in both sites. Livestock sales were ranked as the third source of income, and livestock products (e.g. meat, milk and skin) as the fourth source of income in both sites.

3.2.4 Statistical analyses

The PROC FREQ of SAS (2010) was run to compute household demographics and sources of household income. The PROC MMEANS of SAS (2010) was used to rank the reasons of keeping goats, goat production constraints, common diseases, common parasites, and causes of kid mortality. General Linear Model (GLM) of SAS (2010) was used to analyse farmers' livestock herd composition. An ordinal logistic regression (PROC LOGISTIC) was used to estimate the probability of a household experiencing water scarcity and the probability of household experiencing high loads of gastrointestinal parasites (SAS, 2010). The results were

Table 3.1: Household characteristics of farmers owning Nguni goats

	Household	
Characteristic	**No water shortage**	**Water shortage**
Gender of head of household (%)		
Males	68.9	64.0
Female	31.1	36.0
Household size	9	7
Highest education (%)		
No education	23.8	33.3
7 years of education	36.1	43.1
12 years of education	35.3	22.0
Tertiary	4.8	1.6
Source of household income (%)		
Crops	6	2
Livestock sales	13	12
Livestock products	8	9
Salary	27	25
Government old age and social grant	60	65
Other sources	9	11

interpreted for age, gender, household size, residence of farmer (staying away from the farm and staying at the farm), level of education (educated and uneducated), extent of water shortage (low and high), goat flock size, production system (extensive and semi-intensive/herding during the day and not herding during the day) and distance from the major water source (within 3 km and > 3 km).

The following logit model was used:

$$\text{In } [P/1-P] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 \ldots + \beta_t X_t + \varepsilon$$

Where:

P = probability of household experiencing water scarcity; household experiencing high loads of gastrointestinal parasites;

[P/1−P] = odds ratio (the odds of household experiencing water scarcity; the odds of a household experiencing high loads of gastrointestinal parasites)

$\beta 0$ = intercept;

$\beta 1X1 \ldots \beta tXt$ = regression coefficients of predictors;

ε = random residual error.

3.3 Results

3.3.1 Goat flock sizes

Goat flock sizes were similar ($P > 0.05$) in households experiencing water shortages and the ones who did not face water shortages (Table 3.2). Flock sizes for chickens were different ($P < 0.05$) in the two sites, and the largest compared to goats and other livestock species.

Table 3.2: Livestock herd sizes of farmers in households with access to perennial rivers (experiencing no water shortages) and seasonal rivers facing water shortages

	Household	
Livestock species	**Perennial rivers**	**Seasonal rivers**
Cattle	10.7	9.6
Goats	14.7	13.2
Sheep	1.3	1.1
Chickens	14.8^{a}	19.4^{b}
Pigs	0.3	0.1
Donkeys	0.1	0.5
Peacocks	0.0	0.1
Geese	0.1	0.2
Ducks	0.0	0.3

^{ab} Values within a row with different superscripts ($P < 0.05$)

^{aa} Values within a row with same superscripts are not significant ($P > 0.05$)

3.3.2 Reasons for keeping goats

As shown in Table 3.3, farmers in both sites ranked ceremonies, sales and meat in that order. However, the least important use of goats in households experiencing water shortages was for milk whilst farmers from the site with no water shortages considered use of goats for gifts as of low importance. Farmers from the site with no water shortages valued milk more than investments in comparison with farmers from the site with water shortages who valued investments. Manure and skin were considered more important in households with water shortages than the one without water shortages.

3.3.3 Goat production constraints

Farmers in households experiencing water shortages ranked diseases and gastrointestinal parasites in that order whereas households with no water shortages ranked gastrointestinal parasites and diseases in that order (Table 3.4). Ectoparasites were, however, more important in households that were not experiencing water shortages than their counterparts with water shortages. Water scarcity was significantly different ($P < 0.05$) in households experiencing water shortages and those not facing water shortages, with greater importance in sites experiencing water shortages as compared to the site facing no water shortages.

There was no difference ($P > 0.05$) in the importance placed on kid mortality by farmers from both sites. Feed shortages were not significantly different in both sites. There was a significant difference ($P < 0.05$) in goat thefts in both sites, with greater importance in households experiencing water shortages. There was no difference in the importance placed on predators, which is the least important constraint in both sites.

The most common disease constraints to goat production in households from both sites are shown in Figure 3.1. Farmers in both sites ranked coccidiosis, diarrhoea and abortion in the

Table 3.3: Ranking of the reasons for keeping goats in households with access to perennial rivers (experiencing no water shortages) and seasonal rivers facing water shortages

	Rank	
Goat use	**Perennial rivers**	**Seasonal rivers**
Meat	1.90[a] (3)	1.82 (3)
Milk	2.00 (4)	3.30 (8)
Manure	2.17 (6)	2.12 (5)
Skin	2.90 (7)	2.16 (6)
Sales (live goats)	1.66 (2)	1.50 (2)
Investments	2.15 (5)	1.95 (4)
Ceremonies	1.00 (1)	1.08 (1)
Gifts	3.10 (8)	2.89 (7)

[a] The lower the mean rank of a goat use, the greater is its importance.

Values in parenthesis are the ranks of the reasons for keeping goats

Table 3.4: Goat production constraints in households experiencing with access to perennial rivers (experiencing no water shortages) and seasonal rivers facing water shortages

Constraint	Perennial rivers	Seasonal rivers	Significance
Water scarcity	1.52[a] (3)	1.73 (6)	*
Feed shortage	1.62 (6)	1.69 (5)	NS
Ectoparasites	1.64 (7)	1.54 (3)	NS
Gastrointestinal parasites	1.45 (2)	1.50 (1)	NS
Diseases	1.43 (1)	1.53 (2)	NS
Livestock theft	1.61 (5)	1.75 (7)	*
Predators	1.91 (8)	1.94 (8)	NS
Kid mortality	1.57 (4)	1.59 (4)	NS

[a] The lower the mean rank of a constraint, the greater is its importance

Values in parenthesis are the ranks of the constraints

*$P < 0.05$; NS – $P > 0.05$

NS: Not significant

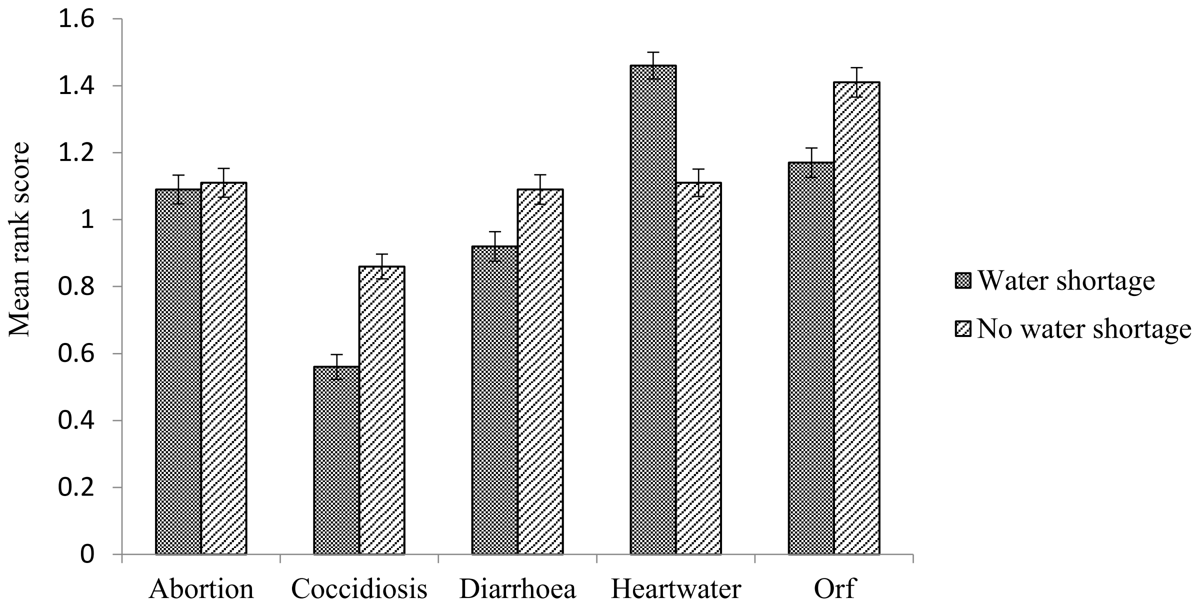

Figure 3.1: Common diseases of goats in households with access to perennial rivers (experiencing no water shortages) and seasonal rivers (facing water shortages)

same order (Figure 3.1). Coccidiosis was the most important disease affecting goats in both sites as compared to other diseases, and was different in both sites with larger importance in the site with shortage of water. There was a significant difference ($P < 0.05$) in the importance of diarrhoea and orf in both sites, with more importance for households experiencing water shortage. There was no difference in the importance of abortion in both sites. Heartwater was, however, of larger importance in goats from households that were experiencing shortages of water.

The most common parasites which are constraints to goat production in both sites are shown in Figure 3.2. Roundworms were ranked as the most important common parasites affecting goats in the households that experienced water shortages, whereas in households facing no water shortages ticks were more important. Roundworms were of larger importance ($P < 0.05$) in households experiencing shortages of water; whereas ticks were of larger importance in households experiencing no shortage of water. Tapeworms were ranked the second and mites the fourth common parasite affecting goats. Tapeworm were of larger importance in households experiencing shortages of water that those with access to perennial rivers. The importance of lice affecting goats was larger in goat flocks kept in household with no water shortages. There was no significant difference ($P > 0.05$) in importance of liverfluke prevalence in both sites.

Kid mortality was another constraint that farmers faced (Table 3.4). As also shown in Figure 3.3, farmers in the site with households experiencing water shortages ranked feed shortages as the main cause of kid mortality as compared to other causes, and was different from the households facing no water shortage. The lack of milk was different in both sites, with the households experiencing water shortages being the largely affected. Farmers indicated that

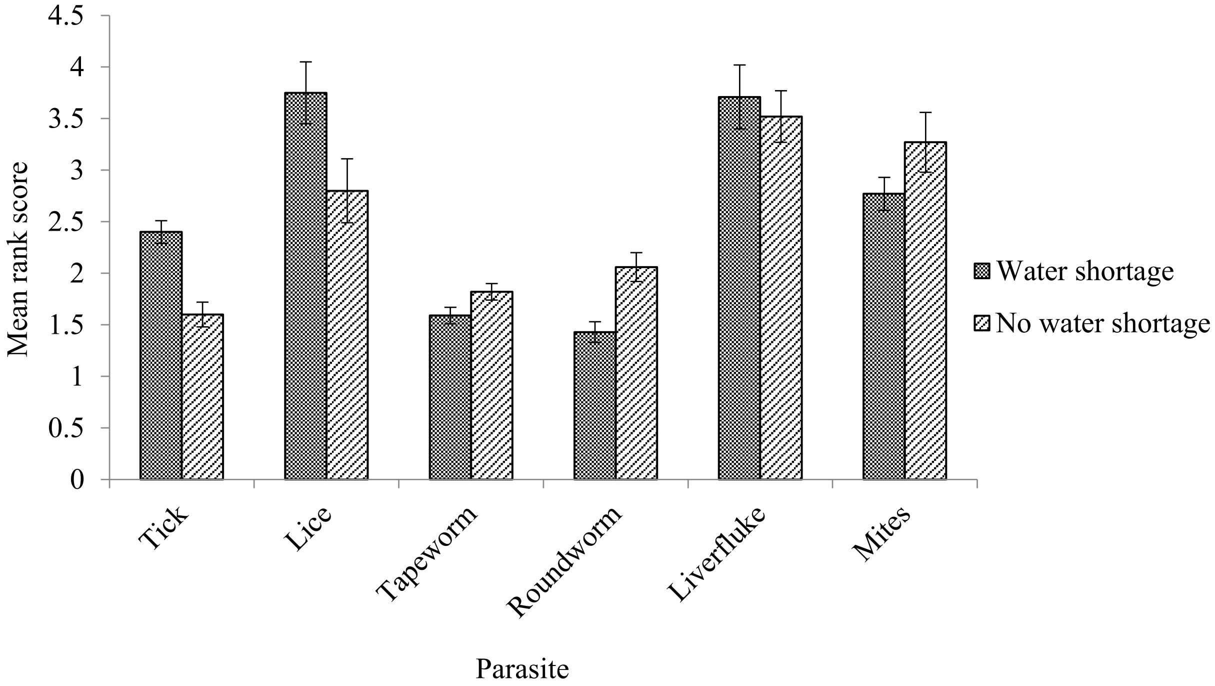

Figure 3.2: Common parasites of goats in households with access to perennial rivers (experiencing no water shortages) and seasonal rivers (facing water shortages)

there was no difference in lack of colostrum, predators, and not deworming kids at weaning in both sites (Figure 3.3).

