PREVALENCE AND ABUNDANCE OF TICK GENERA AND THEIR CONTROL IN MERINO SHEEP IN THE FOUR AGRO-ECOLOGICAL ZONES OF LESOTHO

By

Mabokang Francinah Motsienyane

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DISSERTATION APPROVAL

We, undersigned, approve that the work reported in this thesis was done by Mabokang Francinah Motsienyane under supervision of Prof. P.M. Dawuda and Dr. S. M. Molapo.

Major supervisor

Signature: ……………………………………. Date: ……………………………….

Co-Supervisor:

Signature : ……………………………………Date:………………………………….

Head, Departement of Animal Science

Dr. Setsomi Molapo

Signature: ………………………………………Date:…………………………………

Dean, Faculty of Agriculture

Prof. Philip Makama Dawuda

Signature: ………………………………………Date:…………………………………

ABSTRACT

Ticks are blood sucking ecto-parasites that transmit haemoparasitic diseases and cause other ill-health problems such as traumatic dermatitis, anorexia and weight loss which leads to total loss in productivity of the sheep industry in Lesotho. In order to help farmers to control ticks infestation, a survey study was conducted with the following specific objectives: (i) to evaluate farmers' demographic structure in different agro-ecological zones of Lesotho. (ii) to evaluate level of awareness of merino sheep farmers on ticks' infestation in their flocks in different agro-ecological zones of Lesotho (iii) to determine commonly used control measures for ticks by merino sheep farmers in different agro-ecological zones of Lesotho (iv) to determine effect of agro-ecological zone and age of sheep in prevalence of tick genera in merino sheep of Lesotho and (v) to evaluate the efficacy of ivermectin in the control of ticks in different agro-ecological zones and sheep age groups of Lesotho**.** For the demographic study, a total of 403 respondents were interviewed using a structure questionnaire and a total number of 720 sheep were used for the remaining objectives. Ticks were collected and transferred into sample containers containing 70% ethanol kept in labelled screw-lid container before identification in the laboratory using a stereomicroscope. The efficacy of Ivermectin (1%) was determined using the following formula as prescribed by Abbott (1925): Efficacy % = 100 x (Mc – Mr)/Mc; Mc = mean number of live ticks on the host; Mr = mean number of live or dead ticks on host after treatment. Drug efficacy of 0.5 is threshold for medium tick response ratio. The data from 403 respondents was stored in Microsoft excel and analyzed using descriptive statistics. Binary logistic regression was used to analyse the data for ticks' prevalence, age and ivermectin efficacy on ticks' infestation. Data on ticks' concentration was analyzed by Poisson model. The results showed that the majority of sheep farmers were males with a distribution of 67% in lowlands, 66% in foothills, 58% in highlands and 64% in Senqu River Valley ($P > 0.05$). Farmers in all four agro-ecological zones had very high level of awareness for ticks' infestation - Lowlands (99.0%), Foothills (100.0%), Highlands (97.9%) and Senqu River Valley (97.3%) ($P > 0.05$).79%, 70%, 86% and 58% of farmers in Lowlands, Foothills, Highlands and Senqu River Valley, respectively used various drugs combinations (both traditional and conventional) to control ticks. Overall prevalence for different tick genera was 40% with Rhipicephalus having higher prevalence and abundance than other genera: Rhipicephalus (36%), Boophilus (0.7%), Amblyomma (0.4%), Hyalomma (0.2%) and Otobius (0.5%). Most ticks were in abundance under tail and around the anal region. The prevalence of ticks did not vary significantly ($P > 0.05$) with age of sheep. Ivermectin 1% subcutaneous injection overall efficacy was 28% and reduction percentages for major genera (Rhipicephalus) were as follows: Senqu River Valley (36%), Lowlands (46%), Foothills (70%) and Highlands (100%). In conclusion, the current study has established that (i) there are more male than female farmers in all agro-ecological zones (ii) farmers' awareness of ticks infestation is very high in all the four agro-ecological zones (97-100%) (iii) All farmers routinely used both traditional and conventional drugs to control ticks (vi) Age of sheep did not significantly affect the prevalence of ticks in all agro-ecological zones and (v) The overall efficacy of 1% ivermectin was 28%.

Key words: Merino sheep, ticks' infestation, predilection site, Agro-ecological zone

DECLARATION

I, Mabokang Francinah Motsienyane declare that the research project report on PREVALENCE AND ABUNDANCE OF TICK GENERA AND THEIR CONTROL IN MERINO SHEEP IN THE FOUR AGRO-ECOLOGICAL ZONES OF LESOTHO is my own work towards the Master of Science (M.S.c) and that to my best knowledge contains no material previously published by any other person or material which has been accepted for the award of any degree of the University. Any part of used material from other people had been acknowledged in the text and details had been given in the references.

DEDICATION

The dissertation is dedicated to my sisters and my colleagues for their support; my daughters Reitumetse and Boithatelo Motsienyane and also my son Bokang Motsienyane whom were always giving me motivation during the course of the study, without their lovely and willing hearts to help me, this project would not have been successful.

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CHAPTER 1

PREVALANCE TOGETHER WITH ABUNDANCE AND CONTROL OF TICKS IN MERINO SHEEP IN THE FOUR AGRO-ECOLOGICAL ZONES OF LESOTHO

1.0 INTRODUCTION

1.1 BACKGROUND

Lesotho is a developing country totally surrounded by South Africa and then depends on it for all agricultural inputs like rams for improving local sheep. Its population was estimated to be less than 2 million by 2009 and is highly vulnerable to climatic changes due to its geographic build up (Sissay *et al* ., 2011). Agriculture remains a major source of income for more than 80% of rural population in Lesotho with total land area of 30,355 square kilometres and of which 9% of the land was arable by 2011 (BOS, 2011). The rural economy has been languishing due to poor land management and farming practices. Among other things, the overall decline is attributed to poor weather; declining fertility of land and poor management of water resources. The current crop yields were about half the level achieved in the late 1970s Sissay et al, 2011) so livestock industry especially wool production remains the major focal and promising industry for Basotho as they export wool and mohair internationally.The local sheep is a Merino breed which arose from the upgrading of the indigenous fat-tailed sheep to Merino by rams from South Africa over many generations since the 1800s to the extent that the characteristics of the fat-tailed sheep have virtually disappeared in Lesotho (Mafisa, 1993). The sales of wool and live animals are a major source of income for the rural communities but production per animal is lower.

In most developing countries and some other countries in Africa, there is low sheep productivity (Gizaw *et al*., 2010; Mengesha and Tsega., 2012). Ticks infestations might be the major factor contributing to low sheep productivity. The diagnosis of ticks' infestation in small ruminants has great importance due to the major threats this group of parasites might pose to the welfare and productivity of ruminants and particularly of grazing sheep.

Infestation by ticks could lead to considerable economic losses to farmers due to loss of productivity, mortality, and skin damage. Kusina and Kusina (1999) had indicated that low sheep productivity is due to poor management practices in communal grazing which is a major predisposing factor for ticks transmission from one animal to other. Animal infested with ticks can be observed by mechanical tissue damage, irritation, inflammation, hypersensitivity, abscesses, weight loss, lameness, anemia, and in severe cases death of infested animals. In addition, ticks infestations could induce great economic losses due to reduction of wool quality, meat and milk yield, and losses as a result of culling and related cost of treatment and prevention of the problem (Parola and Raoult, 2001). They are also responsible for great pre-slaughter skin defects, resulting in downgrading and rejection of sheep skins. Moreover, ticks are known to have zoonotic importance and be capable of transmitting several types of disease pathogens from animal to animal and from animals to humans due to their blood sucking habit as Parola and Raoult (2001) define them as ecto-parasites that feed on blood and transmit pathogens including protozoan parasites, bacteria, viruses which are disease causing agents in animals and humans.

Despite these consequences to animals and human beings, the prevalence, abundance and magnitude of ticks' infestation in sheep have not been largely assessed in Lesotho, Therefore, information on prevalence, distribution and potential risk factors of ticks' genera of sheep is significant because the outcome could be used to make objective decisions on control strategies in relation to risk factors such as agro-ecological zone and age.

1.2 PROBLEM STATEMENT

There is low production per animal as a result of ecto-parasites (ticks) infestation in sheep in Lesotho. Tick infestation leads to haemo-parasites infestation that lead to tick borne diseases which result to poor conception rates, high mortality rate at birth and weaning, poor growth rates, poor wool quality/quantity and low carcass weight. These aggregates negatively lead to poor financial returns among sheep farmers in Lesotho and hence loss in revenue and increase in poverty.

1.3 JUSTIFICATION

The study determined ticks' prevalence, abundance and efficacy of commonly used scientific drug (ivermectin) to treat sheep with tick infestation and recommend the use of it in a wider scale to control tick infestation in order to improve sheep productivity and economic standard of sheep farmers in Lesotho. This study was therefore justified.

1.4 HYPOTHESIS

1.4.1 NULL HYPOTHESIS (H_0)

There is no prevalence of ticks' infestation in the four agro-ecological zones and farmers are not aware of such tick infestation in sheep in Lesotho. Ivermectin has no beneficial effect in the treatment of sheep against all genera of ticks.

1.4.2 ALTERNATE HYPOTHESIS (H1)

There is prevalence of ticks' infestation in the four agro-ecological zones and farmers are aware of such tick infestation in sheep in Lesotho. Ivermectin has a beneficial effect in the treatment of sheep against all species of ticks.

1.5 OBJECTIVES

1.5.1 General objective:

To determine the prevalence, concentration and control methods of ticks as well as farmers' awareness of ticks and their control in Lesotho

1.5.2 Specific objectives:

1. To evaluate farmers' demographic information in different agro-ecological zones of Lesotho.
2. To evaluate level of awareness of Merino sheep farmers on ticks' infestation in their flocks in different agro-ecological zones of Lesotho.
3. To determine commonly used control measures for ticks by Merino sheep farmers in different agro-ecological zones of Lesotho.
4. To determine effect of agro-ecological zone and age in prevalence and abundance of tick genera in Merino sheep of Lesotho.
5. To evaluate the efficacy of ivermectin in the control of ticks in different agro-ecological zones and age of Merino sheep in Lesotho.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

Sheep farming is done mostly compared to other livestock species in developing countries like Lesotho with Merino sheep being a local breed (Mafisa.,1993). Agricultural land is being used for extensive grazing on natural veld (Department of Agriculture, Forestry and Fisheries (DAFF), 2012, Fayemi and Muchenje, 2014). Most of the developing countries had high population that depend on agriculture for their entire household income. This is supported by the study previously conducted in Eastern Cape Province (ECP) which stipulated that more than 80% of its rural population is involved in livestock integrated production systems (Braker *et al*., 2002; Perret and Mercoiret, 2003). Production of livestock including sheep in Lesotho is low as Bembridge (1989) said despite the importance of livestock husbandry, both at household and national economic, production and productivity within the sheep sub-sector has been quite low in EPC and in other countries in Africa (Gizaw *et al*., 2010; Mengesha and Tsega, 2012).

The major problems of low livestock productivity in the communal areas include poor management practise of farmers like unhygienic housing, health and inadequate feed and nutrition (Kusina and Kusina, 1999). However, according to Ajala (2004), Ben and Smith (2008), the high incidence of diseases is another major constraint associated with small ruminant production and some might be highly transmitted by ticks that farmers may be not aware of.

Ticks are closely related to animals such as spiders and insects, belong to a group called the phylum Arthropoda, and are within a group called the order Acari (Latif *et al*., 2004). They are large parasitic mites which attach themselves to, and suck blood of ruminants and other animals as Parola and Raoult (2001) define them as ecto-parasites that feed on blood and transmit pathogens including protozoan parasites, bacteria, viruses which are disease causing agents in animals and humans.

2.2 DEMOGRAPHIC INFORMATION OF SHEEP FARMERS

Sheep farmers are characterized by subsistence farming with low irregular earning of income which is generated from the sale of livestock and their by-products: wool, meat and dung for fuel or manure, thus contributing to farm household livelihood, poverty alleviation and food security (Miao *et al*., 2005; FAO, 2009;Yitayew *et al.*, 2013).They use low inputs for farming as they practice communal grazing areas which are mostly subsistence in nature (Mthi*et al.,* 2017).

2.2.1 Socio-economic characteristics of sheep farmers

Farmers households are headed by married persons mostly male farmers due to privilege accorded them as heads of families and cultural values that make farmland easily accessible to them through transfer of animals by virtue of inheritance from the parents (Mthi *et al*., 2017, Garoma, 2006; Kunene and Fossey, 2006; Taye, 2006; Mapiliyao *et al*., 2012). Farmers in this sector are old. Young and active people migrate to urban areas to seek better opportunities and do not consider livestock farming as a potential business while some are involved in other farming enterprises such as crop production (Mthi *et al*., 2017). Dercon and Krishman (1996) reported that age can affect the rate of household adoption of innovations, that in-turn affects household productivity and livelihood strategies. Most of sheep farmers acquired at least basic school education and this provides opportunity for improvement of sheep production by extension services through training of farmers and provision of extension materials such as leaflets and hand-outs, which can be used to transfer knowledge to the farmers to easily adopt new technologies (Karimuribo *et al*. 2011; Kuldeep Porwal *et al*., (2006).

2.2.2 Livestock species and Flock size reared by sheep farmers

Farmers in Lesotho like other developing countries have low number of animals per farm hence most of farms are owned by so called small scale farmers (Lesotho Bureau of Statistics and Planning, 2007). Small scale farmers' production is characterised by mixed crop-livestock production and integrated livestock production made up of sheep, cattle, poultry, pigs, dogs and other livestock species (Karimuribo *et al.*, 2011). Ayalew *et al.* (2013) also indicated that sheep farmers are characterized with small scale farming with bought foundation stock, some are inherited and others obtained theirs from "Lobola" (Nsoso and Madimabe, 2003). So such movements from one area to another may be source of tick genera transition from one place to another.

2.3 AWARENESS OF MERINO SHEEP FARMERS ON TICKS' INFESTATION

Knowledge of farmers on tick infestation among their flocks depends on their level of education. According to study conducted by Ramzan *et al.* (2018) large number of farmers observed tick infestation mostly in summer and disappear in winter, hide in the cracks and crevices in the farm walls and under the animal dung. Other researchers showed that farmers are aware about tick infestation in their livestock especially where the long summer season is followed by short rainy spell (Muchenje et al.,2008; Marufu et al., 2008; Sayin et al., 2003;Spickett et al., 1989).