3.3.4 Severity of water scarcity

As indicated in Table 3.5, water scarcity was significantly different ($P < 0.05$) in households that experienced water shortages than households in sites facing no water shortages. Goats in households experiencing water shortages were 11.0 times more likely to experience water scarcity as compared to the site facing no water shortage. Goats in households that were located closer (within 3 km) to the nearest water source were 2.52 times more likely to experience water scarcity as compared to goats in households located over 3 km from the nearest water source.

3.3.5 Prevalence of gastrointestinal parasites

The prevalence of gastrointestinal parasite per season in both sites are shown in Table 3.6. There was no difference in gastrointestinal prevalence in the four seasons in households experiencing water shortages and those facing no water shortages (Table 3.6). A unit increase in age of the adult taking care of goats is likely to result in the odds of experiencing high loads of gastrointestinal parasites during rainy season decreasing by 1.2. A unit increase in the owner of goats that stays at the farm is likely to result in the odds of experiencing high loads of gastrointestinal parasites during rainy season decreasing by 2.4. A unit increase in level of formal education of people looking after goats is likely to result in the odds of experiencing high loads of gastrointestinal parasites during the rainy season decreasing by 2.8. A unit increase in not herding goats during the day is likely to result in the odds of experiencing high loads of parasites during the cool dry season decreasing by 2.9.

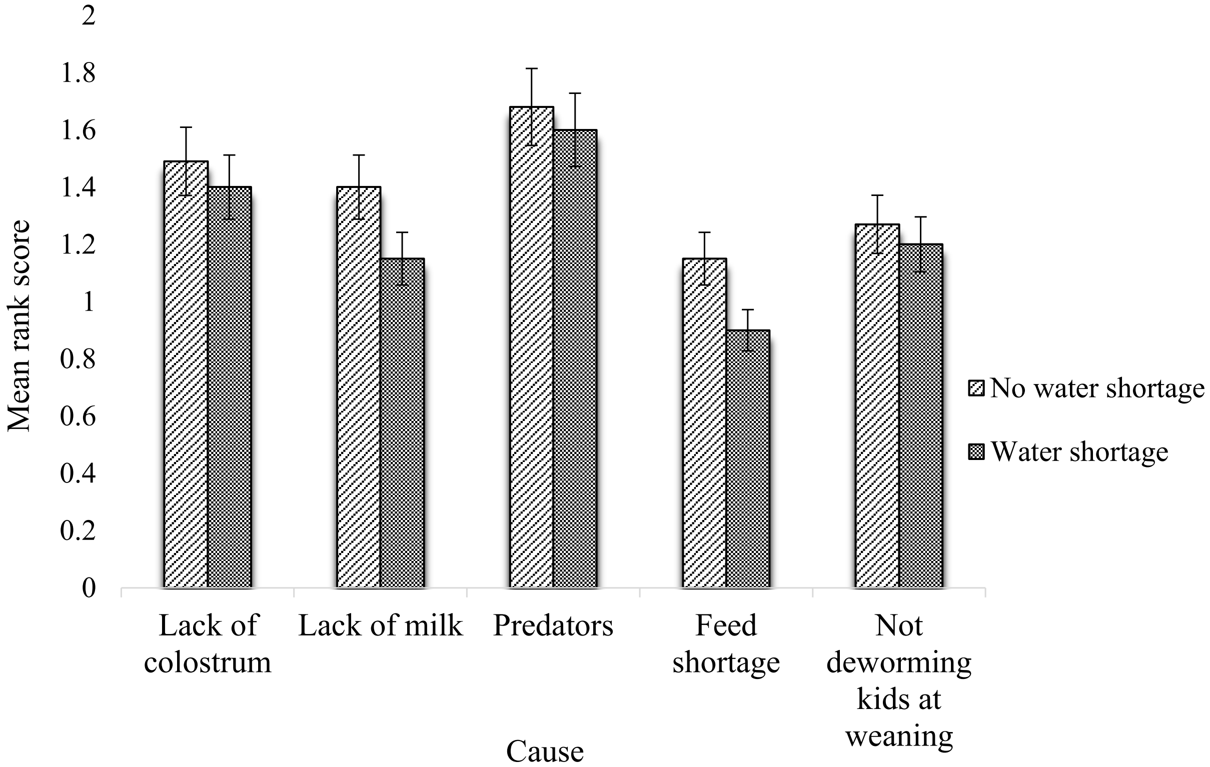

Figure 3.3: Causes of kid mortality in goats from households with access to perennial rivers (experiencing no water shortages) and seasonal rivers (facing water shortage)

Table 3.5: Odds ratio estimates, lower (LCI) and upper confidence (UCI) interval of water scarcity among communal households

Predictor	Water scarcity			Significance
	Odds	LCI	UCI	
Water scarcity (seasonal versus perennial)	10.95	5.34	22.42	*
Age (youth versus adult)	1.25	0.43	3.66	NS
Gender (male versus female)	1.95	1.00	3.78	NS
Flock size	1.00	0.92	1.08	NS
Household size	1.00	0.92	1.08	NS
Production system (extensive vs semi-intensive)	0.64	0.19	2.17	NS
Distance (within 3 km vs > 3 km)	2.52	1.19	5.33	*
Siltation (yes versus no)	0.75	0.20	2.75	NS

- Higher odds ratio estimates indicate greater difference in occurrence between levels of predictors.

- * $P < 0.05$; NS = Not different ($P > 0.05$)

- vs indicates versus

Table 3.6: Odds ratio estimates, lower (LCI) and upper confidence (UCI) interval of households experiencing gastrointestinal parasite prevalence challenge in goats

Predictor	Odds	LCI	UCI	Odds	LCI	UCI	Odds	LCI	UCI	Odds	LCI	UCI
Water scarcity (seasonal versus perennial)	**1.72**	**0.83**	**3.59**	**1.09**	**0.55**	**2.13**	**1.67**	**0.84**	**3.45**	**0.57**	**0.28**	**1.17**
Gender (male versus female)	1.05	0.56	1.97	1.26	0.70	2.24	1.03	0.57	1.87	1.22	0.65	2.32
Age (youth versus adults)	0.82	0.45	0.50*	0.89	0.50	1.58	1.40	0.79	2.49	1.22	0.67	2.22
Residence (off farm versus on farm)	0.41	0.22	0.77*	0.71	0.40	1.25	0.88	0.49	1.56	1.55	0.85	2.89
Education (uneducated versus educated)	0.36	0.17	0.72*	0.80	0.43	1.49	1.52	0.80	2.94	1.64	0.83	3.35
Flock size	1.01	0.99	1.03	1.01	0.99	1.04	0.99	0.97	1.01	1.00	0.98	1.02
Production system[#]	1.91	0.93	3.95	1.84	0.94	3.63	0.35	0.17	0.69*	0.71	0.35	1.45

Higher odds ratio estimates indicate greater difference in preference between levels of predictors.

* $P < 0.05$

[#]Production system (herding during the day versus not herding during the day)

3.4 Discussion

The finding that males were heading most households in communal production systems agrees with earlier reports (Mahanjana and Cronje, 2000; Kunene and Fossey, 2006) which reported that men are traditional heads of households and owners of most communal production systems. Therefore, men exercise decision-making concerning production and distribution of livestock, regardless of whether they are residing on the farm or not. The majority of respondents in both sites received schooling for seven years and less, with 2 to 3 people out of 10 that had no formal education. The low percentage of respondents that achieved 12 years of and tertiary education explains the higher percentage of people receiving government old-age pensions and children social grants as the source of household income, which illustrates the socio-economic status of this community. The main source of income that farmers from the study site identified disagrees with Kunene and Fossey (2006) who reported that the highest source of income was obtained through employment and sales.

The observation that farmers do not farm with goats only, but with cattle, chicken, sheep, pigs and other livestock, is typical of most communal production systems to promote sustainable development through diversification (Mashatise *et al*., 2005). The findings that chickens flock sizes were higher than goat flock sizes could be due to that chickens are mostly slaughtered for meat consumption than other livestock (Kunene and Fossey, 2006). The higher goat flock sizes as compared to cattle could be ascribed to the fact that goats can withstand harsh environments (Silanikove, 2000; Debele *et al.*, 2011). The goat flock size is in contrast with findings from Kunene and Fossey (2006), who reported that cattle flock sizes were higher than that of goats in the same district.

The reason behind crops being the least source of income in both sites could be due to unreliable rainfall patterns causing limited probability of crop production in the area (Mpanza, 1996). Water scarcity restricts fodder production, and leads to degradation of ranges due to continued overgrazing. In most areas goats were allowed to graze and browse freely, and this could be associated with the availability of grazing land that is not used for cropping.

The observations that farmers ranked their major reasons for keeping goats as for traditional ceremonies, agrees with earlier reports (Mahanjana and Cronje, 2000; Akingbade *et al.*, 2001; Kunene and Fossey, 2006). The reason behind keeping goats could be that South African communities perceive goats as animals to be sacrificed for communicating with ancestors, therefore, hard to give as gifts. Goats were sold to local communities for traditional ceremonies (Masika and Mafu, 2004), as this is a common practice in KwaZulu-Natal where goats are seldomly slaughtered outside the cultural context (Phillips, 2013).

Manure is a source of organic fertilizer to improve crop production. Manure is of great importance especially to resource-limited farmers who cannot afford inorganic fertilizers. In many cultures in Africa, goat milk is not valued in communal production systems as goats are regarded as a ‘poor man’s cow’, therefore, milking goats is associated with poverty and something not to be proud of (Anteneh *et al.*, 2004). It is, however, important to encourage resource limited farmers in communal production systems to milk goats as is an important source of protein, has therapeutic properties and is easily digestible especially to infants, old and convalescent people (Zenebe *et al.*, 2014). The farmers did not value goat skin, and this could be due to that goats are slaughtered in low numbers informally for ceremonies and traditional functions, not at abattoirs. Therefore, farmers could make a viable business if they could combine skins from different households and market them.

The findings that water scarcity was one of the major production constraints that farmers were experiencing is likely influenced by climate change, leading to seasonal and inter-annual variations in rainfall which are amplified by high run-off production and rates of evaporation (Mukheibir, 2007). Mukheibir (2007) reported that much of South Africa is arid or semi-arid, therefore, subject to drought and reduction of reliable rainfall that might cause serious lack of surface and groundwater. The findings that water scarcity was high in sites with households experiencing water shortages could be due to that seasonal rivers dry up in dry seasons (Ben Salem and Smith, 2008). Goats that were nearer to water sources experienced higher water scarcity than those distant to water sources, and this is likely due to the fact that goats travel longer distances looking for feed, and therefore able to access available water storage sources in the site.

Climate change threatens to aggravate range conditions, causing further limits to feed availability and giving rise to outbreak of diseases that reduces goat productivity. Fluctuations in fodder availability is caused by lack of water and increasing land degradation (Iniguez, 2004). This was confirmed through transect walks around sites with households experiencing water shortages, which had no crops available and exhibited high rate of siltation; while famers located in sites facing no water shortages practiced crop production. Secondary informants which were made up of elderly people discouraged crop production due to the past crop failure as a result of drought.

The findings that goat theft was a significant goat production constraint higher households experiencing water shortages than those facing no water shortages, could be due to that goats were allowed to graze and browse freely in unfenced communal grazing areas without being herded, therefore travel long distances and were prone to theft and predation. This also predispose kids to theft and predation as kids are small and lack experience. Households that experienced water shortages live in desert; like conditions, particularly during dry season. The area is mountainous with sparse vegetation and thorns.

The findings that diseases and gastrointestinal parasites were the major production constraints that farmers from both sites were experiencing concur with Slayi *et al.* (2014) that reported starvation, abortions and diarrhoea as production constraints facing communal production systems. Shortage of feed for animal consumption in grazing lands could lead to malnutrition and escalation of diseases (Kunene *et al.*, 2015). Amongst the common disease conditions that farmers revealed, abortion is the only one that was not different between the two sites. Bacterial and viral infections resulting from poor management could be the causative agents of abortion as well (Kashem *et al.,* 2011).