Ramzan *et al.* (2018) clarified that emission of heat and carbon dioxide from animal's body may also be involved in tick distribution. However, earlier studies conducted by Riaz *et al*. (2017) and Rony *et al*. (2010) enlisted large number of factors promoting tick infestation, such as lack of veterinary services, climate change and lack of information about ticks. Some other factors which predispose sheep to ticks infestation may be production systems they use as some studies' stated that high prevalence might be most probably attributable to conducive environment, malnutrition and poor husbandry systems, poor awareness of farmers and inadequate veterinary services (Mekonnen *et al*.,2001; Mekonnen *et al*., 2007; Pegram *et al*.,1981).

2.4 PRACTICES OF SHEEP FARMERS IN CONTROLLING TICKS IN DIFFERENT ECOLOGICAL ZONES

Some sheep farmers use only chemicals for the control of tick infestation in domestic animals with few farmers adopted cultural (picking by hands and crush them) practices for the management of ticks in their animals, while others used both chemical and cultural practices, some may consult qualified veterinarian for checking of their animals and vaccinated their animals against ticks especially those with monthly income to buy chemical (Ramzan *et al.,* 2018). In most of developing countries governments had no subsidies for tick control services and farmers purchase medicine from private sectors which are costly (Ramzan *et al.,*2018). According to Ndebele *et al*. (2007) from Zimbabwe, extension officers and government provide acaricides for the control of ticks, but most farmers used traditional methods such as minerals and kerosene oil for the control of ticks because they think that acaricides provided by government, may harm their animals as regular use of acaricides may induce resistance in ticks against these chemicals.

Farmers lack better and safe measures to control ticks as Masika *et al*. (1997) had said that farmers control ticks with some chemicals which can be harmful for animals due to absorption of lead in animals' body and due to lack of knowledge and information some farmers crush the ticks with their hands resulting in contact with contaminated fluid from ticks, through which contagious diseases may be transmitted. According to Anitha *et al*. (2013), small scale farmers rear other livestock species with poultry which may be biological control of ticks hidden under dung or cracks of the kraals. Khan *et al*. (1993) and Irshad *et al*. (2010) explained that some farmers' practices in other ecological zones like Pakistan may lead to high tick infestation due to the reason that residents lack education, awareness and unhygienic conditions. The less infestation of ticks was observed in places where there are regular vaccinations, and good management practices accompanied by high educational levels (Irshad *et al*., 2010).

2.5 FARMERS CAPACITY BUILDING STRATEGIES

The domesticated animals of this region have high infestation of tick species due to the fact that herdsmen are illiterate and less educated and are unable to update their knowledge regarding ticks and tick-borne diseases. So, there is need to educate them about the subject matter. A gap of coordination between farmers and Extension staff needed to be mitigated Ramzan *et al*., (2018).

Extension service is seen to be important in wool industry as it was reported by Tiar (2009) as means to help wool growing businesses towards more resilient and profitable production systems. The report by Ramzan *et al*. (2018) indicates that animal health seems to be a major problem to wool growers which can be solved by extension service. There is a need for innovation priorities responsive to sheep industry needs that deliver adoption of both established practices and new technologies aimed at promoting a productive learning environment and culture (Ramzan *et al*., 2018). Some researchers reported that there are some programmes which may help farmers to eliminate ticks on sheep body, in kraals and rangelands as extension trains on technologies and 'styles of farming' (Vanclay *et al.*, 1998; Howden and Vanclay, 2000; Vanclay *et al.*, 2006; 2007). Hunt *et al.* (2008) argued for long-lived knowledge bases to ensure the retention of important skills and knowledge for ongoing rural industry competitiveness and sustainability so farming communities which use full extension service in their areas may be in position to prevent, control or even eliminate ticks among their flocks with proper technologies.

Even though most of countries had extension services, it is very poor that farmers do not get benefit from available services (Ramzan *et al.,* 2018). Farmers associations also seemed to be very important for sharing skills of improving wool production as had been reported in previous studies (Clark and Timms, 2001; Carruthers and Vanclay, 2007). Associations might be considered as group acted as a 'compass' for guiding the improvement programmes at a given time like dipping, vaccination and others *(*Hunt *et al.,* 2011*).*

2.6 COMMON TICKS GENERA AND THEIR PREDILECTION SITES

Ticks (Class Arachnida) are ectoparasites of many vertebrates from wild to domesticated ones which suck blood. Ticks have different genera, according to Walker *et al*. (2014) the following ticks' genera are present in Africa: Amblyomma, Argas, Dermacentor, Haemaphysalis, Hyalomma, Ixodes, Rhipicephalus, Margaropus, Ornithodoros, Otobius. Figure 1 illustrates some of tick genera pictures reported in South Africa report by Jongejan *et al*. (2018).

In most of the experimental reports reviewed, genera of ticks found were: Rhipicephalus, Haemaphysalis, Ixodes, Ambylomma, Hyalomma, Boophilus and Otobius (Khan *et al*., 1993; Sajid *et al*., 2008; Rehman., 2017). Walker *et al*. 2014 had grouped them into five groups based on their size, mouth parts and other features.

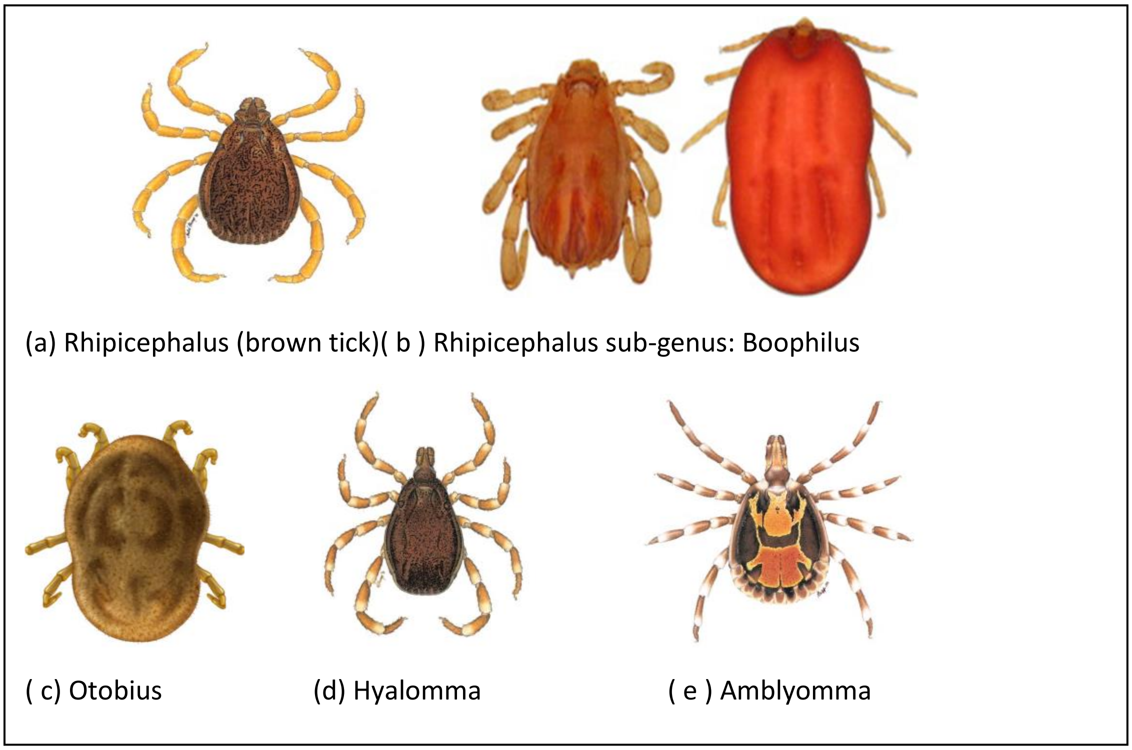


Figure 1: Common tick genera (Jongejan *et al*., 2018; Saari *et al*., 2017)

2.6.1 Rhipicephalus

According to Walker *et al*. (2014), Rhipicephalus has many species which exist in one, two or three-host life cycle. It transmits the protozoans Babesia ovis to sheep, causing ovine babesiosis. It also transmits Anaplasma bacteria to cattle and sheep, causing Anaplasmosis (Parola and Raoult. 2001). The adults are found on the hairless area around the anus as well as the groin region of equids, cattle and sheep. Some species prefer cool weather while some prefer warm rainy conditions (Walker *et al*. 2014).

2.6.2 Boophilus

Boophilus (Bo) is sub-genus within the genus Rhipicephalus (Rh), most of its species are one-host-ticks and it transmits babesiosis and also Walker *et al.* (2003) have described Rh. (Bo.)

decoloratus as a vector of Borrelia theileri in ruminants. Cattle are the main hosts of Rh. (Bo.) but also occasionally sheep, goats and wild ungulates can support successful completion of the life cycle. The life cycle can be completed in two months, and six generations per year are possible under conditions of continuous high temperature and humidity (Walker *et al,* 2014). The preferred feeding sites are legs, belly, neck and dewlap but in heavy infestations the tick may be found over the back and shoulders. In some areas, where there are distinct summer and winter seasons, the tick's activity begins in late summer and extends with a peak in autumn. It transmits protozoans Babesia which causes Babesiosis disease Parola and Raoult., 2001).

2.3.3 Hyalomma

Hyalomma has been reported by Walker *et al.* (2014) as a two-host life cycle tick which takes one year to complete its life cycle and adults feed on cattle, sheep, goats, horses and large wild herbivores. They are active mainly during the summer months. It is a tick of areas with steppe and desert climates. Hyalomma is not known to be a main vector of pathogens causing disease to domestic animals but is considered a vector of the virus causing Crimean-Congo haemorrhagic fever in humans. Its feeding on domestic animals causes serious direct damage to the skin at the attachment site (Ramzan *et al*., 2018).

2.6.4 Otobius

It is a one-host tick which is being centred on cattle kraals and horse stables. Only the larvae and nymphs are parasitic; the adults do not occur on the hosts. Otobius megnini is eyeless as nymph and adult. Its preferred hosts are cattle, sheep, goats, horses, donkeys and mules. It also infests dogs and cats. Otobius megnini is not known to transmit any pathogen but it causes irritation to infected animal (Walker *et al*., 2014).

2.6.5 Amblyomma

Most of its species are three host ticks and based on Walker *et al*. (2014) some species are not of economic importance to health of animals and some can transmit Cowdria ruminantium which is causative agent of cowdriosis. It prefers large ruminants and temperate (highlands) to dessert weather conditions. The adults prefer the hairless areas under the tail, in the lower perineal region, on the udder, around the genitalia and in the axillae of cattle, as well as around the feet of sheep and goats. (Walker *et al.*, 2014).

2.6.6 Predilection sites of ticks' genera

Ticks attached in different parts on sheep body; for instance, under tail, around anus, belly udder, scrotum, ear, head, back, shoulder. The above statement is supported by study which reported that ticks were mostly found underside of the tail, followed by ears and least on udder of the animals. According to Rehman *et al*. (2004) ticks have a common preferred site of attachment on their host animals that might be due to easiness for ticks to acquire blood for nourishment and previously mentioned author also reported that ticks preferred to reside and feed on ears rather than other parts of the body of the host. This might be attributed to the fact that the attachment of tick is dependent on the temperature and the thickness of the skin of the animal (Feldman and Borut., 1983). According to Hamito (2010) each tick species have preferable predilection site for attachment. It had been reported on high infestation on fat tails of infested sheep by Yakhchali *et al*. (2011). Again Rasouli *et al*. (2010) in a study on infested sheep in Maragheh city concluded that the highest tick aggregation site was head and tail, axilla and groin were next positions. Moshaverinia *et al*. (2012) reported that frequency of tick distribution on the body surface of host was mostly under tail (42.66 %) *Walker et al.,* (2003) indicated that the preferred feeding sites are legs, belly, neck and dewlap but in heavy infestations the tick may be found over the back and shoulders, the reason being that different genera prefer different attachment sites. Rashid *et al* (2018) reported an ear to be the commonest site for tick infestation in sheep followed by thighs with Rhipicephalus species being the common followed by Hyalomma. Similar results were reported by Asmaa *et al*. (2014) who recorded 87.5% ear infestation in sheep. Irshad *et al.* (2010) also reported 78.5% of tick infestation in the ears, followed by under the tail and inner side of thighs. On the other hand, Tadesse *et al*. (2018) showed that most infested body part was udder-scrotum (32.4%). The reason for disagreement in above reports might be that of different preferable areas of detachment of ticks on sheep body.

Some researchers emphasised that the attachment of ticks is dependent on the temperature and the thickness of the skin of the animal and other factors (Tukahirwa, 1976; Feldman and Borut, 1983; James-Rugu, 1998; Opasina *et al.*,1983).). The similar sentiments were shared by Irshad *et al.* (2010) who reported that the temperature of the skin covering the body was 350 C while that of the ear was 250 C. Ear was the highest preferred predilection area in most of reports reviewed, like Opasina *et al*. (1983), Latha *et al*. (2004) reports .and study conducted by Bukbuk *et al*. (2016) whom found most of the ticks around the ear region than in other parts of the animal body.

2.7 TICK IDENTIFICATION

Identification of ticks can pave a way in tracing diseases down to their host associates and interpreted habitat range, and distribution patterns, but misidentification might lead to the opposite (Anderson *et al.*, 2004). Precision through identification of tick species has a primary key role in controlling tick borne diseases. Morphology based approach to describe tick species has been applied as a conventional method in most studies (Soneshine, 1991; Coporale *et al*., 1995; Mangold *et al*., 1998). Identification of tick is mostly done under stereomicroscope by using the key of Walker *et al*. (2003).

In contrast, morphological techniques to describe species have limitations on poorly preserved specimens, similar shared features among taxa (e.g. Ixodes ricinus and I. paracinus) and unreadily describable features seen after feeding (Nava *et al.*, 2009; Ronaghi *et al.*, 2015). For instance, Rhipicephalus microplus and Haemaphysalis bispinosa are difficult to differentiate by just using their physical features, because they both appear dark in colour, have similar sizes and their festoon are not visible once they are engorged (Braham *et al.*, 2014). In addition, these ticks have respectively unique traits of hexagonal capitulum and rectangular capitulum that cannot be seen with naked eyes (Braham *et al.,* 2014).

Ticks have an oval body shape with lengths ranging from 2 - 7 mm. Thus the frontal (anterior) body part of a tick composes of mouthparts with sensory, cutting and immobile (the hypostome) organs, but lacks antennae. This anterior part is named capitulum (Sonenshine, 1991; Hillyard, 1996; Sonenshine and Roe, 2014).

2.8 MORPHOLOGICAL FEATURES OF TICKS

In order to correctly identify ticks, knowledge of their morphology is important. Adult and nymphae forms can be easily recognized by the presence of four pairs of legs from the larval form of most genera, which only has three pairs. Pores are present in adults and, absent in both larval and nymphae forms (Sonenshine, 1991; Hillyard, 1996; Sonenhine and Roe, 2014). According to Olivier (1989), blood meals serve as prerequisites for egg production in most female ticks. Ticks have a circulatory system where all organs and tissues are bathed by the haemolymph (Sonenshine, 1991; Hillyard, 1996; Sonenhine and Roe, 2014). They have a variety of sensory organs that facilitate the location of hosts and communication amongst each other. Most ticks have no eyes, but if present it is doubtful that their purpose is to produce a detailed vision of the surrounding environment (Parola and Raoult, 2001). Mouth parts can be short or long and seen ventral or anterior. The genera of ticks size differs from small, medium and large (Walker *et al.*, 2004). Figure 2 below indicates morphological features for identifying different types of ticks.

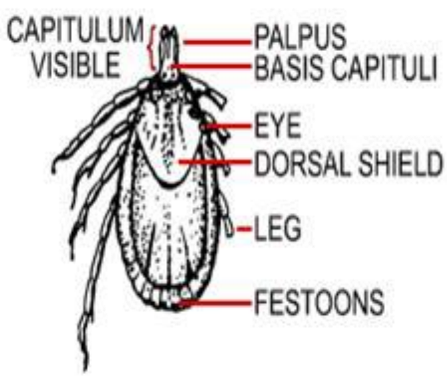
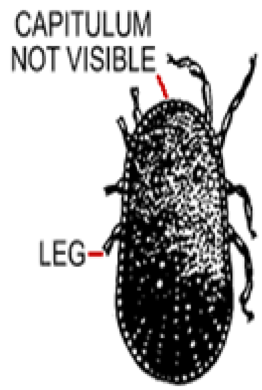
	
Hard tick (Family Ixodidae)	Soft tick

Figure 2: Distinguishing features of hard and soft ticks (Hamito, 2010)

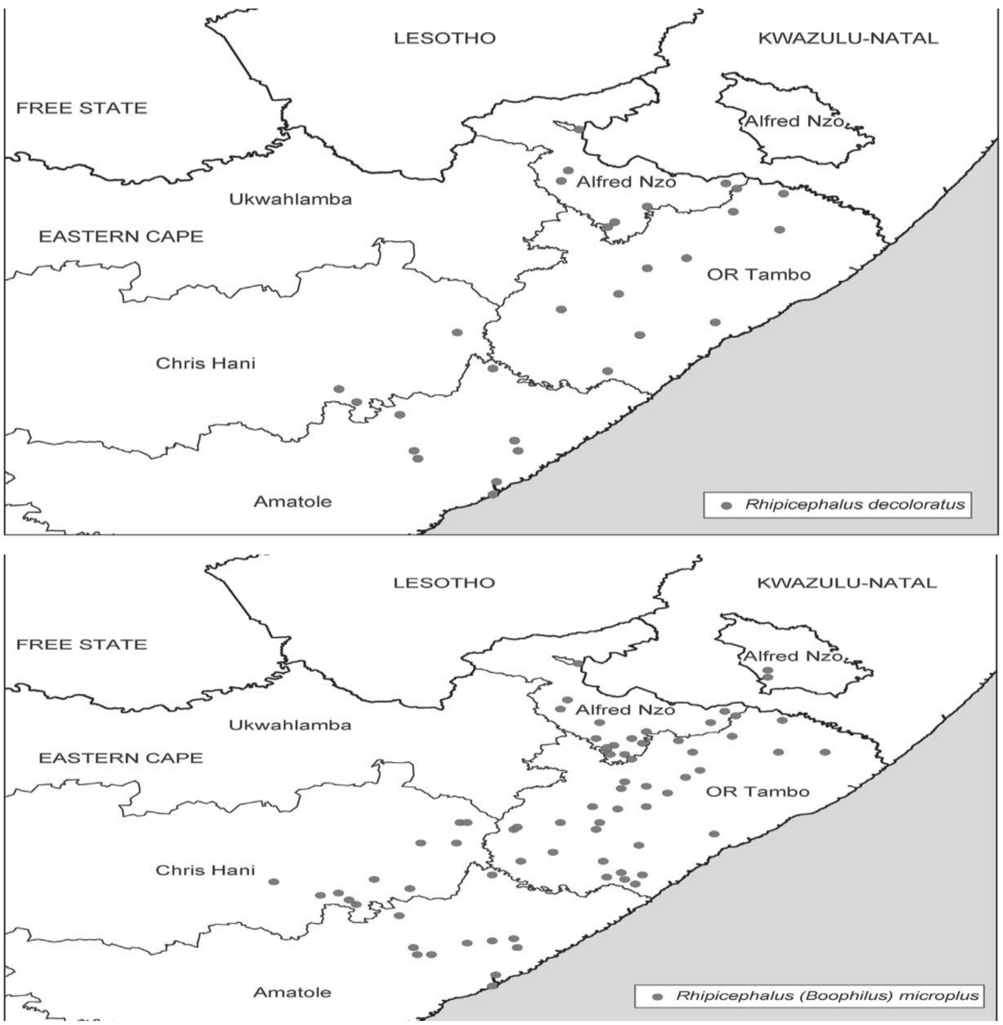
2.9 PREVALENCE AND ABUNDANCE OF TICK GENERA AND THEIR CONTROL

All ticks spend most of their life cycle away from their hosts, hiding either in soil and vegetation or in the nests of their hosts. Latif (2004) report revealed that the absence of rural poultry, not using any acaricides, traditional rural housing systems and grazing seem to be potential risk factors associated with a higher tick prevalence in livestock farms. Diseko (2018) conducted study that identified tick genera in Lesotho. Lesotho had high risk of having some tick genera as it is near South Africa (SA). Horak *et al*. (2009) had indicated species composition and geographic distribution of ticks in SA areas near to Lesotho and other Countries.

The previously conducted studies found high prevalence of ectoparasites in small ruminants from different parts of Ethiopia (Mulugeta 2008; Sertste and Wossene 2007a; Teshome 2002) and other countries of the world (Mohammed and Ali 2006; Rahbari, Nabian and

Bahohar 2009). The above findings was most probably attributable to several important factors including conducive environment, malnutrition and poor husbandry systems, poor awareness of farmers and inadequate veterinary services (Mekonnen, Hussein and Bedane 2001; Mekonnen *et al*. 2007). Irshad *et al*. (2010) also reported about tick prevalence in Pakistan. In a tick survey in four geographical zones of Iran by Rahbari *et al*. (2007) the occurrence of ticks on sheep (55 %) was reported. Yakhchali *et al*. (2011) in a study on diversity and seasonal also reported high tick prevalence. In previous studies on ixodid tick fauna in Iran overall six genera and 22 species were reported by Rahbari *et al*. (2007) and 24 species by Mazlum (1971).

Figure 3 illustrated that Rhipicephalus was present in some countries and Koc *et al*. (2015)and Telmadarraiy *et al.* (2004, 2010) indicated that Rhipicephalus genus prevalence dominates other genera and this genus had been reported to survive in dry areas (Walker, 1974). Again figure 4 indicated Boophilus was found in some countries as Bukbuk *et al.* (2016) also found that Boophilus was more prevalent while Soundararajan *et al.* (2018) had found Hyalomma to be highly prevalent than Rhipicephalus. These revealed that there might be difference in climatic conditions in the area of study done previously.


LESOTHO
KWAZULU-NATAL
FREE STATE
Alfred Nzo
Alfred Nzo
Ukwahlamba
EASTERN CAPE
OR Tambo
Chris Hani
Amatole
Rhipicephalus decoloratus
LESOTHO
KWAZULU-NATAL
FREE STATE
Alfred Nzo
Alfred Nzo
Ukwahlamba
EASTERN CAPE
OR Tambo
Chris Hani
Amatole
Rhipicephalus (Boophilus) microplus

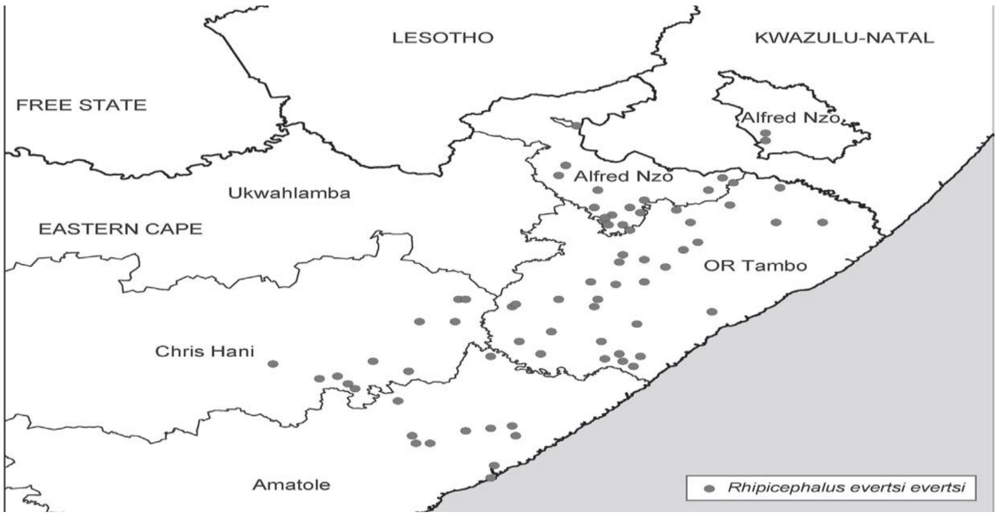


Figure 3: The geographic distribution of *Rhipicephalus* (*Boophilus*) *Decoloratus*, *Rhipicephalus* (*Boophilus microplus* and *Rhipicephalus evertsi evertsts*) the eastern region of the Eastern Cape Province and (C) Maputo Province(Horak *et al*., 2009)

Figure 4: The geographic distribution of *Amblyomma hebraeum* in (A) the eastern region of the Eastern Cape Province, South Africa, and (B) Maputo Province, Mozambique Province (Horak *et al.*, 2009)

Figure 5: The geographic distribution of Hyalomma rufipes in the eastern region of the Eastern Cape Province, South Africa Province (Horak *et al*., 2009)

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Figure 5 indicated that in some countries Hyalomma was present and in some countries it was found to be the most dominant tick in the study area done by Moshaverinia *et al.* (2012) and Telmadarraiy *et al*. (2004). Furthermore, Maltezou *et al.* (2010) stated the Hyalomma tick genera species as the main vector for Crimean-Congo Hemorrhagic Fever (CCHF) in southern Europe.

Generally, ixodid ticks were mostly available than soft ticks in different parts of Ethiopia (Wallaga 1997; Abunna *et al*., 2009; Abera *et al*., 2010; Bekele *et al.,* 2011). The prevalence in different tick genera might occur due to variation in the climatic conditions and temperature (Alekaw., 2000; Walelign., 2016). This is supported by Telmadarraiy *et al*. (2004) who reported the highest prevalence of Rhipicephalus spp. in summer. Spring and summer were reported to have high tick prevalence (Moshaverinia *et al*., 2012). Yakhchali *et al.* (2011) in a study on diversity and seasonal distribution of Ixodid ticks in north and south of Iran reported the occurrence of tick infestation in sheep in north of Iran. Most of tick type found was ixodid tick fauna in Iran in which overall of six genera were reported by Rahbari *et al*. (2007) and four genera by Moshaverinia *et al.*, (2012).

2.9.1 Effect of agro-ecological zone on tick prevalence and abundance

An agro-ecological zone is a land resource mapping unit, defined in terms of climate, landform and soils, and/or land cover, and having a specific range of potentials and constraints for land use. It might affect tick prevalence based on different risk factors. Abundance may be estimated by collection and counting of all ticks from animal body or rangeland. Andersson *et al.* (2018) recorded different tick abundance means in different areas and recommended that 16.5 tick abundance mean in endemic natural areas to be considered as high value of economic importance of tick infestation. Ticks prefer rainy warm climatic conditions.

Prevalence of ticks in hot and humid season favors the propagation and multiplication of ticks (Soulsby., 1982). The variation in tick prevalence in different areas can be attributed to a variety of factors like geo-climatic conditions, association and life style of different species of animals, awareness/ education of the farmers and farm management practices (Khan *et al*., 1993; Bell-SakyI *et al*., 2004).

The high or low prevalence in different tick genera might occur due to some predisposing factors as some studies indicated that there might be difference tick prevalence in different areas due to climatic conditions and temperature variation (Alekaw., 2000; Walelign., 2016). Ecological zones had different in tick prevalence as Wallaga (1997), Abunna *et al*. (2009), Abera *et al*. (2010) and Bekele *et al*. (2011) had reported the infestation of sheep by different tick genera of ixodid ticks in different parts of Ethiopia. Pegram *et al*. (1981) and Kumsa *et al*. (2012) reported higher prevalence of ixodid tick infestations in the midland, moderate in lowland zones and very low in highland agro-ecological zone. High prevalence is attributable to higher temperatures and relative humidity and prolonged sunlight in the midland and lowland zones that favour the survival and reproduction of these ticks, as has been suggested by Pegram *et al*. (1981) and Kumsa *et al*. (2012). The distribution of ticks within a specific habitat depends on several environmental and climatic factors such as annual rainfall, atmospheric temperature and relative humidity (RH), vegetation cover, altitude and host availability.

Walker (1974) report had indicated that hard tick three host genera (Hyalomma and Rhipicephalus) survived in dry agro-ecological zones. In contrary to the statement of above report, Hamito (2010) reported that in sub humid areas the period of highest tick activity is the wet season and only few ticks are found on animals during the dry season that agreed with study conducted in Turkey in various domestic animals, including sheep (Koc *et al*., 2015).