The observation that orf was affecting goats from households that experience water shortages more than the ones with access to perennial rivers could be coupled with the geographical location of households with water shortages. Goats with orf have sores around the mouth and nose, caused by viral infection and damage caused by thorns and other objects in feed, ticks and lice (Turton, 2002); and therefore sores could limit browsing and grazing of goats. Vatta *et al.* (2006) observed that orf and other infections could also be flared up by stress of kidding. It was also revealed that ticks were one of the parasites affecting goats in communal production systems, thereby transmitting heartwater disease which affected mainly goats from households with access to perennial rivers, as these areas provide a favourable environment for growth and survival of ticks (Marufu *et al.*, 2010). This agrees with Muchenje *et al.* (2008) who reported high mortalities in cattle due to ticks and tick-borne diseases.

The farmers did not dip their goats to control ticks, lice and mites, which agrees with Kunene and Fossey (2006) that none of the farmers in the same district dipped their sheep and goats. Mites host tapeworms and goats get infected by ingesting herbage containing mites carrying the infective stage of the tapeworm. Liverfluke is transmitted by snails and slungs and these vectors are active during wet conditions, therefore, explains the larger importance of liverfluke in households with access to perennial rivers.

The findings that farmers identified kid mortality as a constraint to goat production could be due to diseases and gastrointestinal parasites, shortages of feed during the dry season and drought and also cold stress (Debele *et al.*, 2011). The observations that feed shortages were the main cause of kid mortality in households experiencing water shortages, concurs with Debele *et al.*, 2011. Feed shortages could be due to water scarcity resulting in unpalatable forages, insufficient forages, low forage quality, poor goat health status and low water quality resulting in reduced milk production. Transect walks revealed that most goat houses had no roof and raised slatted floors to allow faeces to pass through, to create an environment that impede the spread of gastrointestinal parasites and other diseases. This could be another cause of kid mortality. High kid mortality affects the economic viability of goats, thereby threatening the impact of litter size and fecundity of the flock (Debele *et al.*, 2011).

The observations that farmers identified roundworms and tapeworms to be severe especially in households that experienced water shortages explains the high prevalence of gastrointestinal parasites in goats. Farmers complained about high prevalence of gastrointestinal parasites in the study area, with the likelihood of higher burdens during the rainy and cool-dry season (Mbuh *et al.*, 2008; Khajuria *et al.,* 2013). The prevalence of gastrointestinal parasites is related to agro-climatic conditions such as quality and quantity of pasture, temperature, humidity and the host grazing behavior. During the rainy season, the environment and climate provide conditions conducive for optimum growth and proliferation of gastrointestinal parasites, whereas in cool-dry season goats become severely stressed mainly due to malnutrition and their immune systems become weak, then fail to fight infections. Kids and adult goats with weakened immune systems due to diseases are predisposed to gastrointestinal parasite infection (Henton, 2009).

The severity of diarrhoea and coccidiosis could be due to high loads of gastrointestinal parasites and agents arising from poor environmental conditions especially in the area with seasonal rivers where infection was severe. Diarrhoea manifests due to inflammation of gastrointestinal tracts (gastroenteritis) which causes indigestion, thus interfering with absorption due to the animal's inability to digest feed completely (Slayi *et al.,* 2014). Coccidiosis could be precipitated by stress caused by unfavourable conditions such as shortage of feed, high stocking density, increase in temperature and are mostly aggravated by gastrointestinal parasites infestation, resulting in watery diarrhoea and other clinical signs (Vatta *et al.,* 2006). Farmers did not deworm kids at weaning and this could be another cause of mortality, since kids have a weak immune system, therefore highly susceptible to gastrointestinal parasites and other diseases.

The findings revealed that when adults were taking care of goats there was a likelihood of decrease in gastrointestinal parasite infestation. The probable explanation could be the fact that they have a wide indigenous knowledge and experience in rearing and managing goats (Rumosa Gwaze *et al.*, 2009). Goats with owners that stayed at the farm were likely to decrease the gastrointestinal parasite load infestation, and could be related to the fact that farmers have a close relationship with their goats and know how to manage them effectively. Farmers with low levels of education worked with their goats on full time basis as is the source of their income; and have established a good relationship with their goats.

Herding goats during the day in the cool-dry season is likely to expose them to limited feed in the grazing land, where they will only graze and browse in a restricted area, whereas if not herded, they graze and browse as far as they could go and that gives them time to select and consume nutritious forages. Restricting goats expose them to little choice of feed, which induces stress that lowers their immunity and predispose goats to heavy gastrointestinal parasite infestation and other diseases (Caldeira *et al.*, 2007). Therefore, gastrointestinal parasites in combination with malnutrition, water scarcity and poor management could have a major effect on goat productivity.

3.5 Conclusions

The source of income for most communal farmers came from government pensions and children grants, therefore resulting in low household income. Farmers kept goats for traditional ceremonies Water scarcity, shortage of feed, diseases and prevalence of gastrointestinal parasites were major challenges experienced by farmers in the study site. It is important for farmers to adopt better management and preventive interventions to reduce gastrointestinal parasite infestations in communal productive systems, as well as improvement of productivity status of goats, and hence farmer livelihood. There is need to investigate the role of water restriction and deprivation on gastrointestinal parasites loads.

3.6 References

Agholor IA (2013). The revitalisation of water resources for sustainable agricultural development in South Africa: A review. *Journal of Agricultural Science* 5 (5): 76-82.

Akingbade AA, Nsahlai IV, Bonsi MLK, Morris CD and du Toit LP (2001). Reproductive performance of South African indigenous goats inoculated with DHP degraded rumen bacteria and maintained on Leucaena leucocephala/grass mixture and natural pasture. *Small Ruminant Research* 39: 73-85.

Al-Khaza'leh JM, Reiber C, Al Baqain R and Zàrate AV (2015). Drinking water sources, availability, quality, access and utilization for goats in the Karak Governorate, Jordan. *Tropical Animal Health Production* 47: 163-169.

Anteneh NT, Mekala DG, Mnisi PE, Mukisira C, Muthui M, Murungweni C and Sebitloane O (2004). Goat production and livelihood systems in Sekhukhune district of the Limpopo Province, South Africa. Opportunities for commercialising goats and their by-products, *Working Document Series* 118.

Ben Salem H and Smith T (2008). Feeding strategies to increase small ruminant production in dry environments. *Small Ruminant Research* 77: 174-194.

Botha AF and Roux JA (2008). Fibre, yarn and fabric properties of South African indigenous goat hair. *4th International Cashmere/wool Technique Symposium*. Erdos City, China, 17-18 November: 140-147.

Caldeira RM, Belo AT, Santos CC, Vazques MI and Portugal AV (2007). The effect of long-term feed restriction and over-nutrition on body condition score, blood metabolites and hormonal profiles in ewes. *Small Ruminant Research* 68: 242-255.

DEA (2011). South Africa's Second National Communication under the United Nations Framework Convention on Climate Change. *Department of Environmental Affairs*, Republic of South Africa, Pretoria.

Debele, G, Duguma, M and Hundessa, F (2011). Effect of different factors on mortality rate of Arsi-Bale kids in Mid Rift Valley of Ethiopia. *Global Veterinaria* 6 (1): 56-60.

Easterling DR, Horton B, Jones PD, Peterson TC, Karl TR, Parker DE, Salinger MJ, Razuvayev V, Plummer N, Jamason P and Folland CK (1997). Maximum and minimum temperature trends for the globe. *Science* 277 (5324): 364-367.

Griffin J (2012). The effect of climate change on South Africa. *Climate Emergency Institute (Climate Science Library)*. South Africa. info@sadamp.co.za.

Groisman PY, Knight RW, Eastelling DR, Karl TR, Hegerl GC and Razuvaev VN (2005). Trends in Intense Precipitation in the Climate Record. *Journal of Climate* 18: 1326-1350.

Henton M (2009). Pasteurella vrektes by lammers. Vra vir Faffa column. Landbou.com online.

Iniguez L (2004). Goats in resource-poor systems in the dry environments of West Asia, Central Asia and the Inter-Andean valleys. *Small Ruminant Research* 51: 137-144.

Kashem MA, Hossain MA, Ahmed SSU and Halim MA (2011). Prevalence of diseases, morbidity and mortality of Black Bengal goats under different management systems in Bangladesh. *University Journal of Zoology, Rajshahi University* 30: 1-4.

Khajuria JK, Katoch R, Yadav A, Godara R, Gupta SA and Singh A (2013). Seasonal prevalence of gastrointestinal helminths in sheep and goats of middle agro-climatic zone of Jammu province. *Journal of Parasitical Diseases* 37 (1): 21-25.

Kunene NW and Fossey A (2006). A survey on livestock production in some traditional areas of Northern KwaZulu-Natal in South Africa. *Livestock Research for Rural Development* 18: 113.

Kunene WN, Fon FN and Qwabe CSZ (2015). Management of Nguni goats to control gastrointestinal parasites and anthelmintic resistance at KwaMthethwa and Owen Sitole College of Agriculture area. *African Journal of Agricultural Research* 10 (11): 1197-1202.

Kruger AC and Sekele SS (2013). Trends in extreme temperature indices in South Africa. *International Journal of Climatology* 33 (3): 661-676.

Mahanjana AM and Cronje PB (2000). Factors affecting goat production in a communal farming system in the Eastern Cape region of South Africa. *South African Journal of Animal Science* 30 (2): 149-154.

Marufu MC, Chimonyo M, Dzama K and Mapiye C (2010). Seroprevalence of tick-borne diseases in communal cattle reared on sweet and sour rangelands in semi-arid area of South Africa. *The Veterinary Journal* 184 (1): 71-76.

Mashatise E, Hamudikuwanda H, Dzama K, Chimonyo M and Kanengoni A (2005). Socio-economic roles, traditional management systems and reproductive patterns of Mukota pigs in semi-arid north-eastern Zimbabwe. *Bunda Journal of Agriculture, Environmental Science and Technology* 3: 97-105.

Masika PJ and Mafu JV (2004). Aspects of goat farming in the communal farming systems of the central Eastern Cape, South Africa. *Small Ruminant Research* 52 (1-2): 161-164.

Mbuh JV, Ndamukong KJN, Ntonifor N and Nforlem GF (2008). Parasites of sheep and goats and their prevalence in Bokova, a rural area of Buea subdivision. Cameroon. *Veterinary Parasitology* 156: 350-352.

Mkhize NR (2008). Diet selection and foraging efficiency of Nguni goats in the Zululand thornveld, KwaZulu Natal. MSc thesis, University of Zululand, KwaZulu Natal, South Africa.

Mpanza SM (1996). The relationship between poverty and rural land use in Nongoma. MSc thesis, University of Zululand, KwaZulu Natal, South Africa.

Muchenje V, Dzama K, Chimonyo M, Raats JG and Strydom PE (2008). Tick susceptibility and its effect on growth performance and carcass characteristic of Nguni, Bonsmara and Angus steers raised on natural pasture. *Animal* 2: 298-304.

Mukheibir P (2007). The impact of climate change on small municipal water resource management (The case of Bredasdorp, South Africa). *Energy Research Centre,* University of Cape Town.

Nel W (2009). Rainfall trends in the KwaZulu-Natal Drakensberg region of South Africa during the twentieth century. *International Journal of Climatology* 29 (11): 1634-1641.

Phillips L (2013). Communal goat farmer thinks commercial. *Farmer's weekly*. Friday May 24 at 12:00.

Rijsberman FR (2006). Water scarcity: Fact or fiction? *Agricultural Water Management,* 80: 5-22.

Rumosa Gwaze F, Chimonyo M and Dzama K (2009). Communal goat production in Southern Africa: a review. *Tropical Animal Health Production* 41: 1157-1168.

SAS (2010). Statistical Analysis System User's Guide, Version 9.3. *SAS Institute Incorporate Cary,* North Carolina, USA.

Scogings PF, Dziba LE and Gordon IJ (2004). Leaf chemistry of woody plants in relation to season, canopy retention and goat browsing in a semiarid subtropical savannah. *Austral Ecology* 29: 278-286.