One tick genera can be distributed over many areas as had been previously reported that Rhipicephalus genus was mainly found in central Greece, in Fokida and the island of Cephalonia (Psaroulaki *et al.,* 2003; Psaroulaki *et al.,* 2006). Again Rhipicephalus genus prevailed highly in sheep in a study that was conducted in Sicily, with the only other genus being Hyalomma (Torina *et al*., 2006). Furthermore, that genus was previously reported on sheep from northern Sudan (Hoogstraal, 1956) and from Khartoum Province in central Sudan (Latif and Paine, 1987). Jongejan *et al*. (1987) also indicated that different species of the Rhipicephalus group may inhabit different ecological zones in Sudan.

Most of hard ticks had high prevalence and study conducted by OSIS (2019) observed a significantly ($p<0.05$) higher prevalence of ixodid tick infestations. It is most probably attributable to the higher temperatures and relative humidity as well as prolonged sunlight in the foothills and lowlands agro-ecological zones that favour the survival and reproduction of these ticks (Pegram *et al.,* 1981); Kumsa *et al*., 2012); Serste and Wossene, 2007). Furthermore, Jongejan *et al*. (1987) indicated that different species of the Rhipicephalus group may inhabit different ecological zones.

Hyalomma genera were not present in a high percentage in northern Greece compared to their percentage in the prefectures of Achaia and Chania (Wall and Shearer, 2001). The reason of variation in Hyalomma prevalence might be that Hyalomma can survive exceptionally in cold and dry (Urquhart *et al*., 1996; Chanie *et al*., 2010; Mekonnen, 2001). Walker (1974) also stated that the hard tick three-host ticks survive well in dry agro-ecological zones for instance Amblyomma species. This might be because of warm weather in those areas. Boophilus is associated with lowland rainforest and secondary grassland, with a clear increase in the vegetation cover (Lorusso *et al*., 2013).

The tick wide distribution might be probably attributable to several important factors including conducive environment, malnutrition and poor husbandry systems, poor awareness of farmers and inadequate veterinary services in study areas (Mekonnen, Hussein and Bedane 2001; Mekonnen *et al*. 2007; Pegram, Hoogstral and Wassef 1981).

2.9.2 Effect of sheep age on tick prevalence and abundance

Sheep age seems to be a risk factor in tick prevalence as previous report by Tjomsland (2013) had shown that lambs were more at risk than older sheep, because the older animals have developed some immunity. However, Rachid *et al.*(2018) reported that older sheep (>1 year) had higher prevalence than young animals, because they have weaker immune systems. Lambs face high risk from tick bites hence high mortality of up to 30% was reported by Tjomsland (2013). In addition, Rashid *et al.* (2018) indicated that the lower rate of tick infestations in adult sheep could be attributed to acquired resistance incidental to repeated exposure of host.

The attachment of ticks is dependent on the temperature and the thickness of the skin of the animal hence the prevelance is higher in lambs due to their light and soft skin (Tukahirwa, 1976; Feldman and Borut, 1983; James-Rugu, 1998; Opasina *et al.,* 1983).) Latif (2004) also indicated that the young animals have low tick burden than old animals hence host characteristics determine abundance and intensity of tick infestation.

2.9.3 Ivermectin effectiveness in controlling ticks

Ivermectin is a macrocyclic lactone produced by Streptomyces avermitilis and is highly effective against endoparasites and ectoparasites of cattle, sheep, goats and swine (Amaral *et al*., 1983 and Benz *et al*., 1989). It is widely used as a broad-spectrum drug against a wide range of endo- and ectoparasites in ruminant animals (Gokbulut *et al*., 2008; Jameel *et al*., 2014). It is commercially available in different formulations including injections, oral, and rumino-reticular and cutaneous delivery systems (Mestorino *et al*., 2003). Mahmoud *et al*., (2018) indicated that subcutaneous (S/C) injection is a more efficient route for this drug in terms of drug bioavailability, efficacy, and persistency compared to other routes of administration (Lespine *et al*., 2005; Gokbulut *et al*., 2007;Willadsen, 1997).

Ahamme *et al.*(2016) reported 100% ivermectin efficacy against against Otobius and Rhiphicephalus ticks genera when animals were given dose at the rate of 0.02 ml/kg body weight and drug given with subcutaneous injection. Also report of previous study by Sundararajan *et al*,. (2003). Recommended dosages are 0.02ml/kg to 1ml/50kg body weight (200µg/kg body weight) for high drug efficacy (Ahamme *et al*,. 2016)

Ahamme *et al*. (2016) stated that the expected output of ivermectin is above 0.08 which is large output. The above statement implies that when drug is deemed effective, it means it has an intended or expected outcome. The report on medication or drug effectiveness done by Stefan *et al*. (2015) had indicated measures of medication efficacy percentage response ratio (PRR) and the Effect sizes and were ranked as “small” (0.2), “medium” (around 0.5) or “large” (above 0.8). For an outcome affecting quality of life, ½ (0.5) of a standard deviation is considered to be a minimal clinically important difference as reported by Stefan *et al*. (2015).

Ivermectin effectiveness after treatment can last approximately up to 49 days and this stated the by Straten and Jongejan 1993) who reported that Ivermectin sera concentration in tick body increased to 13.0ppb within 1day after treatment, and peaked at 26.2ppb at 11day post-treatment. Ivermectin sera levels remained above the threshold level for control of feeding ticks (>or=8ppb) for 42.6day after treatment and the therapeutic efficacy of ticks on treated animals was >99.9%, and tick number, index of fecundity, engorgement weight, and egg mass weight of ticks from treated animals remained dramatically less than ticks from untreated animals. Tick number and reproductive capacity of ticks infested on treated animals at 14 and 28d post-treatment were less than for ticks on untreated animals, whereas engorgement weight and egg mass weight of treated ticks remained lower than that of untreated ticks 49d post-treatment. However, the level of control against ticks infested at 14 days after treatment (99.9%) was the only post-treatment infestation interval that provided the required 99% control. The above report further indicated that Ivermectin proved to be effective in controlling R. sanguineus. All brown dog ticks infesting the treated dogs (subcutaneous injections) with 1.5 ml or 2 ml/50 kg dropped off within 4 or 3 days respectively. The dropped off ticks were completely inactive and died within one day or two. Ivermectin in general is efficient in several animal species, different age groups and different areas or zones as Soundararajanl *et al.* (2003) reported 100% efficacy in Hoggets treated with ivermectin. On the other hand, some studies reported that although overall levels of control with avermectin (ivermectin) compounds were high, the levels of control during the first few days after treatment were relatively low (Nolan *et al*., 1981; Cramer *et al*., 1988; Bridi *et al.,* 1992; Kumar *et al.,* 1992; AFPMB., 1998; Cramer *et al*., 1988.).

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 STUDY SITE

The study was conducted in spring to summer in the four agro-ecological zones of Lesotho. The country is situated within the Southern African plateau at an elevation of between 1,500 m and 3,482 m above sea level. It is divided into four agro-ecological zones (Figure 7) based on climate and elevation with the total area coverage of: Lowlands (17%), Senqu River Valley (9%), Foot-hills (15%) and Mountains (59%) (Cauley, 1986).The four districts that were chosen to represent different agro-ecological zones are Qacha's Nek (Ha-Sekake) for Senqu River Valley, Leribe (Pitseng) for Foothills, Mafeteng (Kolo) for Lowlands and Thaba-Tseka (Mant'sonyane) for Highlands. The Lowlands are in the west lying between altitudes of 1500m and 1830m above sea level and are characterized by relatively high rainfall and moderate to high temperatures. The Foothills are in the centre between 1830 and 2130 meters above sea level with lower rainfall and temperatures compared to the Lowlands. The Senqu/Orange River Valley runs from east to west across the country and characterized by a low rainfall especially in the south-western part and it lies between 1500 and 2250 meters above sea level. The Highlands are characterized by very cold winters. They rise to elevation of 3500 meters and constitute by far the largest, and yet the least densely populated part of the country. They are in the mountainous zone where rangelands are mostly found and livestock is commonly found (Mafisa, 1993).

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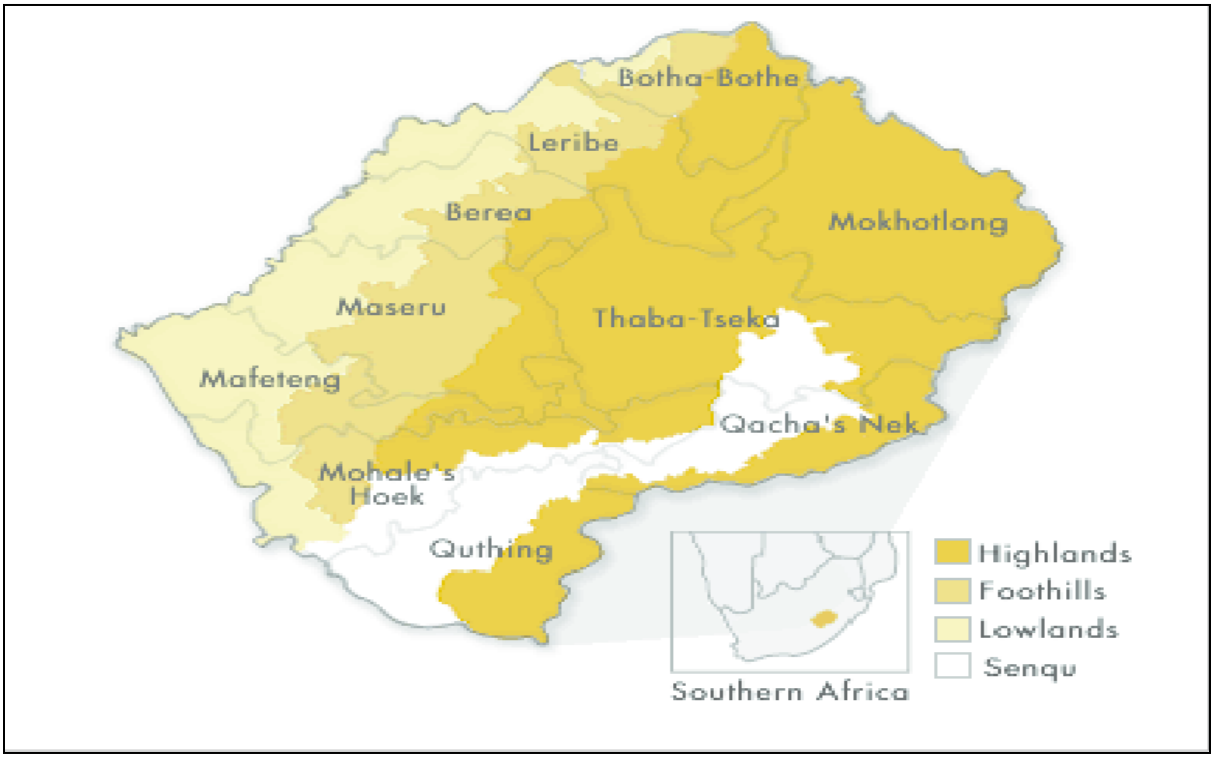

Figure 6: The map of Lesotho showing the four agro-ecological zones Province (Sissay *et al*., 2011).

This study was divided into two components being the survey and experiment.

3.2 STUDY DESIGN AND PROCEDURE

Part 1: Survey

A cross sectional baseline study was carried out at Leribe, Mafeteng, Qacha's Nek and Thaba-Tseka districts using questionnaire. The questionnaire was prepared in English but the questions were asked in local language (Sesotho). Four hundred and three (403) sheep farmers' from Senqu River Valley (110), Highlands (94), Foothills (103) and Lowlands (96) were selected by using random sampling technique (Mureithi *et al*., 2015). The information collected included farmers profile (gender, age, education, sex of respondents), sheep management practices, ticks awareness and their control).

Part 2: Experiment

Experimental animals

The total number of 720 sheep was used in this study. The animals were selected with the assistance of Extension staff and farmers associations at wool shed level from the four agro-ecological zones: Lowlands, Senqu River Valley, Foot-hills and Mountains. Each wool shed that was representing an agro-ecological zone was further subdivided into four areas and in each area three farmers were selected. Each farmer supplied 15 animals comprised of 5 lambs (less than 1 year), 5 juveniles (1-2 years) and 5 adults (2-3 years) to be used as experimental animals. The animals were kept under semi-intensive production system. Dentition was used to estimate the age of animals in this study.

Experimental data collection

The tick samples were first collected and counted in January at day zero before sheep being injected with ivermectin and they were also collected after thirty days after animal were injected against ticks. The ticks were searched by passing hands through the animal's skin and the different stages of ticks (larva, nymph and adult) were collected manually using forceps to avoid damage of their mouth parts. The collected ticks were transferred into sample containers containing 70% ethanol kept in labelled screw-lid container and then preserved in ethanol before identification in the laboratory using a stereomicroscope. All the required information like date and place of collection, predilection sites and sheep age were recorded. The efficacy of the drug (Ivermectin) was done using the following formula as prescribed by Abbott (1925):

Efficacy % = 100 x (Mc – Mr)/Mc

Mc = mean number of live ticks on host

Mr = mean number of live or dead ticks on host after treatment.

Drug efficacy of 0.5 is threshold for medium tick response ratio as per Stefan et al. (2015) report.

Ticks identification

The preserved ticks were identified by their morphological features through stereomicroscope using a manual with specified table of features of ticks' genera and tick identification keys provided by Walker *et al*., (2003). The guidance of an entomologist was followed. The observed features were tick length using well calibrated ruler of stereomicroscope, paying attention to engorged ticks with blood, presence or absence of eyes, long or short mouth, small or big scutum, tick colour and shape. Major focus was on the adult stages of these arthropods as a large number of immature ticks can be easily overlooked during field collection because of their small size resulting in a biased estimate of counts. Therefore, counts of adults were taken as representative of the total infestation of ticks, especially for three-host tick, whose immature feed for short periods on each of three different hosts which is at least 4 days (Lorusso *et al*.,2013). In addition, larvae and nymphs of most genera lack the neatly distinctive morphological features needed for identification of ticks.

3.3 DATA ANALYSIS

The data from survey study was entered into Microsoft Excel 2010 and transferred to statistical package (SPSS version 16) for analysis. Individual interview data were coded into appropriate variables and assigned numerical values. The descriptive statistics was employed in order to determine the means and standard errors of the mean (X±S.E.M.). The Chi-Square test was subsequently used to determine the level of association between dependable variables (agro-ecological zones) and predictor variables (Sex, level of education and flock size). The mean (±S.E.M.) results were presented in terms of percentages using, Tables and Charts.

The experimental data was analysed with General Linear Model (GLM) to determine the effect of agro-ecological zone, age and ivermectin efficacy on the prevalence and abundance of ticks' infestation in sheep. The Generalized Estimating Equation (GEE) was used to analyse the tick abundance in each agro-ecological zone and age group. GEE was also used to compare risk effect of independent variable upon dependent variable with ticks genera count adopting a binary logistic for identifying ticks prevalence and Poisson model for analysing ticks abundance expressing the results in terms of Beta Exponential in percentages. The confidence level was set to be 95% for determining any significant differences on the factors evaluated between the different categories such as level of infestation within the animal age groups, between agro-ecological zone before and after ivermectin treatment. Efficacy of ivermectin was analysed by Wilcoxon signed ranks Table.

CHAPTER 4

4.0 RESULTS AND DISCUSSION

4.1 SHEEP FARMERS DEMOGRAPHIC CHARACTERISTICS

The profile of sheep farmers as summarized in Table 1 indicated that sheep farming in Lesotho is generally done by 64% of males and 36% of females in all the agro-ecological zones. The association between males and females in farming activity was not significant (P>0.05) and had the chi-square value of 2.15. The interviewees were mostly young people that are married at Senqu River Valley (47%), Lowlands (54%), Foothills (65%) and Highlands (56%). The involvement between young, middle and adult age groups engaged in sheep farming was significantly different (P< 0.05).

The majority of people involved in sheep farming in all agro-ecological zones possessed the primary educational level and were dominant in Senqu River Valley compared to other three agro-ecological zones even though the difference was insignificant (P>0.05). The sheep industry is comprised of small-scale farmers despite of an agro-ecological zone.

The results of the present study imply that young and active people nowadays do consider farming as a potential business as compared to previous years about 3-5 decades ago youths were mostly engaged in the mines in South Africa where they were eventually retrenched (Mthi *et al*. 2010). A possible reason for lower age groups being involved in farming might be that of cultural reasons by allocating animals to young boys for future heritage. Increasing the involvement of active and productive age can have a direct bearing on increased agricultural productivity and production which may lead to improvement in household livelihood and reducing poverty in rural areas. This is supported by Dercon and Krishman (1996) who reported that age can affect the rate of household adoption of innovations and that can also affect household productivity and livelihood strategies.

The results of the present study are in contrast with finding of Mthi*et al*. (2010) who found that the majority of farmers were males who were within the age bracket of 51 to 89 years.

Senthilkumar *et al*. (2005) also reported that nearly half of urban sheep farmers belonged to the older age group (> 65 years). In addition, Pushpa (2006) reported that 50% of livestock owners in rural and peri-urban livestock production systems belonged to middle age group.

The results of the present study are in agreement with previous studies which reported livestock farming to be a male dominated business (Garoma, 2006; Kunene and Fossey, 2006; Taye, 2006; Mapiliyao *et al*., 2012). However, Anaeto *et al*. (2009) reported that the sheep industry is dominated by females (70%). Gender inequality reflected in the current report of the study are related to the fact that culturally in Lesotho, women are associated with minor work like vegetable plots and domestic work. Traditional norms and customs for many years proved that males were the ones responsible for possession and management of animals while women were known to take care of the children in the household. Again gender inequality in farming might be that sheep farming mostly is done as hereditary activity as Mthi *et al*. (2010) had made a statement which implies that it is a cultural practice to allocate animals to young boys for future heritage. Moreover, the lower proportion of female farmers in Lesotho could also be attributed to their inability to get their own farmland as head of families if they are not married.

The current findings are in agreement with previously conducted study that found that the majority (62%) of small-scale farmers acquired at least basic school education (Karimuribo *et al*., 2011). Similarly, Mthi *et al*. (2017), Ayelew *et al*.(2013), Mapiliyao *et al*. (2012) Marinda *et al*. (2006), Garoma (2006), Kunene and Fossey (2006) and Taye (2006) reported that livestock farming is mostly in the hands of illiterate or less educated men than women in most developing countries. This observation is not surprising as culturally livestock farming activity is perceived as more or less a tedious work that needs a lot of energy, resilience and strength (Mahlehla, (2017). Furthermore, Adamas and Yankyera (2014) stated that it is common in the developing countries that culturally men are responsible for household productive assets. The highest proportion of sheep farmers being in low level of education might be the reason that boys are made to be farmers by being allocated animals during their early stage of which nearly every boy is taught informally on how to care for animals and so their level of formal education is low as indicated by Mthi *et al*. (2010).

Table 1: Farmers' profile in the four agro-ecological zones of Lesotho

Category	Senqu%	Lowlands%	Foothills%	Highland%	X^2value	Sig
		Gender				
Male	64	67	66	58	2.15	0.542
Female	36	33	34	42		
Age groups						
Youth age	47	65	54	56	25.1	0.000
Middle age	46	58	56	57		
Older age	41	44	40	43		
		Marital status				
Single	15	22	21	14	2.51	0.006
Married	70	60	62	78		
		Level of Education				
Primary	48	56	50	50	36.55	0.000
Secondary	17	25	21	15		
High School	10	7	14	3		
Tertiary	6	5	3	0		
None	7	7	13	33		
		Farm size				
Small	74	81	85	81	11.85	0.065
Medium	22	18	8	22		
Large	5	1	6	6		

X^2= chi square, Sig = significance value.

4.2 STRATEGIES IN PLACE TO HELP FARMING INDUSTRY IN LESOTHO

The results of the current study indicated that farmers are aware that there are some informal strategies in place such as non-governmental organizations trainings by farmers association but farmer's usage of such strategy seem to be very low as illustrated (Figure 8). The lower percentage of farmers received trainings at Ha Sekake (30%), Leribe (4%), Mafeteng (25%), Thaba-Tseka (13%). Again there were a low number of farmers who were members of associations, of which Leribe district registered the lowest percentage (5%). Some farmers (5%) did not see benefit of being members of the association.

The current results indicated that although there is Wool and Mohair Growers Association (WAMGA) for farmers to share knowledge and experience, sheep farmers did not readily join this association with Foothills having very low percentage (5%) of farmers being members of association. The majority of farmers had a feeling that they do not benefit from such supportive strategies like WAMGA in all agro-ecological zones. The results of current study showed that farmers had access to extension service to build their capacity but few farmers reported that they use the Senqu River Valley having insignificantly ($P>0.05$) higher percentage compared to other agro-ecological zones.

The findings of current study are in agreement with statement by Ramzan *et al*. (2018) which stated that the domesticated animals had high infestation of tick species due to the fact that herdsmen were illiterate and less educated and are unable to update their knowledge regarding ticks and tick-borne diseases. So, this means there is need to educate herdsmen about the subject matter. A gap of coordination between farmers and Extension staff needed to be mitigated (Ramzan *et al*., 2018). Extension service is seen to be important in wool industry as it was reported by Tiar (2009) as means to help wool growing businesses towards more resilient and profitable production systems. Other researchers previously reported that there might be programs which may help farmers to eliminate ticks on sheep body, in kraals and rangelands as extension trains on technologies and 'styles of farming' approach (Vanclay *et al.,* 1998; Howden and Vanclay, 2000; Vanclay *et al.,* 2006; 2007). Hunt *et al.* (2008) argued for long-lived knowledge bases to ensure the retention of important skills and knowledge for ongoing rural industry competitiveness and sustainability. Therefore, the farming communities which use full extension service in their areas may be in position to prevent, control or even eliminate ticks among their flocks with proper technologies.

The results of the current study are in disagreement with the study conducted in Lesotho by Mahlehla (2017) who found that the majority of farmers (100% in lowlands, 99% in foothills and 96% in the mountains) were members of farmers' associations.

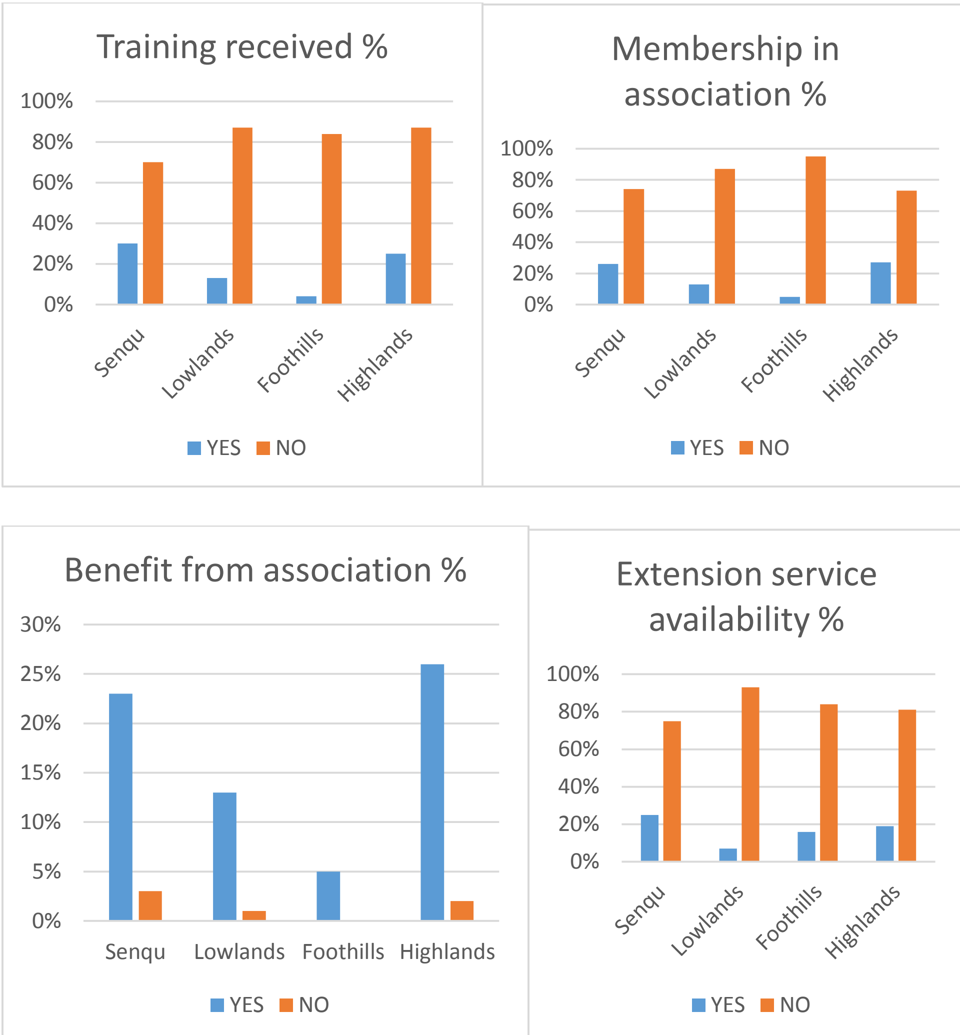

Figure 7: Strategies to capacitate farmers

4.3 FARMERS' AWARENESS ON SHEEP HEALTH PROBLEM INCLUDING TICK INFESTATION IN SHEEP IN FOUR AGRO-ECOLOGICAL ZONES

The findings of the current study indicate a complete unawareness of farmers to ticks' infestation in the Foothills zone (0.0%). The low level of awareness was reported in the Senqu River valley (2.7%), lowlands (1.0%) and highlands (2.1%). The majority of farmers' response implied that farmers were better aware of mites' infestation especially in the Foothills (35%) as compared to other agro-ecological zones. The level of awareness on health problems in different agro-ecological zones was statistically ($P< 0.05$) different with X^2-vaue of 1.2 (Figure 9).

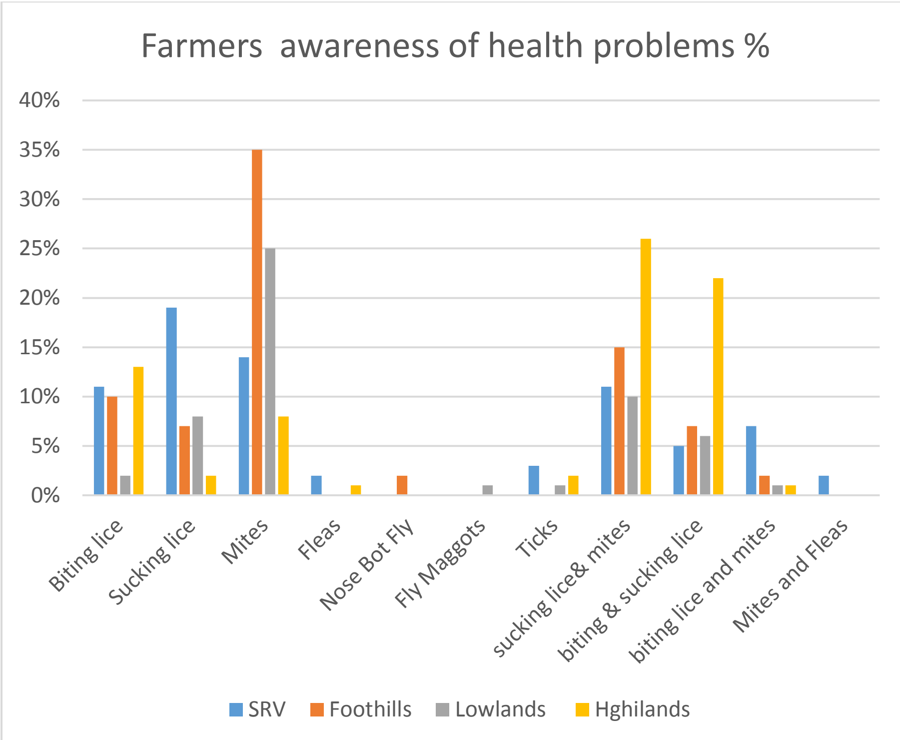

Figure 8:farmers' awareness of the presence of ticks and other ecto-parasites health problems in four agro-ecological zones of Lesotho

The findings of current study indicated low observation of ticks by farmers; therefore, these results are in agreement with the findings of previous study which indicated poor awareness of farmers and inadequate veterinary services in the areas where studies were conducted as source of high tick prevalence (Mekonnen, Hussein and Bedane 2001; Mekonnen *et al*. 2007; Pegram, Hoogstral and Wassef 1981).