Silanikove N (2000). The physiological basis of adaptation in goats to harsh environments. *Small Ruminant Research* 35: 181-193.

Slayi M, Maphosa V, Fayemi OP and Mapfumo L (2014). Farmers' perceptions of goat kid mortality under communal farming in Eastern Cape, South Africa. *Tropical Animal Health Production* 46: 1209-1215.

Turton JA (2002). Common and important diseases of sheep and goats. *Animal Health for Developing Farmers, ARC-Onderstepoort Veterinary Institute*. Department of Agriculture.

Vatta AF, Abbott MA, de Villiers JF, Gumede SA, Harrison LJS, Krecek RC, Letty BA, Mapeyi N and Pearson RA (2006). Goatkeepers' Animal Health Care Manual. *Agricultural Research Council, Onderstepoort Veterinary Institute with KwaZulu-Natal Department of Agriculture and Environmental Affairs*: 32.

WRC (2016). Insight into indigenous coping strategies to drought - WRC study. WRC Report No. 2084/1/15. *South African Water Research Commission*. 28/10/2016.

Zenebe T, Ahmed N, Kabeta T and Kebede G (2014). Review on medicinal and nutritional values of goat milk. *Academic Journal of Nutrition* 3 (3): 30-39.

CHAPTER 4: Effects of water deprivation on gastrointestinal parasite loads in Nguni does

Abstract

The objective of the current study was to determine the effect of water deprivation on gastrointestinal parasite loads in Nguni does. Twelve goats were subjected to each of three levels of water deprivation; control (0), 24 and 48 hours. The trial ran for six weeks. The daily water intake (DWI), daily feed intake (DFI), body condition score (BCS), FAMACHA were measured. Faecal samples were collected and analysed for faecal egg counts (FEC) using the McMaster technique and were cultured for larval identification and counting (FLC). The DWI was similar ($P > 0.05$) at all deprivation levels, however largest in goats deprived of water for 48 hours. An increase in water deprivation period resulted in a decrease in DFI, ratio of DWI to DFI (DWI: DFI ratio), BCS and BWT. As water deprivation period increased, FEC and FAMACHA scores also increased. There was a significant difference ($P < 0.01$) in FLC for all deprivation periods. In general, goats deprived of water for 0 and 24 hours had the same FEC and lower counts of FLC as compared to goat deprived of water for 48 hours. Nearly 99% of the nematode larvae identified were *Haemonchus* species. It can be concluded that water deprivation up to 48 hours increases *Haemonchus* species loads in Nguni does.

Keywords: Body condition scores; daily feed intake; daily water intake; faecal egg counts; faecal larval counts; *Haemonchus*

4.1 Introduction

Water is limited in several countries, especially in many parts of Southern Africa (Schoeman and Visser, 1995). Factors contributing to water shortages include climate change, increase in human population and droughts (Thornton *et al.,* 2014). Humans and goats share drinking water sources, therefore this increases competition amongst the two. Rainfall is erratic and seasonal, contributing to shortage of drinking water for livestock, especially during the long dry season (Qinisa *et al.,* 2011). To maximise productivity, livestock genotypes that are less dependent on water should be identified, selected and utilised.

Nguni goats withstand harsh conditions, tolerate high temperature regimes and water scarcity during droughts, and are resistant to many endemic diseases and parasites (Rumosa Gwaze *et al.,* 2009a; Phillips, 2013). During dehydration periods, goats activate several mechanisms to save water and minimize water losses, and use a rumen as a water reservoir (Silanikove, 2000). Goats adapt to dehydration by limiting dry matter intake and respiration, as well as storing water in extracellular spaces during water availability to use during water shortage. This allows them to go for long periods without drinking water, whilst utilising water from the rumen and feed (McGregor, 2004). Although Nguni goats are resilient, the influence of climate change and water shortages on their ability to tolerate high worm burdens is unclear and needs to be determined.

Findings from the communal farmers in Chapter 3 highlighted that water shortages are getting worse with years. Water shortage leads to low forage quality and quantity, low nutrition levels in goats, and consequently aggravate gastrointestinal parasites. Although research has been done to assess the extent to which goats can tolerate water restriction (Qinisa *et al.,* 2011), limited research has been done to assess the extent to which water deprivation in Nguni does influence parasite loads. In Chapter 3, it was reported that Nguni goats went for up to two days without drinking water. An increase in water deprivation periods may cause stress in goats that could reduce their levels of immunity. The relationship between water deprivation and parasite burden is poorly understood. Therefore, there is a need to subject Nguni goats to various levels of water deprivation to understand their adaptability and monitor the nutritional status and gastrointestinal parasite burden when subjected to limited input resources. As gastrointestinal parasite loads increase, control programmes for nematodes have to be modified to suit these water shortages. The objective of the current study was to determine the effect of water deprivation on gastrointestinal parasite loads in Nguni does. It was hypothesised that increasing periods of water deprivation increases gastrointestinal parasite loads.

4.2 Materials and methods

4.2.1 Study site

The study was conducted at Ukulinga Research Farm, University of KwaZulu-Natal, Pietermaritzburg, KwaZulu-Natal, South Africa. The farm is located at 30°24′S, 29°24′E at an altitude of 700 m above sea level. The vegetation is characterized of various trees and grass species that are dominated by *Acacia nilotica*, *Acacia sieberiana* and *Acacia karoo*. The annual rainfall of 735 mm mostly occurs in summer between October and April. The mean annual temperatures are 8.9˚C minimum and 25˚C maximum.

4.2.2 Goats, housing and management

Thirty-six clinically healthy, 30-month old Nguni, non-lactating does with a body weight of about 25 kg were used. The body condition scores ranged from 3.0 to 4.0. These goats were purchased from Jozini communal area in Northern KwaZulu-Natal. Goats were housed in an enclosed naturally ventilated goat shed with a raised floor to keep goats dry, and slats on the floor to allow droppings and other dirt to fall through and allow air to pass through. Goats were confined in individual pens that were 140 x 80 cm, for the duration of the experiment. Each pen had a feeding trough and was fitted with a 5 L water bucket secured to the pen railing inside, with a thin flexible wire to ensure that goats do not trip the bucket and spill water. The average maximum and minimum temperatures were 25 ºC and 18 ºC respectively, and the average relative humidity was 58 %.

Goats were allowed to adapt for 10 days, then a 32-day trial period commenced. Goats had access to 1 kg/goat/day of *Medicago sativa* (lucerne) hay. Lucerne hay was used because it meets the maintenance and growth requirements of goats (Baba *et al.,* 2000; Xazela *et al*., 2012). The hay was ground to pass a 1 mm sieve; and dry matter (DM) was determined by drying in an oven at 105 ºC for 48 hr (AOAC, 1995a). Lucerne hay was analysed for crude protein (CP) using the Dumas combustion method (Leco CNS, Leco corporation) (AOAC, 1997). Acid detergent fibre (ADF) and neutral detergent fibre (NDF) were determined using the Ankom fibre technology (Van Soest *et al.,* 1991). Ash content was estimated using the furnace at 550 ºC overnight (AOAC, 1995b), Crude fat (ether extract) using the Soxhlet apparatus (AOAC, 1995c), calcium and phosphorus using the inductively coupled plasma - atomic emission spectroscopy (ICP-AES) (Spettrometro ICP-AES, Vista MXP Rad Varian). The nutritional composition of the lucerne hay is shown in Table 4.1. Feed offered and feed residues were weighed to estimate daily feed intake.

4.2.3 Treatments and experimental design

Goats were divided into three groups and randomly assigned to each water deprivation period, with 12 goats receiving each treatment. The treatments were 0 (control), 24 and 48 hours of water deprivation. Goats on the control were provided with 2 L of tap water. Goats were

Table 4. 1 Nutritional composition of *Medicago sativa* used in the study

Component	Content (g/kg DM)
Dry matter (DM)	906.0
Crude protein	135.9
Acid detergent fibre	361.1
Neutral detergent fibre	524.1
Ash	88.6
Ether extract	13.8
Calcium	7.1
Phosphorus	1.1

rehydrated by being given 2 L of drinking water for 24 hours in between each treatment period, to limit stress induced by water deprivation. See Appendix 2 for ethics approval.

The maximum period of water deprivation of 48 hours was allocated based on the results from the survey that was conducted in Nguni goats at KwaNongoma (Chapter 3). Nguni goats in areas with seasonal rivers could go for up to 48 hours without having access to drinking water. The amount of water given to goats was adjusted during the adaptation stage to determine water requirement of Nguni does, which was 2 L a day.

4.2.4 Measurements

4.2.4.1 Body weight

Each goat was weighed at the beginning of the experiment, and then once every week. Body weights (BWT) were taken at 0800 h before feed was provided. This was done using a RUUDWEIGH, KM-2E electronic weighing scale (RUUDSCALE, Durbanville, South Africa) to the nearest 0.1 kg. The precision of the scale was 0.5 kg.

4.2.4.2 Feed intake

Each goat was offered 1 kg of lucerne hay at 0800 h in an individual feeding trough every day. Feed loss through spillage was collected by placing an empty bag of 100 % polypropylene underneath each feeding trough. The daily feed intake (DFI) was calculated by calculating the difference between the weight of feed offered and the weight of feed left after consumption. Feed was measured using a Mettler Toledo digital scale, to the nearest 0.1 g.

4.2.4.3 Water intake

Tap water was offered to each goat at 0800 h. Water intake for each goat was measured daily using a 1000 ml graduated measuring cylinder to the nearest 10 ml. Daily water intake (DWI) was calculated by measuring a difference between the volume of water provided and the volume of water left. Water evaporation was estimated daily by placing a bucket of known volume of water in an empty pen and, therefore, measuring the volume using a graduated measuring cylinder. Water evaporation was subtracted from the amount of water each goat consumed a day. The DWI is to DFI ratio was calculated, by dividing DWI by DFI.

4.2.4.4 Body condition scoring

Body condition scores (BCS) for each goat were assessed once a week using the 5-point European system which ranges from 1 (emaciated), 2 (thin), 3 (average condition), 4 (fat) and 5 (obese), as described by Gerhard *et al*. (1996) and Marume *et al*. (2011). Body condition scores were estimated by the same observer, to obtain consistent records.

4.2.4.5 FAMACHA scoring

To assess levels of anaemia, FAMACHA scores were recorded at the beginning of the experiment and thereafter once every week for the duration of the experiment. The FAMACHA scores used were based on Malan *et al.* (2001) and Kaplan *et al.* (2004).

4.2.4.6 Faecal egg counting

Faecal samples were collected directly from the rectum of goats at the beginning of the experiment to determine the gastrointestinal parasite load, and thereafter, once every week for the duration of the experiment. Faecal samples were put in labelled plastic ziplock bags and immediately stored in a refrigerator at 4 ºC before analyses. The McMaster technique was used to count nematode eggs (Reinecke, 1973). Faeces (2 g) were measured into a 500 ml beaker and pellets crumbled finely. Exactly 58 ml of a floatation medium (40 % sugar solution) was added into the beaker, and the mixture was blended thoroughly using a blender. Few drops of amyl alcohol were added to break the foam and the suspension was mixed well with a Pasteur pipette.

The two chambers of McMaster slide were filled with the suspension immediately after mixing. The slide was allowed to stand for approximately two minutes to allow eggs to float and lie in contact with the upper glass of the chambers. A microscope [Olympus BX41, model: BX41TF (Olympus corporation, Tokyo, Japan), at 10X magnification] was used to count eggs in the grid of each counting chamber, including those in contact with the lines on the right and bottom of the grid, ignoring those on the left and top lines of the grid. The total number of eggs from both chambers were multiplied by 100 to estimate egg count per grams of faeces (epg).

4.2.4.7 Faecal larval identification and counting

The faecal samples that were collected for egg counting were also used for larval identification. Faecal larvae were cultured once a week to identify the third stage larvae of strongyle nematodes present in faeces. Faecal cultures were prepared for each individual goat. The faecal larval culture and count (FLC) method used was adopted from (Clark and Turton, 1973; Wood *et al.*, 1995). Crumbled faeces were mixed with the same volume of vermiculite in a large tray to improve the aeration of the culture and facilitate maximum hatching. A 2 cm thick glass rod was placed upright in the centre of a 100 ml glass bottle, and faecal mixture was added slowly and pressed down with a second glass rod, until the layer was 5 to 7 cm thick.

The outside of the bottle was thoroughly cleaned to avoid contamination, and the upright rod removed so that the centre hole improved aeration further. The compacted faecal mixture was moistened using distilled water in a water wash bottle, without soaking the contents. The bottle containing the faecal mixture was then placed into a 500 ml jar containing about 1 ml of distilled water. The jar lid was lightly screwed, and therefore, the jar was incubated at 25 °C for seven days for *Haemonchus* species, and 12 days for other gastrointestinal parasites.

To harvest the culture, the inner sides of the bottle as well as the surface of the culture were moistened and placed in the light, but not in direct sunlight. Larvae began to migrate up the bottle and fell onto the jar. The inside of the bottle was then rinsed with distilled water into the jar while holding the bottle at a slant, to collect more larvae. The larvae were allowed to sediment on the jar and a single drop of larval culture from the bottom of the jar was placed onto the microscope slide. A drop of iodine was added onto the slide and covered with a coverslip. This was examined microscopically and larvae were identified according to the morphology keys described by Zajac and Conboy (2006). The Olympus BX2 (Olympus corporation, Tokyo, Japan) microscope was used, at 10X magnification.

4.2.5 Statistical analyses

The effect of duration of water deprivation on DWI, DFI, DWI: DFI ratio, FEC and FLC were determined using the General Linear Model Procedures of SAS (2010). The effect of duration of water deprivation on BWT, BCS, FAMACHA score were determined using the mixed models procedures for repeated measures. The FEC, FLC, FAMACHA and BCS scores were transformed (square-root) to normalise the data and generate homogenous variances among treatments. The following model was used:

$$Y_{ijk} = \mu + P_i + W_j + (P \times W)_{ij} + E_{ijk}$$

Where:

Y_{ijk} = response variable (DWI, DFI, DWI: DFI ratio, BWT, BCS, FAMACHA score, FEC and FLC);

μ = mean common to all observations;

P_i = effect of the i^{th} deprivation period (i = 0, 1, 2);

W_j = week

E_{ijk} = residual error ~ N (0; $I\sigma^2$).

Pearson's correlation coefficients were computed among DWI, DFI, DWI: DFI ratio, BCS, BWT, FAMACHA, FEC and FLC.

4.3 Results

4.3.1 Water and feed intake

The influence of water deprivation on DWI, DFI and ratio of DWI: DFI ratio is shown in Table 4.2 and Figure 4.1. The DWI was the same in goats deprived of water for 0, 24 and 48 hours (P > 0.05). There was, however, a similarity in DWI in goats deprived of water for 0 and 24 hours throughout the entire deprivation period. In general, the DWI was largest in goats deprived of water for 48 hours compared to those deprived for 0 and 24 hours. The DFI was the same in goats deprived of water for 0 and 24 hours as water deprivation period increases (P > 0.05). The DFI was highest in goats deprived of water for 0 hours, and the smallest in goats deprived of water for 48 hours. The ratio of DWI to DFI was the smallest in goats deprived of water for 48 hours as compared to goats deprived of water for 0 and 24 hours (P < 0.01).

4.3.2 Body weight changes

Body weight changes were the same in goats deprived of water for 0 and 24 hours as water deprivation period increases (Figure 4.1). The BWT changes (P < 0.01) were highest in goats deprived of water for 0 hour as compared to those deprived for 24 and 48 hours.

Table 4. 2: Level of significance for the influence of water deprivation on water intake, feed intake and parasite burden in Nguni goats

Variables	#Period	Week	Period × Week
DWI	NS	**	*
DFI	**	**	**
DWI: DFI ratio	**	**	**
BCS	*	NS	**
BWT	*	NS	**
FEC	**	*	NS
FAMACHA	NS	NS	NS
FLC	**	**	**

**P < 0.01; *P < 0.05; NS = Not significant (P > 0.05)

#Period: Period of water deprivation

DWI = Daily water intake; DFI = Daily feed intake; DWI: DFI ratio = Ratio of DWI to DFI; BCS = Body condition score; BWT = Body weight; FEC – Faecal egg count; FAMACHA = Faffa Malan Chart scores; FLC = Faecal larval count

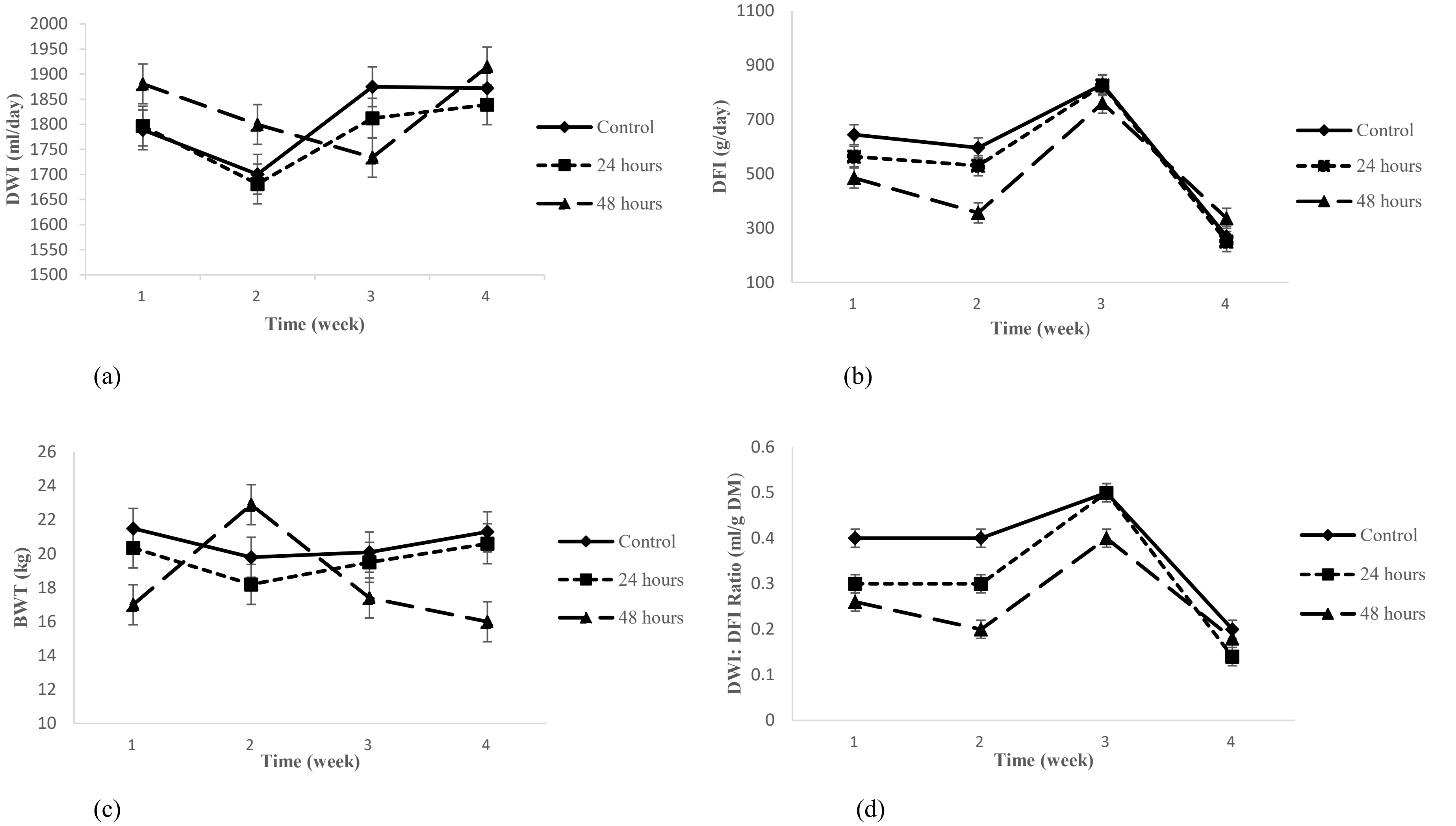

Figure 4. 1: Relationship between water deprivation per week; and DWI (a), DFI (b), DWI: DFI ratio (c), and BWT (d)

4.3.3 Body condition scoring

Body condition scores ($P < 0.05$) were highest in goats deprived of water for 0 hour as compared to those deprived for 24 and 48 hours (Figure 4.2). The BCS decreased with an increase in water deprivation period.

4.3.4 FAMACHA scores

Figure 4.2 shows that FAMACHA scores were the same in goats subjected to all water deprivation levels ($P > 0.05$). Goats that were deprived of water for 48 hours had, however, larger FAMACHA scores compared to those deprived of water for 0 and 24 hours ($P > 0.05$).

4.3.5 Faecal egg and larval counts

Figure 4.2 shows that FEC and FLC increased with an increase in water deprivation period. The FEC ($P > 0.05$) was the same in goats deprived of water for 0 and 24 hours throughout the deprivation period. The FEC was the largest in goats deprived of water for 48 hours. The FLC differed ($P < 0.01$) with water deprivation levels. The FLC has a significant effect on parasite load in goats deprived of water for 24 hours, and the significance was approximately doubled in goats deprived of water for 48 hours. The type of gastrointestinal parasite egg identified in Nguni goats subjected to water deprivation were *Strongyles* and coccidian, and the most prevalent gastrointestinal larva was *Haemonchus* species. The other nematode genera recovered was *Oesophagostomum*, being occasionally recorded in very low numbers accounting to 1 % and did not allow any meaningful comparison between the two genera identified in the study.

4.3.6 Correlations

The Pearson's correlation coefficients among water deprivation, DWI, DFI, ratio of DWI to DFI, BCS, BWT, FEC, FAMACHA, and FLC for Nguni goats are shown on Table 4.3.

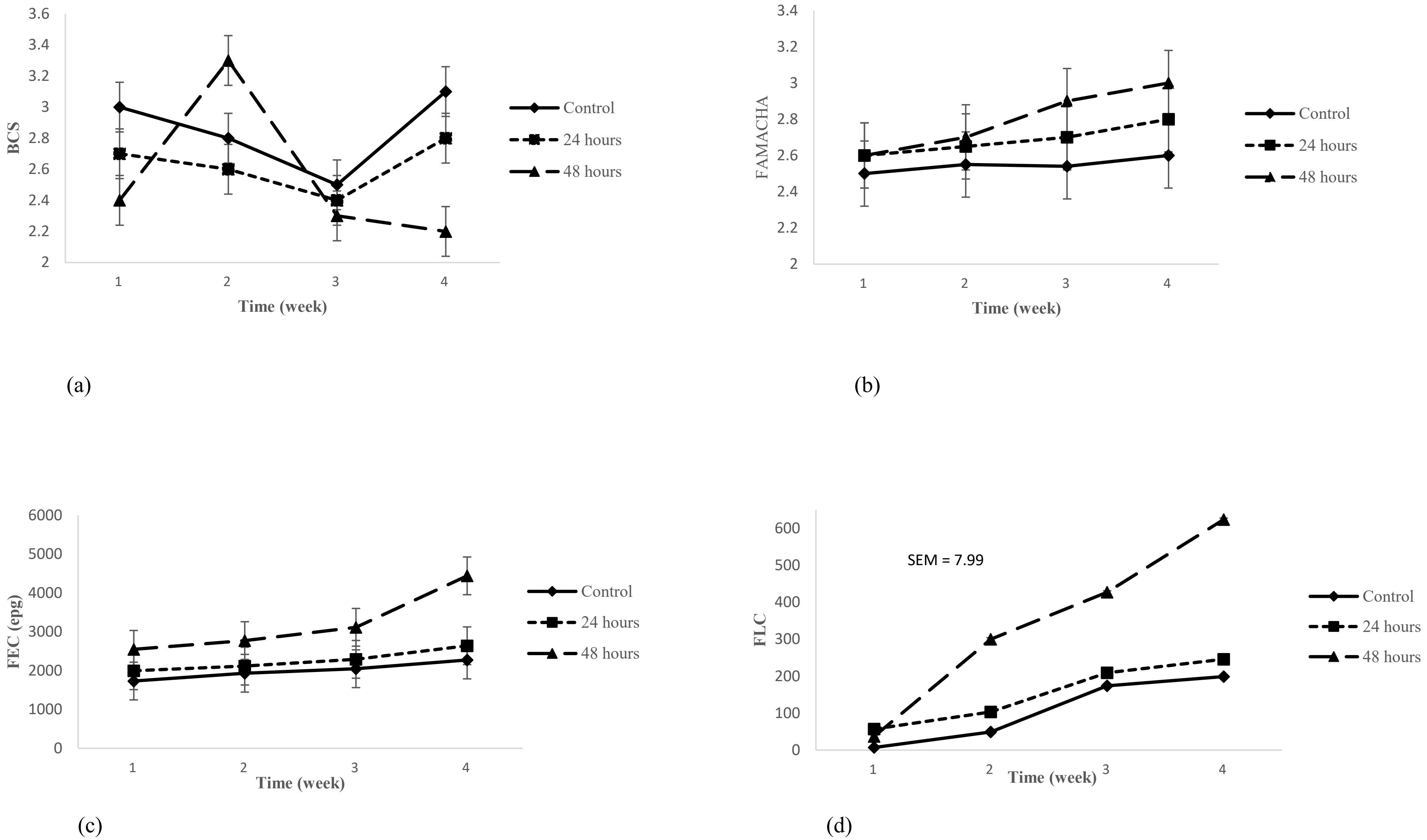

Figure 4. 2: Relationship between water deprivation per week; and BCS (a), FAMACHA (b), FEC (c), and FLC (d)