In disagreement with the results of this study, Ramzan *et al*. (2018) reported that large number of farmers observed tick infestation mostly in summer. Several researchers showed that farmers were aware tick infestation in their livestock especially where long summer season is followed by short rainy spell (Spickett *et al*., 1989; Muchenje *et al*., 2008; Marufu *et al*., 2008; Sayin *et al*., 2003).

4.4 CONTROL OF ECTO-PARASITES IN SHEEP IN FOUR AGRO-ECOLOGICAL ZONES

The summary of results on how farmers' were controlling ticks' infestation and other ecto-parasites in sheep is presented in Table 4. Dipping was mostly used to control external parasites in the Senqu River Valley (51%), Mountains (36%), Foothills (33%) and Lowlands (28%) of Lesotho. Some farmers were not applying anything at all, thereby, allowing nature to take its control. The results of this study indicated that most of sheep farmers control health problems through vaccination at the rate of 48%, 26%, 45% and 45% in the Lowlands, Foothills, Mountains and Senqu River Valley respectively. Most of farmers do not spray their kraals or even washing them. The involvement in vaccination activity and dipping between four agro-ecological zones was different and the difference was significant ($P < 0.05$).

Sheep farmers of Lesotho buy their breeding stock from South Africa but the results revealed that there were a small number of sheep farmers who practice stock quarantine before mixing their flocks. This type of practice can lead to the introduction of ticks and other ecto-parasites into their flocks.

The low level of education of these sheep farmers could be the cause of wrong farming practices such as lack of regular spraying of the kraal against ecto-parasites of sheep. Even though drugs from shops are expensive and are out of reach of many poor sheep farmers, the results of the current study revealed that few sheep farmers vaccinate their sheep but they do not spray their kraals of which is the easiest way of controlling ticks. Alternatively, some farmers had resorted to measures that include the use of medicinal plants to treat and control livestock parasites as indicated in Table 4; this could be because they could not afford to buy drugs from the shops.

The findings of current study are not in agreement with those of Ramzan *et al*. (2018) who reported that some sheep farmers use only chemicals for the control of tick infestation while few farmers adopted cultural (picking by hands and crushing of ticks) practices or used both chemical and cultural practices. In most of developing countries governments had no subsidies for tick control services as Ramzan *et al*. (2018) had indicated in the study conducted in previous years that farmers had to purchase medicine from private sectors which are most of the time costly. That might also be the case for farmers of Lesotho as there are no subsidies for tick control. In support of the results of the current study, Ndebele *et al*. (2007) reported that most farmers used traditional methods such as minerals and kerosene oil for the control of ticks.

Cultural medicine used by Lesotho farmers in the current study had not been scientifically proven since they are just collected from the wild and used with dosages that might be harmful. Similar findings had been reported as Masika *et al*. (1997) had reported that farmers control ticks with some chemicals which had not been scientifically proven. Due to illiterate and lack of information some farmers crush the ticks with their hands resulting in contact with contaminated fluid from ticks, through which contagious diseases such as CCHF can be disseminated so this is not healthy practice adopted by herdsmen it has to be discouraged and the use of proper control measures should be adopted. According to Anitha *et al*. (2013) small scale farmers rear other livestock species with poultry which may be biological control of ticks hidden under dung or cracks of the kraals.

The reluctancy to control ticks and poor control measures revealed by the results of the current study might lead to tick outbreak. Similarly, Khan *et al*. (1993) stated that some farmer's practices in other ecological zones like tehsils in Pakistin may lead to high tick infestation due to the reason that residents lack education, awareness and unhygienic conditions. The same sentiments were also shared by Irshad *et al*. (2010). However, Ramzan *et al*. (2018) and Irshad *et al*. (2010) reported that less infestation of ticks was observed which may be due to regular vaccination, educational level and good management practices.

Table 2: Control of ticks and other in Merino sheep

Category	Senqu%	Lowlands%	Foothills%	Highlands%	X2 Value	Sig
			Treatment of ecto-parasites			
Dipping	51	33	28	36	73.24	0.00
Insecticides Use	1	7	10	5		
			Control of ecto-parasites			
Vaccination	11	0	0	2	83.6	0.00
Culling	16	4	0	12		
Kraals spraying	6	15	17	10		
Vaccination and kraals spraying	0	0	0	0		
Vaccination and Culling	22	1	1	0		
Quarantine	28	45	29	21		
			Source of medicine			
Shop	3	10	13	3	73.24	0.00
Wild and shop	46	17	17	36		

X^2= chi square. df=degree of freedom. Sig = significance value

4.5 FARMERS MANAGEMENT PRACTICES IN THE FOUR AGRO-ECOLOGICAL ZONES

The results in Table 3 indicate that most farmers mixed animals in all agro-ecological zones of Lesotho. The highest percentage of farmers with 11-50 sheep was seen in the Foothills (37%) and higher percentage of farmers use livestock as their source of income and this is happening mostly in the Senqu River Valley (55%). Famers who clean, wash and disinfect kraals were rare. The fact that kraals were not cleaned regularly could possibly encourage parasites build up and expose susceptible animals. The involvement in better management practice of good hygiene among farmers of different agro-ecological zones was varying significantly (P< 0.05).

Table 3: Livestock production system and management practice in four agro-ecological zones.

Category	Senqu %	Foothills%	Highlands%	Lowlands%	X2 Value	Sig
			Animal species			
Sheep	21	7	11	14	1.70	0.00
Goats	8	4	3	0		
Cows	15	3	1	0		
Equines	8	1	1	0		
Broilers	3	0	0	0		
Mixed livestock	9	17	17	17		
			Number of sheep			
1 to 5	24	13	12	8	38.8	0.00
11-Jun	17	21	17	32		
11-51	26	29	37	16		
>50	10	14	25	32		
none	23	23	9	13		
			Sources of income other than sheep farming			
Crop farming	16	31	22	22	27.5	0.154
Livestock farming	55	45	51	41		
Mining	7	2	4	3		
Domestic work	3	7	4	7		
Gardening	6	2	5	3		
Businesses	6	3	4	6		
Piece job	6	10	10	18		
Crop and livestock	1	0	0	0		
			Kraal hygiene			
Daily wash/disinfect	2	1	0	1	20.85	0.053
Wash/disinfect weekly	6	6	1	0		
Wash every day	1	0	1	0		
Wash every week	3	0	4	0		
None of the above	90	93	94	99		

X^2= chi square. df=degree of freedom. Sig = significance value

These results are in agreement with those which indicated that subsistence agriculture production remains the main employer of the labour force of which livestock farming assumes a critical role (Ogunmefun and Achike., 2015). Livestock farming has a potential to increase income generation for all farmers especially the rural poor and could serve as an insurance for food security especially during extended droughts (Adama and Yakyera, 2014; Dantankwa and Asafu-Adjei, 2001).

The findings from the current study indicated that sheep farming is not only activity done by farmers rearing Merino sheep but also they were engaged in other livestock and crop activities. This is in agreement with the study previously carried out in Tanzania and Ethopia done by (Ayalew et al., 2013; Karimuribo *et al*.,2011; Mthi *et al*., 2017). Generally, livestock production system was characterized by mixed crop and livestock farming system. In all the four agro-ecological zones the results indicated that sheep farming is the predominant occupancy compared to other livestock farming.

The present study revealed that the majority of sheep farmers were small scale farmers (79.7%) while large scale farmers (4.5%) were fewer. The results of the current study are approximately close to the study conducted by Mthi *et al*. (2017) who found the mean flock size of 79±53.9 sheep for small scale farmers per household. Moreover, Musemwa *et al*. (2008) in a study conducted in South Africa indicated that most of sheep farmers are small scale. The current study results also showed that small-scale sheep farmers do engage in other activities like keeping other livestock species such as poultry, goats, equines and cattle, mining, business, growing crops and piece jobs (Mapiliyao *et al.*, 2012; Kunene and Fossey,2006; Costales *et al.*, 2007; Kariga *et al.*, 2010; Karimuribo *et al.*, 2011).

4.6 PREVALENCE OF TICKS IN SHEEP IN LESOTHO

4.6.1 Overall tick prevalence of identified Genera

The identified tick's genera were: Rhipicephalus (36%), Boophilus (0.7%), Amblyomma (0.4%), Hyalomma (0.2%) and Otobius (0.5%). Rhipicephalus prevalence was higher than other genera as shown in Table 4.

Table 4: Tick genera identified in all agro-ecological zones of Lesotho and their prevalence.

Tick	NO. of sheep Examined	Prevalence Percentage (%)	Standard Error
Rhipicephalus	1427	36.0	0.02
Boophilus	1427	0.7	0.00
Hyalomma	1427	0.2	0.00
Amblyomma	1427	0.4	0.00
Otobias	1427	0.5	0.00

The results of the current study revealed that there were four hard (ixodidae) and one soft (argasidae) tick families in the four agro-ecological zones of Lesotho in all age groups. The ticks' genera that were detected were Ixodidae (Rhipicephalus, Boophilus, Amblyomma, Hyalomma) and Agarasidae (Otobius).

The results of the present study were in agreement with previous study done by Diseko (2018) in Lesotho where ixodidae ticks genera which were identified were Rhipicephalus, Hyalomma and one Argasidae tick (Otobius megnini). The difference between the two studies is that Amblyomma and Boophilus were now observed in the present study and that might be due the fact that the two studies were done in different areas of the country and different seasons.

Yakhchali *et al*. (2011) reported that the occurrence of tick infestation in sheep in north of Iran was 33.19 %. This finding is in close agreement with result of the present study. In a study that was done in four geographical zones of Iran, Rahbari *et al*. (2007) reported 55% of ticks' occurrence in sheep. However, the obtained percentage from the current study is low compared to that obtained in a study that was done in Eastern Ethiopia by Mohammed *et al*. (2015) where 79.7% tick infestation was found.

The higher prevalence of Rhipicephalus genus obtained in the present study corresponds with the previously conducted study in Turkey which demonstrated that Rhipicephalus was dominating other genera (Koc *et al*., 2015). Telmadarraiy *et al*. (2004, 2010) also revealed Rhipicephalus genera as most dominant tick. The results of the current study are in disagreement with those reported by Bukbuk *et al.* (2016) who found that Boophilus was more prevalent.

Even though Hyalomma prevalence was found to be low in the present study its presence is the threat as it transmits vector borne diseases. Low prevalence of Hyalomma reported in the present study is in disagreement with previous studies conducted in other countries as Hyalomma was found to be the most dominant tick in the study area done by Moshaverinia *et al*. (2012) and Telmadarraiy *et al*. (2004). It is possible that difference in occurrence time, area, altitude and climatic changes might be factors bringing difference in results of the present study and previously conducted studies. The Hyalomma tick genus species was reported by Maltezou *et al*. (2010) as the main vector for Crimean-Congo Hemorrhagic Fever (CCHF) in southern Europe. Hyalomma genera availability in Lesotho raises awareness that (CCHF) disease might be a problem if not controlled.

4.6.2 Effect of agro-ecological zone on the prevalence of ticks' genera

Hyalomma and Amblyomma genera were having very low prevalence so much that they were unable to be analysed by GEE. The results of this study as illustrated in Table 5 indicated Rhiphicephalus, Boophilus, and Otobius genera prevalence in sheep and on how the agro-ecological zone affected the prevalence of ticks' genera.

The Rhipicephalus prevalence was higher in the Foothills (48%) compared to Senqu River Valley (34%), Lowlands (41%) and Highlands (6%) agro-ecological zones.. The chances of increase in Rhipicephalus prevalence from the Highlands to Senqu River Valley was 0.03 times and then to Lowlands was 0.01 and the increase was found to be significant ($p<0.05$). The results give a clear picture that the chances are higher ($p<0.05$) for the sheep reared in the Foothills to get tick infestation compared to those kept in the Mountains and Lowlands.

Table 5: Prevalence of ticks' genera by agro-ecological zones

AEZ	No.examined	Prevalence (%)	SE	Exp(B) %
	Rhipicephalus			
Senqu	312	34[a]	0.24	0.01
Lowlands	379	41[b]	0.36	0.01
Foothills	415	48c	0.23	0.01
Mountains	321	6[d]	0.04	1
	Boophilus			
Senqu	312	1[a]	0.01	0.00
Lowland	379	1[a]	0.01	0.00
Foothills	415	1[a]	0.00	0.00
Mountains	321	0[b]	0.00	1
	Otobius			
Senqu	312	1[a]	0.00	0.00
Lowlands	379	1[a]	0.00	0.00
Foothills	415	0[b]	0.00	0.00
Mountains	321	0[b]	0.00	1

Values within rows followed by different letters (a, b, c, d) are significantly different ($p<0.05$). AEZ= Agro-ecological Zone Exp. (B)= Exponential Beta. SE= Standard Error. NO=Number

In the present study, the higher ticks' prevalence in the Foothills and Lowlands is in line with previous study whereby the significantly ($p < 0.05$) higher prevalence of ixodid tick infestations was in the midland (23.1%) and lowland (17.1%) zones than in the highland (2.1%) agro-ecological zone. The similarity might most probably be attributable to higher temperatures and relative humidity and prolonged sunlight in the midland and lowland zones that favour the survival and reproduction of these ticks, as has been suggested by Pegram *et al*. (1981) and Kumsa *et al*. (2012). In the current study Rhipicephalus had high prevalence in all agro-ecological zones. This shows that Lesotho seemingly provides an ideal environment for Rhipicephalus which prefers high altitudes with certain amount of relative humidity. The distribution of ticks within a specific habitat depends on several environmental and climatic factors such as annual rainfall, atmospheric temperature and relative humidity (RH), vegetation cover, altitude and host availability. Previously contacted survey had indicated that most of farmers practice mixed farming of different species of animals thus providing host availability. This study was carried out in the middle of wet summer season, when RH as well as the vegetation coverage were high, and therefore the abundance of adult ticks on sheep, are expected to be at their peak in Lesotho.