Table 4.3: Pearson correlation coefficient among intake, growth performance and gastrointestinal parasites of Nguni goats subjected to water deprivation

	DWI	**DFI**	**DWI/DFI**	**BWT**	**BCS**	**FEC**	**FLC**	**FAMACHA**
WD	NS	-0.18*	-0.18*	-0.22**	-0.21*	0.27**	0.58**	NS
DWI		NS	-0.30**	NS	NS	NS	NS	NS
DFI			0.97**	NS	NS	NS	-0.19*	NS
DWI: DFI ratio				NS	NS	NS	-0.20*	NS
BWT					0.27**	-0.56**	-0.19*	-0.44**
BCS						-0.20*	-0.16*	NS
FEC							0.40**	0.60**
FLC								0.27**

**P < 0.01; *P < 0.05; NS = Not significant (P > 0.05)

WD = Water deprivation period; DWI = Daily water intake; DFI = Daily feed intake; DWI: DFI ratio = Ratio of DWI to DFI; BCS = Body condition score; BWT = Body weight; FEC = Faecal egg count; FAMACHA = Faffa Malan Chart scores; FLC = Faecal larval count

Correlations for water deprivation period were positive with FEC and FLC, negative with DFI, DWI: DFI ratio, BCS and BWT. The DWI: DFI ratio had a positive correlation with DFI and a negative correlation with DWI. The BWT had a positive correlation with BCS, and a negative correlation with FAMACHA. Correlations for FEC were positive with FAMACHA and moderate with FLC, negative but strong with BWT. Correlations for FLC were positive but weak for FAMACHA, negative but weak for DFI, DWI: DFI ratio and BWT.

4.4 Discussion

Goats in all deprivation periods were observed to have a decrease in DWI on the first 2 weeks, which could be viewed as an adaptive mechanism employed by goats to preserve water. These findings agree with Alamer (2009). Goats increased their water intake thereafter, which could be ascribed to the fact that water deprivation activated water saving mechanisms in goats that minimized water loss and increased the capability to withstand water scarcity (Silanikove, 2000). The high water intake in goats deprived of water for 48 hours could be because goats consumed more water during rehydration in order to compensate for the high water deficiency.

The high water intake shows an improvement in water intake when goats are thirsty for a longer period. Similar responses were obtained by Alamer (2009) where water restriction caused goats to consume more water to fill their rumen and counteract the loss of body weight. Interestingly, Bedouin goats that were deprived of water for six days imbibed the entire amount of water lost, upon rehydration, and suddenly died from haemolysis (Etzion *et al.*, 1984). Therefore, upon rehydration, goats should not be given water that exceeds their daily requirement, which accommodates the shortage of water that the world is facing.

The observed decrease in initial DFI in all treatments could be ascribed to the insufficient supply of water that suppressed feed intake (Ahmed and El-Kheir, 2004; Abdelatif *et al.*, 2010). Such findings suggest that Sahiwal cattle could be using similar water conservation strategies to goats (Ali *et al.*, 2015). On the other hand, the decrease of DFI in all treatments from the third week of water deprivation could be due to that goats were attempting to satisfy their hunger by filling up the rumen with water, as ruminal osmoreceptors play an important role in controlling feeding in ruminants (Teixeira *et al.,* 2006).

The observation that an increase in the period of water deprivation decreased DFI, DWI: DFI ratio, BCS and BWT are in agreement with results from Misra & Singh (2002) and Abdelatif *et al.* (2010). The decrease of DFI, DWI: DFI ratio and BWT during the increase in period of water deprivation could be due to reduced appetite and digestive capability of the abomasum caused by infection from *Haemonchus* species (Kanyari *et al.*, 2009). The negative correlation between DWI and DWI: DFI ratio agrees with Kaliber *et al.* (2016), but contrast with Hadjigeorgiou *et al.* (2000) where the reduction of water intake in Karagouniko sheep fed on Lucerne hay resulted in the decrease of DWI: DFI ratio.

A loss of BWT observed in goats deprived of water for 0 and 24 hours in the beginning of the trial could be a result of the reduction in feed and water intake, together with the loss of water content from the rumen and other parts of the body. Most of the loss of BWT could be accounted for body water loss, and this concurs with findings by Alamer (2006) who reported that Saudi Arabia indigenous goats regained their BWT loss within 15 minutes of rehydration after being deprived of water for three days. An initial increase in BWT that was observed in goats deprived of water for 48 hours could be due to the fact that, during rehydration, goats were highly thirsty so they drank an amount of water that exceeded the losses of their body weights. The findings on the initial increase of BWT agree with that of Qinisa *et al.* (2011. It is attributed that an increase in BWT could be the cause of an increase in BCS of goats deprived of water for 48 hours at week 2, since a positive correlation between the two variables was observed in the current study. These findings differ with earlier reports (Nsoso *et al.,* 2003; Gallego-Calvo *et al.,* 2014) where no apparent relationship was found between BWT and BCS. In general, an increase in the period of water deprivation resulted in a decrease in BWT and BCS in goats. Such decrease of BWT and BCS could be a result of decrease in nutrient reserves.

The similarities of FEC in goats subjected to 0 and 24 hours of water deprivation were most likely influenced by the similarities of DFI in these treatments, as the nutritional status of goats plays a significant role in fighting infections (Abebe *et al.*, 2010; Marume *et al*., 2011). The increase in water deprivation period resulted in an increase in FEC, FLC and levels of anaemia. The gradual increase of FEC and FLC in goats could be due to the decrease in feed intake that resulted in poor nutrition that weakened the immunity system and lowered the resistance and or resilience of goats, thus giving rise to establishment of gastrointestinal parasite burdens that increased the severity of parasitosis.

Goats infected with large numbers of larvae, as observed in goats deprived of water for 48 hours, may suffer from anaemia as a result that *Haemonchus* species suck blood from the stomach lining. The high number of larvae in goats deprived of water for 48 hours is likely due to the number of egg output from individual adult parasite established in the gastrointestinal tract. The number of eggs produced also depends on the level of immunity the goat possesses to the gastrointestinal parasite. Therefore, this suggests that depriving goats of water for 24 hours has no significant effect on FEC and FAMACHA.

The observed negative correlation of FEC and FLC against BWT and DWI: DFI ratio agrees with Nieuwoundt *et al.* (2002) that reported a negative correlation with *Haemonchus contortus* in Merino sheep, as more feed nutrients were taken up by the parasite leaving less for the animal to meet its body nutrient requirement. Similar findings have been reported earlier (Odoi *et al.,* 2008; Rumosa Gwaze *et al.,* 2009b). The dominance of *Haemonchus* species in the current study concurs with findings from Vatta *et al.* (2002) and Sissay *et al.* (2007). An explanation to such dominance could be the climate suitability for survival, development and adaptation of *Haemonchus* species to shed eggs throughout the year (Biffa *et al.,* 2007).

4.5 Conclusions

Water deprivation in Nguni goats affected DWI, DFI, DWI: DFI ratio, BCS, BWT, FEC, FLC, and FAMACHA. During water deprivation, Nguni goats evoked a mechanism of economizing body water and reached a new balance with the advance of deprivation. This allowed them to increase water intake after it was reduced during adaptation period. An increase in water deprivation period resulted in poor body condition, reduced BWT, increase in FEC and FLC causing anaemia in goats. Depriving goats of water for 24 hours resulted in the same FEC as that of goats deprived for 0 hours. Lower counts of faecal larvae were attained in goats deprived of water for 24 hours as compared to 48 hours. Therefore, to ensure efficient use of water resources, Nguni goats can be deprived of water for 24 hours, considering that goats subjected to 48 hours of water deprivation had high counts of FEC and FLC.

4.6 References

Abdelatif AM, Elsayed SA and Hassan YM (2010). Effect of state of hydration on body weight, blood constituents and during excretion in Nubian goats (*Capra hircus*). *World Journal of Agricultural Sciences* 6 (2): 178-188.

Abebe R, Gebreyohannes M, Mekuria S, Abunna F and Regassa A (2010). Gastrointestinal nematode infections in small ruminants under the traditional husbandry system during the dry season in southern Ethiopia. *Tropical Animal Health and Production* 42: 1111-1117.

Ahmed MMM and El-Kheir IM (2004). Thermoregulation and water balance as affected by water and food restrictions in Sudanese desert goats fed good-quality and poor-quality diets. *Tropical Animal Health and Production* 36: 191-204.

Alamer M (2006). Physiological responses of Saudi Arabia indigenous goats to water deprivation. *Small Ruminant Research* 63: 100-109.

Alamer M (2009). Effects of water restriction on lactation performance of Aardi goats under heat stress conditions. *Small Ruminant Research* 84: 76-81.

Ali A, Mustafa MI, Bilal MQ, Muhammad G, Lateef M and Ullah S (2015). Effect of watering frequency on feed intake, milk production and composition in Sahiwal cattle during summer. *The Journal of Animal & Plant Sciences* 25 (1): 19-22.

AOAC (1995a). Association of Official Analytical Chemists International. Methods 4.1.03 (934.01) and 4.1.05 (920.36): Moisture/dry matter. *Official methods of analysis of AOAC International,* 16th edition, AOAC International, Maryland, USA.

AOAC (1995b). Association of Official Analytical Chemists International. Methods 4.1.10 (942.015): Total Ash. *Official methods of analysis of AOAC International,* 16th edition, AOAC International, Maryland, USA.

AOAC (1995c). Association of Official Analytical Chemists International. Methods 4.5.01 (920.39): Crude fat. *Official methods of analysis of AOAC International,* 16th edition, AOAC International, Maryland, USA.

AOAC (1997). Association of Official Analytical Chemists International. Methods 990.03: Crude protein (combustion method). *Official methods of analysis of AOAC International,* 16th edition, AOAC International, Arlington, VA.

Baba ASH, Sembiring M and Noraida I (2000). The effects of supplementation with selected browse plants on feed intake, production and composition of milk in lactating Katjang-cross goats. *Asian-Australian Journal of Animal Sciences* Supplement 13: 369-372.

Biffa D, Jobre Y and Chakka H (2007). Ovine helminthosis, a major health constraint to productivity of sheep in Ethiopia. *Animal Health Research Reviews* 7 (1/2): 107-118.

Clark CJ and Turton JA (1973). Estimating roundworm burden and group sizes in anthelmintic trial with sheep and cattle. *Experimental Parasitology* 34: 69-75.

Etzion Z, Meyerstein N and Yagil R (1984). Tritiated water metabolism during dehydration and rehydration in the camel. *Journal of Applied Physiology* 65: 217-220.

Gallego-Calvo L, Gatica MC, Guzman JL and Zarazaga LA (2014). Role of body condition and body weight in control of seasonal reproduction in Blanca Andaluza goats. *Animal Reproduction Science* 151 (3): 157-163.

Gerhard KL, White RG, Cameron RD and Russell DE (1996). Estimating fat content of caribou from body condition scores. *Journal of Wildlife Management* 60: 713-718.

Hadjigeorgiou I, Dardamani K, Goulas C and Zervas G (2000). The effect of water availability on feed intake and digestion in sheep. *Small Ruminant Research* 37: 147-150.