The findings from the current study tally with the work of Walker (1974) who indicated that hard tick three host genera (Rhipicephalus) survived in dry agro-ecological zones. The results of the current study might be like this as the three host genera was highest in dry and lowland agro-ecological zone (Mafeteng district), because the place is located in a lower altitude zone with limited rainfall and warmer summer and autumn conditions which become favorable to the survival of most argasid and ixodid. It is most probably attributable to the higher temperatures and relative humidity as well as prolonged sunlight in the Foothills and Lowlands agro-ecological zones that favour the survival and reproduction of these ticks (Pegram *et al.* (1981); Kumsa *et al*., (2012); Serste andWossene, (2007). Contrary to the results of this study, Hamito (2010) reported that in sub humid areas the period of highest tick activity is the wet season and only few ticks are found on animals during the dry season.

In the current study, the results revealed that Rhipicephalus was the dominating tick genus in all the agro-ecological zones of Lesotho. These results are similar to previous study done in Turkey that was conducted in various domestic animals, including sheep (Koc *et al*., 2015). The present study is also in agreement with previous report which indicated that Rhipicephalusgenus was mainly found in central Greece, in Fokida and the island of Cephalonia (Psaroulaki *et al.,* 2003; Psaroulaki *et al.,* 2006). Again Rhipicephalus genus prevailed highly in sheep in a study that was conducted in Sicily, with the only other genus being Hyalomma (Torina *et al*., 2006). Furthermore, this genus was previously reported on sheep from northern Sudan (Hoogstraal, 1956) and from Khartoum Province in central Sudan (Latif and Paine, 1987). Jongejan *et al*. (1987) also indicated that different species of the Rhipicephalus group may inhabit different ecological zones in Sudan.

In terms of Boophilus prevalence the results of this studyshowed1% of tick infestation in sheep located in all agro-ecological zones except in the mountains. Boophilus is associated with lowland rainforest and secondary grassland, with a clear increase in the vegetation cover after July-August (Lorusso *et al*., 2013).

There is a possibility that 2% of Otobius in the current study in sheep might be taken from other animal species by chance. The survey results obtained in this study as shown in Table 5 indicated that most of farmers were rearing merino sheep with other different animal species which might be the favorite condition for Otobius to be transmitted from one species to the other. This is in agreement with the findings which stipulated that the larval and nymphal stages of Otobius megnini are most often parasites in the ears of dogs, sheep, horses and cattle, but are sometimes found in goats, pigs, cats, ostriches and man, and also in rabbits, deer and other wild animals in America and Africa (Soulsby, 1968).

In general, the results of the present study indicate the widespread occurrence of ticks in sheep in the study areas. The findings are in line with previous studies which reported high prevalence of ectoparasites in small ruminants from Ethopia (Mulugeta 2008; Sertste and Wossene 2007a; Teshome 2002) and other countries of the world (Mohammed and Ali 2006; Rahbari, Nabian and Bahohar 2009). These findingsare most probably attributable to several important factors including conducive environment, malnutrition, poor husbandry systems, poor awareness of farmers and inadequate veterinary services (Mekonnen, Hussein and Bedane 2001; Mekonnen *et al*. 2007; Pegram, Hoogstral and Wassef 1981).

4.6.3 Effect of sheep age on tick genera prevalence

The results of current study as shown in Table 6 indicate the effect of age in ticks' infestation of sheep. In a total of 686 sheep that were examined, 469 (40%) were infested with ticks. The infestation rate for most of tick genera was high in lambs with Rhipicephalus being the most prevalent when compared to other genera. The exponential beta (B) values indicate that the chances of increase in Rhipicephalus prevalence from adult sheep to middle aged sheep and lambs is 1.01 and 0.99 times respectively in exponential logits numbers. The increase was found to be significant ($p<0.05$).

Table 6: Prevalence of Rhiphicephalus, Boophilus, Amblyomma, Hyalomma and Otobius by sheep age.

sheep age	No. examined	Prevalence (%)	SE	Exp (B) %
	Rhipicephalus			
Lamb	473	32[a]	0.02	0.99
Juvenile	494	32[a]	0.02	1.01
Adult	460	32[a]	0.02	1
	Boophilus			
Lamb	473	1[a]	0.00	0.97
Juvenile	494	1[a]	0.00	0.74
Adult	460	1[a]	0.00	1
	Otobius			
Lamb	473	0[a]	0.01	0.16
Juvenile	494	0[a]	0.00	1.04
Adult	460	1[a]	0.00	1

Values within rows followed by different letters (a, b) are significantly different ($p<0.05$). (B)= Exponential Beta. NO=Number

These results give a clear picture that tick prevalence decreases with increase in age. The results of this study tally with the findings of Rashid *et al.* (2018) who indicated the lower rate of tick infestations in adult sheep which could be attributed to acquired resistance incidental to repeated exposure of host to low grade field infestations during the prolonged growth and development period (Rashid *et al.*, 2018). In addition, the same authors highlighted that young animals had soft light skin with soft hair cover, that might also be the cause of high prevalent as compared to other age groups. Some researchers emphasised that the attachment of ticks among other factors is dependent on the temperature and the thickness of the skin of the animal (Tukahirwa, 1976; Feldman and Borut, 1983; James-Rugu, 1998; Opasina *et al*., 1983). Again the reason for high prevalence in lambs might be reinfection by dam during suckling.

4.7 TICK ABUNDANCE ON SHEEP BODY

4.7.1 Overall ticks counted and collected from sheep body

The results as indicated in Table 7 illustrate that from the total of 2072 ticks that were counted and collected from different sheep age groups, Rhiphicephalus had highest number of ticks (1932) while Amblyomma registered the lowest (7) number of ticks. Most of ticks were collected from the Juveniles (723) and the least from the lambs (554).

Table 7: Tick counts in abundance on sheep body in different age groups

Sheep age	Rhipicephalus	Boophilus	Amblyomma	Hyalomma	Otobias	Total
Adult	665	15	5	7	22	714
Juveniles	723	27	0	51	3	804
Young	544	7	2	0	1	554
Total	1932	49	7	58	26	2072

The overall tick abundance mean of ticks on sheep body was 1.41 as reflected in Table 8. The Rhipicephalus infestation was higher in sheep compared to other tick genera. Ticks were highly loaded under tail: around anus with range of 1 to 26 Rhiphicephalus ticks.

Table 8: Overall Tick genera abundance mean on sheep body in different tick genera

Ticks Genera	No. of sheep Examined Tick	Abundance mean (ranges)	Standard Error
Rhipicephalus	1427	1.34 (1-26 ticks)	0.02
Boophilus	1427	0.03 1-7 ticks)	0.02
Hyalomma	1427	0.01 (1-2 ticks)	0.00
Amblyomma	1427	0.00 (1-2 ticks)	0.00
Otobias	1427	0.02 (1-7 ticks)	0.01

The results of the current study do not tally with the findings of Andersson *et al*. (2018) who reported 16.5 in endemic natural areas as higher mean tick abundance. This is suggesting that the abundance of ticks affecting sheep is lower in Lesotho and does not warrant the use of drugs hence farmers can engage on manually killing the ticks whenever they observe in their animals. This can go along with daily hygienic management practices.

4.6.2: Effect of agro-ecological zone on tick abundance on sheep body

The results of the current study reveal the abundance of Rhipicephalus was significantly ($P<0.05$) lower (0.01) in the mountains than in other agro-ecological zones (Table 9). The chances of increase in Rhipicephalus abundance on sheep body moving from the Highlands to Foothills was 40.16 times while to the Lowlands and Senqu River Valley was 43.29 40,43 respectively. The increase was found to be significant ($p<0.05$). The chances of Boophilus and Otobius genus abundance increase or decrease on sheep body moving from one agro-ecological zone to another was not significant ($p>0.05$).

Table 9: Tick abundance means on animal body by agro-ecological zone

AEZ	No. examined	Mean	SE	Exp(B) %
	Rhipicephalus			
Senqu	312	1.69[a]	0.02	40.43
Lowlands	456	1.80[a]	0.13	43.29
Foothills	338	1.67[a]	0.16	40.16
Mountains	321	0.01[b]	0.00	1
	Boophilus			
Senqu	312	0.03[a]	0.01	5.41
Lowlands	456	0.07[a]	0.04	1.53
Foothills	338	0.01[a]	0.01	2.45
Mountains	321	0.00[a]	0.00	1
	Otobius			
Senqu	312	0.03[a]	0.02	1.28
Lowlands	456	0.04[a]	0.01	1.65
Foothills	338	0.00[a]	0.00	1.01
Mountains	321	0.00[a]	0.00	1

Values within rows followed by different letters (a, b) are significantly different (p<0.05). (B)= Exponential Beta. AEZ = Agro-ecological Zone. SE= Standard Error. NO=Number

The results of the current study are in accordance with the findings of Lorusso *et al*. (2013) and Bala *et al., (2018)* who explained that Rhipicephalus is more adapted to sheep and goats, and this might explain the high amount of that genus specimen collected in the study on sheep body. Prevalence of ticks in hot and humid season favors the propagation and multiplication of ticks (Soulsby, 1982). The variation in tick prevalence in different areas can be attributed to a variety of factors like geo-climatic conditions, association and life style of different species of animals, awareness/education of the farmers and farm management practices (Khan *et al*., 1993; Bell-SakyI *et al*., 2004).

The high or low prevalence in different tick genera might occur as some studies indicated that there might be difference due to climatic conditions and temperature variation (Alekaw., 2000; Walelign., 2016).

Ecological zones had difference in tick prevalence as Wallaga (1997), Abunna *et al*. (2009), Abera *et al*. (2010) and Bekele *et al*. (2011) had reported the infestation of sheep by different tick genera of ixodid ticks in different parts of Ethiopia. Pegram *et al*. (1981) and Kumsa *et al*. (2012) reported higher prevalence of ixodid tick infestations in the midland, moderate in lowland zones and very low in highland agro-ecological zone. High prevalence is attributable to higher temperatures and relative humidity and prolonged sunlight in the midland and lowland zones that favour the survival and reproduction of these ticks, as has been suggested by Pegram *et al*. (1981) and Kumsa *et al*. (2012). The distribution of ticks within a specific habitat depends on several environmental and climatic factors such as annual rainfall, atmospheric temperature and relative humidity (RH), vegetation cover, altitude and host availability.

Walker (1974) report had indicated that hard tick three host genera (Hyalomma and Rhipicephalus) survived in dry agro-ecological zones. In contrary to the statement of above report, Hamito (2010) reported that in sub humid areas the period of highest tick activity is the wet season and only few ticks are found on animals during the dry season that agreed with the study conducted in Turkey in various domestic animals, including sheep (Koc *et al*., 2015).

One tick genera can be distributed over many areas as had been previously reported that Rhipicephalus genus was mainly found in central Greece, in Fokida and the island of Cephalonia (Psaroulaki *et al.,* 2003; Psaroulaki *et al.,* 2006). Again Rhipicephalus genus prevailed highly in sheep in a study that was conducted in Sicily, with the only other genus being Hyalomma (Torina *et al*., 2006). Furthermore, that genus was previously reported on sheep from northern Sudan (Hoogstraal, 1956) and from Khartoum Province in central Sudan (Latif and Paine, 1987). Jongejan *et al*. (1987) also indicated that different species of the Rhipicephalus group may inhabit different ecological zones in Sudan. So most of hard ticks had high prevalence and study conducted by OSIS (2019) observed a significantly ($p<0.05$) higher prevalence of ixodid tick infestations. It is most probably attributable to the higher temperatures and relative humidity as well as prolonged sunlight in the foothills and lowlands agro-ecological zones that favour the survival and reproduction of these ticks (Pegram *et al.,* 1981); Kumsa *et al*., 2012); Serste and Wossene, 2007). Furthermore, Jongejan *et al*. (1987) indicated that different species of the Rhipicephalus group may inhabit different ecological zones.

Hyalomma genera were not present in a high percentage in northern Greece compared to their percentage in the prefectures of Achaia and Chania (Wall and Shearer, 2001). The reason of variation in Hyalomma prevalence might be that Hyalomma can survive exceptionally in cold and dry (Urquhart *et al*., 1996; Chanie *et al*., 2010; Mekonnen, 2001). Walker (1974) also stated that the hard tick three-host ticks survive well in dry agro-ecological zones for instance Amblyomma species. This might be because of warm weather in those areas. Boophilus is associated with lowland rainforest and secondary grassland, with a clear increase in the vegetation cover (Lorusso *et al.*, 2013).

The tick wide distribution might be probably attributable to several important factors including conducive environment, malnutrition and poor husbandry systems, poor awareness of farmers and inadequate veterinary services in study areas (Mekonnen, Hussein and Bedane 2001; Mekonnen *et al*. 2007; Pegram, Hoogstral andWassef 1981).

4.6.3: Effect of sheep age on tick abundance on sheep body

The results of the present study indicated that Rhipicephalus was less abundant on sheep body predilection site significantly in lambs. Chances of increase in Rhipicephalus prevalence from the adults to Juveniles was 1.00 times, to lambs was 0.80 and the increase was found to be significant ($p<0.05$). Boophilus genus abundance on sheep body was not increasing significantly ($p>0.05$). Otobius mean was low for all sheep age groups as indicated in Table 10.

Table 10: Tick abundance means by sheep age

sheep age	No. examined	Mean	SE	Exp(B) %
	Rhipicephalus			
Lambs	473	1.15[a]	0.15	0.80
Juveniles	494	1.46[b]	0.46	1.00
Adults	460	1.42[ab]	0.42	1
	Boophilus			
Lambs	473	0.01[a]	0.01	0.02
Juveniles	494	0.05[a]	0.04	2.29
Adults	460	0.02[a]	0.02	1
	Otobius			
Lambs	473	0.00[a]	0.05	0.04
Juveniles	494	0.01[ab]	0.14	0.13
Adults	460	0.05[b]	0.05	1

Values within rows followed by different letters (a, b) are significantly different ($p<0.05$). (EXP)= Exponential Beta. RV = River Valley. SE= Standard Error. NO=Number.

The findings of the present study are in disagreement with previous reports which found the adult animals heavily infested followed by lambs and Juveniles (Yacob *et al*. 2008 and Yakhchali and Hosseine 2006).

Mohr (1961) also indicated that size of host determine infestation of ticks loads. In addition, Latif (2004) reported that the young animals have low tick concentration than old animals hence host characteristics determine concentration, abundance and intensity of tick infestation. The results of the present study suggest that Lesotho weather conditions with high altitude might not favour survival and reproduction of most of tick genera except Rhiphicephalus.