Kaliber M, Koluman N and Silanikove N (2016). Physiological and behavioural basis for the successful adaptation of goats to severe water restriction under hot environmental conditions. *Animal* 10 (1): 82-88.

Kanyari PWN, Kagira JM and Mhoma RJ (2009). Prevalence and intensity of endoparasites in small ruminants kept by farmers in Kisumu municipality, Kenya. *Livestock Research for Rural Development,* 21 (11). Retrieved April 5, 2016, from http://www.lrrd.org/lrrd21/11/kany21202.htm.

Kaplan RM, Burke JM, Terrill TH, Miller JE, Getz WR, Mobini S, Valencia E, Williams M, Williamson LH, Larsen M and Vatta AF (2004). Validation of the FAMACHA eye colour chart for detecting clinical anaemia on sheep and goat farms in the southern United States. *Veterinary Parasitology* 123: 105-120.

Malan FS, Van Wyk JA and Wessels CD (2001). Clinical evaluation of anaemia in sheep: early trials. *Onderstepoort Journal of Veterinary Research* 68: 165-174.

Marume U, Chimonyo M and Dzama K (2011). A preliminary study on the responses to experimental *Haemonchus contortus* infection in indigenous goat genotypes. *Small Ruminant Research* 95: 70-74.

McGregor BA (2004). Water quality and provision for goats. *RIRDC Publication No. 04/036*, *Project No. DAV 202A*. Rural Industries Research and Development Corporation. Australian Government.

Misra AK and Singh K (2002). Effect of water deprivation on dry matter intake, nutrient utilization and metabolic water production in goats under semi-arid zone of India. *Small Ruminant Research* 46: 159-165.

Nieuwoundt SW, Theron HE and Kruger LP (2002). Genetic parameters for resistance to *Haemonchus contortus* in Merino sheep in South Africa. *Journal of South African Veterinary Association* 73: 4-7.

Nsoso SJ, Aganga AA, Moganetsi BP and Tshwenyane SO (2003). Body weight, body condition score and heart girth in indigenous Tswana goats during the dry and wet seasons in southern east Botswana. *Livestock Research for Rural Development* 15 (32). Retrieved March 28, 2016, from http://www.lrrd.org/lrrd15/4/nsos154.htm

Odoi A, Gathuma JM, Gachuiri CK and Omore A (2008). Feeding practices and effects of gastrointestinal parasite infections on live weight gain in small ruminants in smallholder mixed farms in Kenya. *Research in Veterinary Science* 84: 185-193.

Phillips L (2013). Communal goat farmer thinks commercial. *Farmer's weekly*. Friday May 24 at 12:00.

Qinisa MM, Boomker EA and Mokoboki HK (2011). Physiological responses of water-restricted Tswana and Boer goats. *Life Sciences Journal* 8 (S2): 106-111.

Reinecke RK (1973). The larval anthelmintic test in ruminants. *Technical Communication*, *106*. Pretoria Department of Agriculture Technical Services: 1-20.

Roberts J and Swan RA (1982). Quantitative studies of ovine haemonchosis. The interpretation and diagnostic significance of the changes in serial egg counts of *Haemonchus contortus* in sheep flock. *Veterinary Parasitology* 9: 211-216.

Rumosa Gwaze F, Chimonyo M and Dzama K (2009a). Communal goat production in Southern Africa: a review. *Tropical Animal Health and Production* 41: 1157-1168.

Rumosa Gwaze F, Chimonyo M and Dzama K (2009b). Prevalence and loads of gastrointestinal parasites of goats in the communal areas of the Eastern Cape Province of South Africa. *Small Ruminant Research* 84: 132-134.

SAS (2010). Statistical Analysis System User's Guide, Version 9.3. *SAS Institute Incorporate Cary,* North Carolina, USA.

Schoeman SJ and Visser JA (1995). Water intake and consumption in sheep differing in growth potential and adaptability. *South African Journal of Animal Science* 25 (2): 75-79.

Silanikove N (1985). Effect of dehydration on feed intake and dry matter digestibility in desert (Black Bedouin) and non-desert (Swiss Saanen) goats fed on Lucerne hay. *Comparative Biochemistry and Physiology* 80A (3): 449-452.

Silanikove N (2000). The physiological basis of adaptation in goats to harsh environment: a review. *Small Ruminant Research* 35: 181-193.

Sissay MM, Uggla A and Waller PJ (2007). Epidemiology and seasonal dynamics of dynamics of gastrointestinal nematode infections of sheep in a semi-arid region of Eastern Ethiopia. *Veterinary Parasitology* 143: 311-321.

Teixeira IAMA, Pereira Filho JM, Murray PJ, Resende KT, Ferreira ACD and Fregadolli FL (2006). Water balance in goats subjected to feed restriction. *Small Ruminant Research* 63: 20-27.

Thornton PK, Ericksen PJ, Herrero M and Challinor AJ (2014). Climate variability and vulnerability to climate change: a review. *Global Change Biology* 20: 3313-3328.

Umunna NN, Chineme CN, San-or DI, Ahmed A and Abed S (1981). Response of Yankasa sheep to various lengths of water deprivation. *Journal of Agricultural Science, Cambridge* 96: 619-622.

Van Soest PJ, Robertson JB and Lewis BA (1991). Methods for dietary fibre, neutral detergent fibre, and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science* 74: 3583-3597.

Vatta AF, Krecek RC, Letty BA, Van der Linde MJ, Grimbeek RJ, de Villiers JF, Motswatwe PW, Molebiemang GS, Boshoff HM and Hansen JW (2002). Incidence of *Haemonchus spp*. and effect on haematocrit and eye colour in goats farmed under resource-poor conditions in South Africa. *Veterinary Parasitology* 103: 119-131.

Wood IB, Amaral NK, Bairden K, Duncan JL, Kassai T, Malone JB, Pankavich JA, Reinecke RK, Slocombe O, Taylor SM and Vercruysse J (1995). World Association for Advancement of Veterinary Parasitology (W.A.A.V.P.) second edition of guidelines for evaluating the efficacy of anthelmintics in ruminants (bovine, ovine, caprine). *Veterinary Parasitology* 58: 181-213.

Xazela NM, Chimonyo M, Muchenje V and Marume U (2012). Effect of sunflower cake supplementation on meat quality of indigenous goat genotypes of South Africa. *Meat Science* 90: 204-208.

Zajac AM and Conboy (2006). *Veterinary Clinical Parasitology* (7th Edition). Blackwell Scientific Publications, Oxford, UK: 3-114.

CHAPTER 5: General discussions, conclusions and recommendations

5.1 General Discussions

The current study was designed to determine whether subjecting Nguni goats to water deprivation would impact on nutritional status and gastrointestinal parasites load. A survey was conducted to understand the main constraints to goat productivity in communal production systems. Communal production systems are systems that are mainly challenged by change in weather patterns, as goats depend on natural waters for drinking and browse on forages that are subjected to seasonal variations of nutrient content. Nguni goats were, therefore, subjected to varying levels of water deprivation to understand the threshold that Nguni goats could withstand without affecting their nutritional status and gastrointestinal parasite loads.

In Chapter 3, a survey was conducted to test whether water deprivation affects gastrointestinal parasite loads in Nguni goats, as productivity of goats can contribute to the livelihood of communal farmers who depend on them. Most households were headed by males and they influence decision making, although females were major role players in caring for goats. Goats were mainly kept for traditional ceremonies. Farmers indicated that they are faced with diseases and gastrointestinal parasite infestation as major goat production constraints. It was indicated that water scarcity is intensifying with years, as a result of climate change, and consequently resulting in reduction of water in water sources used by livestock in communal areas, as well as reduction of feed availability on pastures. Kid mortality was among the constraints that farmers were facing, and the most important cause identified was shortage of feed, which resulted in low quality and quantity of milk from does. Kid mortality was also associated with gastrointestinal parasite burdens, as farmers from communal areas were not deworming kids at weaning. The hypothesis that the importance of gastrointestinal parasites was higher in households that faced water shortages was, therefore, not rejected.

Since water is a scarce resource and gastrointestinal parasites are a challenge in communal production systems, possible approaches to water challenges had to be explored and their effect on gastrointestinal parasites' infestations be determined. One of the approaches would be subjecting goats to water deprivation, as this is common in communal production systems where goats can go without water for days (Mengistu, 2007). Therefore, in Chapter 4, goats were subjected to varying levels of water deprivation to monitor its influence on nutritional and gastrointestinal parasites load. Daily feed intake, ratio of daily water intake is to daily feed intake and body weight were higher in goats at 0 hours of water deprivation, and this level was not significantly different to 24 hours of water deprivation.

The FAMACHA scores were lower in goats subjected to 0 hours of water deprivation indicating that goats were non-anaemic and required no treatment, however, had no significant difference with goats subjected to 24 hours of water deprivation. As the length of water deprivation was increased, faecal egg and larval counts increased. Faecal egg counts for goats deprived of water for 24 hours were the same as of goats deprived for 0 hours, and different to those deprived for 48 hours. Faecal larval counts were higher in goats deprived of water for 48 hours. So, it can be deduced from these observations that depriving goats of water for 24 hours is adequate to satisfy the water requirement of Nguni goats and to keep FEC and FLC lower, although it has an adverse effect on DFI, DWI, BWT, BCS and FAMACHA.

The most frequently detected gastrointestinal parasite was *Haemonchus*, and that may confirm gastrointestinal parasites as the major health problem affecting goats in communal production systems, as per farmers' perceptions in Chapter 3.

5.2 Conclusions

Water scarcity, shortage of feed, diseases and prevalence of gastrointestinal parasites were major challenges experienced by farmers in communal production systems, especially during the dry season. Goats in households experiencing water shortages were 11.0 times more likely to experience water scarcity as compared to the site facing no water shortage.

Water deprivation influences nutritional status and gastrointestinal parasites load in Nguni goats. The productivity of Nguni goats can be improved by depriving goats of water for 24 hours to ensure efficient use of available water, since 48 hours of water deprivation proved to have a negative effect on parameters tested. Therefore, a threshold of 24 hours can be set for Nguni goats when monitoring their nutritional and health status, taking into consideration the high values of FAMACHA, FEC and FLC at 48 hours of water deprivation.

5.3 Recommendations

It can be recommended to conduct the current study in the presence of a mixture of other gastrointestinal parasites to determine the extent at which Nguni goats will tolerate water deprivation. The main reason to this will be that grazing goats rarely have mono-specific infections in communal grazing areas (Fox, 2014). This will be imperative prior to devising control strategies against gastrointestinal parasites. It is also important to investigate blood metabolites to attain more accurate assessment of the nutritional status, gastrointestinal prevalence and stress levels of Nguni goats subjected to water deprivation. Furthermore, other indigenous goats could be investigated to establish the effect of water deprivation on gastrointestinal parasites and blood metabolites in communal areas, and this will help establish reference values for different genotypes that could be used to determine the nutritional and health status of goats.

The biggest challenge that communal farmers are facing is the lack of veterinary support and access to information, especially with regards to goats. This, therefore, poses a challenge to the South African government to implement effective training programs on primary healthcare to ensure that communal farmers have access to basic knowledge and skills to improve performance of their livestock. In so doing, the government will be forced to monitor the effectiveness of community veterinary services to smallholder farmers, since they cannot easily access private animal health care.

5.4 References

Fox M.T (2014). Overview of gastrointestinal parasites of ruminants. *The Merck Veterinary Manual*. www.merckvetmanual.com

Mengistu U. Performance of the Ethiopian Somali goat during different watering regimes. PhD Thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Appendix 1: Survey questionnaire

Objective:

Assessment of farmer perception on water availability and prevalence of gastrointestinal parasites in Nguni goats

Questionnaire number………………………………….. Village name…………………………

Enumerator name………………..…………………….. Ward number…………………………

Date……………………………………………………..

SECTION A: Household demographics

1. Head of the household

a) Sex: 1. M □ 2. F □

b) Marital status: 1. Married □ 2. Single □ 3. Divorced □ 4. Widowed □

c) Age: 1. < 18 □ 2. 18-30 □ 3. 31-50 □ 4. > 50 □

d) Is the head of the household resident on the farm? 1. Yes □ 2. No □

e) Highest education level: 1. No formal education □ 2. Grade 1-7 □ 3. Grade 8-12 □ 4. Tertiary □

f) Have you ever received any training on goat production? 1. Yes □ 2. No □

g) What are major sources of income? 1. Crops □ 2. Livestock sales □ 3. Livestock products □

4. Salary □ 5. Government grant □ 6. Other □, specify ……………………………..

2. What is your household composition?

Age group	Males	Female
Adults (36+ years)		
Youth (13-35 years)		
Children (0-12 years)		

3. Types of livestock species kept? (Please tick first column as appropriate. The second column is for the number of that appropriate livestock species. The last column is for rank levels of the other types of livestock species kept – 1 is for the highest priority)

Livestock species	Tick (appropriate)	Number of animals	Rank
Cattle			
Goats			
Sheep			

Chickens			
Pigs			
Other (Specify)			

SECTION B: Goat production

1. Why do you keep goats? (Please tick the first column for the purpose and the second column for ranking)

Purpose	**Tick**	**Rank**
Meat		
Milk		
Manure		
Skin		
Sales		
Investment		
Traditional ceremonies		
Gifts		

2. Are you part of any farmer association? 1. Yes □ 2. No □

3. Who is the owner of the goats? 1. Father □ 2. Mother □ 3. Children □ 4. Other □ (specify)………........

4. Who takes decisions about goat management? 1. Owner □ 2. Shepherd □ 3. Children □ 4. Other □, specify……....................

5. What goat production system do you use? 1. Extensive □ 2. Semi-intensive □ 3. Intensive □ 4. Tethering □ 5. Integrated livestock/crop system □ 6. Other □, specify……....................

6. Which goats do you tether? 1. Lactating does □ 2. Dry does □ 3. Bucks □ 4. Kids □

7. What is the reason for tethering your goat? 1. Prevent kids from getting lost □ 2. Protect kids from predators □ 3. Prevent goat theft □ 4. Allow kids to have more milking time □ 5. Other □, specify……....................

8. What role (s) does each household member play in goat production? (You may tick one or more columns in a row)

Role	**Adults**		**Youth**	**Hired labour**
	Male	**Female**		
Feeding				
Penning goats				
Kraal construction and maintenance				
Mating/breeding management				
Health management				
Purchasing				
Slaughtering				
Selling				
Other (specify)…………….				

9. What are the challenges facing goat production? 1. Feed shortage □ 2. Diseases □ 3. Ecto-parasites □ 4. Flies □ 5. Internal parasites □ 6. Inbreeding □ 7. Theft □ 8. Water scarcity □ 9. Other □ (specify) ………………

10. What is the composition of your goat flock?

Goat flock	Male	Female
Kids		
Castrates		
Adults		

11. How do you breed your goats? 1. Select bucks □ 2. Select does □ 3. Freely uncontrolled □

12. When is the breeding season for goats? 1. Rainy season □ 2. Hot dry season □ 3. Cool dry season □ 4. Post-rainy season □ 5. All year round □

13. What do you look for when selecting bucks for breeding? 1. Scrotal circumference □ 2. Libido □ 3. Body conformation □ 4. Health status □ 5. Scrotal palpation □ 6. Body condition □ 7. Physical injuries □ 8. Other □ (specify) ………………

14. How do you select does for breeding? 1. Body condition □ 2. Health status □ 3. Mothering ability □ 4. Ability to reproduce 3 times in two years □ 5. Other □ (specify) ………………

15. How do you manage kids before weaning? 1. Let them go with mothers to the field □ 2. Leave them in the goat house □ 3. Keep them inside the human house □ 4. Other □ (specify) ………………

16. When do you wean kids? 1. Rainy season □ 2. Hot dry season □ 3. Cool dry season □ 4. Post-rainy season □

17. What is your method of weaning? 1. Minimum weight □ 2. Age □ 3. Feed availability □ 4. Other □ (specify) ………………

18. Do you milk your goats? 1. Yes □ 2. No □ (If not, please skip question no. 21)

19. How much milk is produced by goats in each season?

Season	Milk production			
	< 500 ml	500 ml – 1 L	> 1 L	None
Rainy season				
Hot dry season				
Cool dry season				
Post-rainy season				

SECTION C: Goat health

1. Type of vegetation where goats browse? 1. Shrubs □ 2. Grass □ 3. Tree leaves □ 4. Other □ (specify) ………………

2. When do you experience feed shortage for goats? 1. Rainy season □ 2. Hot dry season □ 3. Cool dry season □ 4. Post-rainy season □ 5. All year round □

3. Do you practice supplementary feeding during periods of feed shortage? 1. Yes □ 2. No □

4. What supplementary feed do you give to your goats? 1. Purchased feed □ 2. Feed residues □ 3. Maize mixed with salt □ 4. Other □ (specify) ………………

5. Do you house your goats? 1. Yes □ 2. No □

6. When do you house your goats? 1. During the day □ 2. Afternoon before sunset □ 3. After sunset □ 4. Night □ 5. Other □ (specify) ………………

7. How long do you house them? 1. 0-3 hrs□ 2. < 6 hrs □ 3. < 9 hrs □ 4. < 12 hrs □ 5. < 15 hrs □ 6. Overnight □

8. What form of housing do you have for your goats? 1. Kraal □ 2. Stall/Shed □ 3. Yard □ 4. None □

9. What are common disease challenges that you encounter in your flock? 1. Diarrhoea □ 2. Coccidiosis □ 3. Heart water □ 4. Orf □ 5. Mastitis □ 6. Pneumonia □ 7. Rift valley □ 8. Pulpy kidney □ 9. Abortion □ 10. Foot abscesses □ 11. Other □ (specify) ………………

10. Does mortality occur in? 1. Adults □ 2. Kids □

11. What causes kid mortality? 1. Lack of colostrum □ 2. No milk produced by lactating does □ 3. Predators (Jackals) □ 4. Feed shortage □ 6. Other □ (specify) ………………

12. How do you assess health challenges in kids? 1. Loss of body weight □ 2. Breathing difficulties □ 3. Not standing/playing □ 4. Not eating □ 5. Other □ (specify) ………………

13. Do you deworm kids at weaning? 1. Yes □ 2. No □

14. What types of parasites are prevalent in this farm? (Can tick more than one)

Type of parasite	**Tick**	**Rank**
Ticks		
Lice		
Mites		
Tapeworm		
Roundworm		
Liver fluke		
Other, specify…		

15. Are parasite loads affected by housing and grazing land? 1. Yes □ 2. No □

16. How do you identify a goat which has a problem with gastro-intestinal parasites? 1. Loss of condition score □ 2. Parasites in faeces □ 3. Bottle jaw □ 4. Anaemia □ 5. Post-mortem □ 6. Other □ (specify) ………………

17. Who identifies parasites? 1. Household head □ 2. Shepherd □ 3. Teenagers □ 4. None □

18. What is the effect of season on gastro-intestinal parasite prevalence?

Season	**Prevalence**	
	High	**Low**
Rainy season		
Hot dry season		
Cool dry season		
Post-rainy season		
All year round		

19. What do you use to treat gastro-intestinal parasites? 1. Antihelmintics □ 2. Traditional medicine □ 3. Other □ (specify) ………………

20. What is the name of antihelmintic that you use to treat gastro-intestinal parasites?

21. Do you follow the instructions when using antihelmintics? 1. Yes □ 2. No □

22. What are traditional medicines that you use to control gastro-intestinal parasites?

……………………………………………………………………………………………………
……………………………………………………………………………………………………

………
……….

SECTION D: Water accessibility and quality

1. Is water scarcity a major problem for your livestock? 1. Yes □ 2. No □

2. When is water scarcity a major problem? 1. Rainy season □ 2. Hot dry season □ 3. Cool dry season □ 4. Post-rainy season □ 5. All year round □

3. How far is a water source from your household? 1. < 1 km □ 2. 2-3 km □ 3. < 5 km □ 4. > 5 km □

4. What are the sources of water for goats? (Can tick one or more)

Season	**Water source**							
	Borehole	**Dam/pond**	**River**	**Water well**	**Spring**	**Tap**	**Rain water**	**Grey water**
Rainy season								
Hot dry season								
Cool dry season								
Post-rainy season								

5. Who monitors goats during drinking when they are being herded? 1. Adults □ 2. Shepherd □ 3. Children □ 4. None □ 5. Other □ (specify) ………………

6. What is your frequency of water supply to goats? 1. Freely available □ 2. Once a day □ 3. Twice a day □ 4. Once in two days □ 5. Once a week □ 6. Other □ (specify) ………………

7. What is the estimated water intake per day?

	Estimated water intake				
	0-500 ml	**< 1 L**	**< 1.5 L**	**< 2L**	**< 2.5**
Kids					
Lactating Does					
Castrates					
Bucks					

8. How do you assess water quality for drinking water in goats? 1. Colour □ 2. Smell □ 3. Taste □ 4. Animal drinking any water given □

9. What is the quality of water preferred by goats? (Can tick more than one box)

Season	**Water quality**			
	Good/Clear	**Muddy**	**Salty**	**Smelly**
Rainy season				
Hot dry season				
Cool dry season				
Post-rainy season				

10. Which type of water do you consider to be of high and low quality which is used by goats for drinking?

Type of water	Water quality	
	High	Low
Clear		
Muddy		
Salty		
Smelly		
Grey water		

11. During periods of water scarcity, what do you do to water available for livestock drinking? 1. Prioritize cattle □ 2. Prioritize goats □ 3. Prioritize sheep □ 4. Prioritize chickens □

12. During periods of water scarcity, how do you prioritize water that is available for goats to drink? 1. Milking does □ 2. Kids □ 3. Bucks □ 4. Castrates □

13. Do you provide goats with water during tethering? 1. Yes □ 2. No □

14. Estimated water which is provided during tethering.

    1. 5 L bucket/1goat □ 2. 5 L bucket/2goats □ 3. 5 L bucket/3goats □ 4. 5 L bucket/4goats □ 5. 5 L bucket/5 goats □ 6. 5 L bucket/ < 10 goats □

15. Are housed kids provided with water when mothers are being herded? 1. Yes □ 2. No □

16. Estimated water supply to the housed kids

    1. 0-200 ml □ 2. < 400 ml □ 3. < 500 ml □ 4. < 600 ml □ 5. > 700 ml □

17. What do you think can be done to solve this problem of water scarcity? 1. Build dams □ 2. Use wastewater from dairy □ 3. Use wastewater from meat processing industries □ 4. Other □ (specify) ………………

18. How does water quality and availability for goats differ in the past 30 years and now?

Season	Water quality				Water availability			
	Past 30 years		Present		Past 30 years		Present	
	High	Low	High	Low	High	Low	High	Low
Rainy season								
Hot dry season								
Cool dry season								
Post-rainy season								

19. Comparing temperatures in the past 30 years and now, what are the differences?

Season	Water level			
	Past 30 years		Present	
	High	Low	Higher	Lower
Rainy season				
Hot dry season				
Cool dry season				
Post-rainy season				

20. Is siltation getting worse over time? 1. Yes □ 2. No □

21. What is the major cause of siltation? 1. Ploughing at the riverbank □ 2. Heavy rains □ 3. Other □ (specify) ………………

Appendix 2: Ethical clearance from University of KwaZulu-Natal

UNIVERSITY OF KWAZULU-NATAL™
INYUVESI YAKWAZULU-NATALI

17 March 2014

Reference: 072/14/Animal

Mr CT Mpendulo
Animal Science
School of Agricultural, Earth &
Environmental Sciences
University of KwaZulu-Natal
PIETERMARITZBURG Campus

Dear Mr Mpendulo

Ethical Approval of Research Projects on Animals

I have pleasure in informing you that the Animal Research Ethics Committee has granted ethical approval for **2014** on the following project:

"Hydric and nutritional stress on growth performance, milk yield and chevon quality from indigenous goats."

Yours sincerely

Professor Theresa HT Coetzer
Chairperson: Animal Ethics Sub-committee

Cc Registrar – Mr C Baloyi
Research Office – Dr N Singh
Supervisor – Prof. M Chimonyo
Head of School – Prof. A Modi
SAEES – Mrs M Manjoo

Animal Ethics Committee
Professor Theresa HT Coetzer (Chair)
Postal Address: Room 105, John Bews Building, Private Bag X01, Pietermaritzburg, 3201, South Africa
Telephone: +27 (0)33 260 5463/35 **Facsimile:** +27 (0)33 260 5105 **Email:** animalethics@ukzn.ac.za **Website:** www.ukzn.ac.za
Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

INSPIRING GREATNESS