4.6.4 Ticks abundance percentages on different predilection site of sheep body before and after treatment

The findings of the current study indicated that the majority of ticks were found under tail or around anus (88.5%) as compared to those found in the ears (8.3%), udder (3%) and belly (0.2%) as indicated in Table 11. The Exp (B) values indicated that chances of increase in ticks' attachment from belly to udder was 0.264 times in exponential logits numbers then by 0.316 times to ear and lastly by 0.316 to under tail (around anus) and the increase was found to be significant ($p<0.05$).

Table 11: Attachment (predilection sites) of ticks on sheep body parts in percentage

Sites	Positive sheep	Percentage	Exp (B)
Under tail	415	88.5^{a}	0.314
Ear	39	8.3^{b}	0.316
Udder	14	3.0^{c}	0.264
Belly	1	0.2^{d}	1

(EXP)= Exponential Beta

The abundance of ticks under the tail observed in the current study is in agreement with previous study which stated that the highest tick aggregation was reported on fat tails of infested sheep (Yakhchali *et al*., 2011). Rasouli *et al*. (2010) also concluded that the highest tick aggregation site was head and tail while axilla and groin were next positions. In addition, Moshaverinia *et al*. (2012) reported that frequency of tick distribution on the body surface of host was mostly under tail (42.66 %).

In disagreement of the findings of current study, Walker *et al.* (2003) indicated that the preferred feeding sites are legs, belly, neck and dewlap but in heavy infestations the tick may be found over the back and shoulders, the reason being that different genera prefer different attachment sites. The results of the current study were again not in accordance with the study conducted by

Rashid *et al* (2018) who reported an ear to be the commonest site for tick infestation in sheep followed by thighs with Rhipicephalus species being the common followed by Hyalomma. Similar results were reported by Asmaa *et al.* (2014) who recorded 87.5% ear infestation in sheep. Irshad *et al.* (2010) also reported 78.5% of tick infestation in the ears, followed by under the tail and inner side of thighs which was also not similar to current study. On the other hand, Tadesse *et al.* (2018) showed that most infested body part was udder-scrotum (32.4%).

Other researcher also found most of the ticks around the ear region than in other parts of the animal body (Opasina *et al*., 1983; Latha *et al*.2004; Bukbuk *et al*., 2016). The difference might be brought by the fact that the ear is a preferable predilection site for Boophilus while for other Rhipicephalus species exist mostly under tail: around anus. The ticks habour under the tail as it is warmer and moist than in other predilection sites for the ticks. The similar sentiments were shared by Irshad *et al*. (2010) who reported that the temperature of the skin covering the body was 35^{0} C while that of the ear was 25^{0} C so most of ticks were found in ear with Riphicephalus species being the most prevalent.

The current findings were in disagreement with earlier reports by Opasina *et al*. (1983), Latha *et al*. (2004).and study conducted by Bukbuk *et al*. (2016) whom found most of the ticks around the ear region than in other parts of the animal body. The difference might be brought by the fact that the ear is a preferable predilection site for Boophilus while for other Rhipicephalus species exist mostly under tail: around anus. Rhipicephalus likes summer so the temperature during the study period was conducive for the ticks to habour under the tail as it is warmer and moist than in other predilection sites for the ticks.

4.8 EFFECT OF IVERMECTIN ON TICK CONTROL

4.8.1 Overall Effectiveness of ivermectin 1% on ticks

The overall prevalence of ticks before and after ivermectin 1% subcutaneous injection is indicated in Table 12. The results stated tha tonly 79 sheep were free from tick infestation after 30 days of treatment. Sheep infested with Otobius were not reduced at all but the ones infested with Amblyomma were totally reduced, meaning that the genus was eradicated.

Table 12: Counts in number of sheep infested before and after ivermectin injection

Tick infestation in sheep	Rhipicephalus	Boophilus	Amblyomma	Hyalomma	Otobius	Overall infected sheep
Total infected Sheep by ticks	459	10	5	13	8	495
Group A	261	6	5	11	4	287
Group B	198	4	0	2	4	208

Group A= before treatment number of sheep infested with ticks. Group B = after treatment number of sheep infested with sheep.

The findings of current study indicated that the therapeutic efficacy of ivermectin was effective against Amblyomma but ineffective against most of genera after 30 of injection. The findings of the current study are not in line with previous studies conducted by Ahamme *et al*. (2016) and Soundararajanl *et al*. (2003) against Otobius tick genera who found thatthe effectiveness of ivermectin was 100%. In a study that was conducted in large ruminants Ahammed *et al*. (2016) also found 100% ivermection efficacy on Rhiphicephalus. The variation between the findings of this study and the previous ones might be due to previous abuse of drugs by sheep owners in Lesotho since the survey results had shown that farmers were of low level of education and few were attending trainings, the problem might be that of introducing small quantities of drugs to sheep which might had led to tick resistance to ivermectin. Recommended dosages are 0.02ml/kg to 1ml/50kg body weight (200µg/kg body weight). (Ahamme *et al*, 2016)

4.8.2 Overall efficacy of ivermectin 1% on tick abundance

Overall efficacy of ivermectin on tick abundance on sheep body in Lesotho was 28% as shown in Table 13. There was a slight significant ($p \leq 0.05$) decrease in tick abundance on sheep body. The mean abundance of ticks was 1.65 before sheep were injected with ivermectin and after treatment it was reduced to an average of 0.83.

Table 13: Tick abundance reduction by ivermectin 1% injection on sheep body

No. of sheep examined	No.of sheep infected	Day 0 Ave. Tick mean	Day 30 Ave. tick mean	Tick Reduction%	Significant Value
1427	495	1.65	0.83	28	0.000

The efficacy of ivermectin on tick abundance reduction on sheep body was low compared to manufacture standard of 100% efficacy and the results were not in line with Ahammed *et al*. (2016) report which followed expected output of the drug. Some studies had agreement that lvermetin, a macrocyclic lactone produced by Streptomyces avermitilis, is highly effective against endoparasites and ectoparasites of cattle, sheep, goats and swine (Amaral *et al*., 1983 and Benz *et al*., 1989). In a study that was conducted by Soundararajanl *et al*. (2003) there was a total tick eradication after 35 days of treatment. The disagreement in findings of present and previous studies might be due to tick resistance build up caused by poor drug administration by farmers of Lesotho as proved by survey results that farmers are not eager to use extension service in their areas on animal health issues. This could also be the result of reinfection as sheep treated were allowed to graze in the rangelands with flocks that were not injected because of communal grazing practiced in Lesotho. This is confirmed by Mahmoud *et al*. (2018) who indicated that 90% of adult Amblyomma are picked up daily by grazing animals and therefore re-infection might also be major factor leading to low ivermectin efficacy.

Similar to the findings of the current study, some reports had revealed that in several countries Rhipicephalus resistance to most acaricides has been confirmed, which represents a worldwide drawback for successful tick control (Martins and Furlong, 2001; Klafke *et al*., 2006; Dos Santos *et al*., 2009; Castro-Janer *et al*., 2010). The selection of pesticide resistance in arthropod populations is one of the main obstacles to the chemical control of important vector species (Rosario-Cruz *et al*., 2009). During the last 20 years, almost one century after the first report of arthropod resistance (Melander, 1914), an increase in new cases of resistance has been reported for various parasite species (FAO, 2004). Due to above findings ticks of Lesotho might also had built resistance to commonly used ivermectin as the survey had shown that farmers had access to buy them freely in local and international shops without assistance of animal health specialist.

In the current study subcutaneous injection was not that effective for Rhipicephalus which is in disagreement with other studies. According to Mahmoud *et al*., (2018) previous studies had shown that subcutaneous (S/C) injection is a more efficient route for this drug in terms of drug bioavailability, efficacy, and persistency compared to other routes of administration (Gokbulut *et al.*, 2007). This little response might be that the sheep were used to ivermectin as according to survey results conducted prior to this study had indicated that most farmers were using drugs to control ecto-parasites including ticks.

In support of the results of this study, tick resistance to IVM have been reported in Brazil since 2001 (Martins and Furlong, 2001; Klafke *et al*., 2006) and, more recently, in Mexico (Perez-Cogollo *et al*., 2010) and Uruguay (Castro-Janer *et al*., 2011). So after above discussion it is not surprising with low efficacy of ivermectin to tick genera available in Lesotho as currently reported.

4.8.3 Efficacy of ivermectin on Rhipicephalus abundance in different agro-ecological zones

The results on how ticks on sheep body were reduced by ivermectin 1% subcutaneous injection in four agro-ecological zones are summarized in Table 15. The mean abundance of ticks on sheep body for Rhipicephalus per agro-ecological zones before treatment day 0) were 2.34, 2.35, 1.89 and in 1.28 at Senqu River Valley, Lowlands, Foothills and Highlands respectfully. After the animals were injected with ivermectin the means were reduced to 1.49, 1.28, 0.56 and 0.00 for the sheep in the Senqu River Valley, Foothills, Lowlands and Mountains respectfully as indicated in Table 14. The likelihood of increase in reduction of Rhipicephalus prevalence due to ivemectin 1% injection was significant ($p<0.05$) as shown by different superscripts in all agro-ecological zones. The reduction percentages on tick abundance were as follows: Senqu River Valley (36%), Lowlands (46%), Foothills (70%) and Highlands (100%).

Table 14: Tick abundance reduction on sheep body by Agro-ecological Zones

Category	NO. Examined	Day 0 Tick abundance	Day 30 Tick Abundance	Reduction %	Standard deviation
Senqu	225	2.34[a]	1.49[a]	36	0.02
Lowlands	231	2.35[b]	1.28[b]	46	0.02
Foothills	231	1.89[c]	0.56[c]	70	0.01
Highlands	231	0.02[d]	0.00[d]	100	0.02

a. Rhipicephalus post-treatment < Rhiphicehalus pre-treatment

b. Rhipicephalus post-treatment > Rhipicephalus p post-treatment retest

c. Rhipicephalus post-treatment = Rhipicephalus post-treatment

d. Rhipicephalus post-treatment = Rhipicephalus post-treatment

The results of this study as shown in Table 15 indicate that out of 225, 231, respectively in the Foothills the number of ticks remained constant in 139 sheep even after the animals were injected with ivermectin. This indicates high resistance of Rhpicephalus to iveremectin. The findings of this study are in agreement with the survey that was conducted as part of the study which stipulated that farmers' awareness on tick availability in their area was very low. So farmers were aware of other ecto-parasites and they were using ivermectin to treat them being unaware that the poor administration of drugs dosages might build resistance to other parasites like ticks.

Table 15: Wilcoxon Signed Rank Tables for Rhiphicephalus reduction in sheep agro-ecological zones

category	SRV	Lowlands	Foothills	Highlands
Negative Ranks	73[a]	73[a]	77[a]	73[a]
Positive Ranks	27[b]	27[b]	15[b]	27[b]
Ties	125[c]	131[c]	139[c]	131[c]
Total	225	231	231	231

a. Rhiphicephalus post-treatment < Rhiphicephalus pre-treatment

b. Rhiphicephalus post-treatment > Rhiphicephalus p post-treatment retest

c. Rhiphicephalus post-treatment = Rhiphicephalus post-treatment

The ivermectin 1% efficacy was high to Rhipicephalus on sheep living in the Mountains and Foothills (100% and 70%) as compared to other agro-ecological zones. These results are in agreement with previous study which stated that Ivermectin generally reduced ticks by 78% within two days, and by 98% two weeks after treatment (Crump and Ōmura., 2011). The highest tick (Rhipicephalus) abundance tick mean number on sheep body was 4.59 before ivermectin injection in the Lowlands; it had been reduced to 4.10 after treatment, which is lower than that was reported by Ahmed *et al*. (2005). Low reduction of ticks after treatment in other agro-ecological zones might be that their grazing land were having high abundance of tick number, so animals were re-infected during grazing or might be because of tick resistance to drug. In Leribe district farmers were totally unaware that their sheep flock had ticks during survey study conducted as baseline.

4.6.4 Response of tick infestation to ivermectin 1% in different age groups of sheep

This study evaluated the effectiveness of the macrocytic lactone drug, ivermectin, administered via subcutaneous injection against ticks' infestation on different sheep age groups. The results on how this genus of economic importance responded to ivermectin subcutaneous injection in different ages of sheep are illustrated in Table 16.

The mean loads for Rhipicephalus per age group at day 0 were 1.55, 1.74 and 1.21 which were reduced to 1.29, 1.15, and 1.04 in young, juveniles and adults after ivermectin injection respectively (Table 17). The likelihood of increase in reduction of Rhipicephalus abundance due to ivemectin injection was significant ($p<0.05$) with the following reduction percentages: lambs (16.77%), Juveniles (33.91%) and Adults (1.02%).

Table 16: Tick load reduction for ivermectin (1%) in different age groups

Age	NO. examined	Day 0 Tick abundance	Day 30 Tick Abundance	Reduction %	Standard Deviation	Significant Value
Adult	226	1.55[a]	1.29 [a]	16.77	0.02	0.09
Juvenile	241	1.74[b]	1.15 [b]	33.91	0.02	0.02
Young	233	1.21[c]	1.04 [c]	1.02	0.01	0.36

a. Rhipicephalus post-treatment < Rhipicephalus pre-treatment

b. Rhiphicephalus post-treatment > Rhipicephalus p post-treatment retest

c. Rhipicephalus post-treatment = Rhipicephalus post-treatment

Wilcoxon signed ranks Table showed abundance reduction among sheep age groups (Table 16). There was a little ivermectin efficacy in each of sheep age groups with low reduction (1.01) of tick abundance in lambs compared to adult (16.77) and Juveniles (33.91). The results indicate that 48% of lambs were not affected by treatment because out of 233 lambs, only 111 lambs were treated. Ticks on Juvenile sheep were mostly reduced by ivermectin as compared to other age groups.

Table 17: Wilcoxon signed ranks Table for Rhipicephalus in different age groups

Category	Lambs	Juveniles	Adult
Negative ranks	61[a]	85[a]	66[a]
Positive ranks	61[a]	57[b]	53[a]
Ties	111[c]	99[c]	107[c]
Total	233	241	226

a. Rhipicephalus post-treatment < Rhipicephalus pre-treatment

b. Rhipicephalus post-treatment > Rhipicephalus p post-treatment retest

c. Rhipicephalus post-treatment = Rhipicephalus post-treatment

The finding of current study showed low reduction percentages for efficacy of ivermectin injection especially in young ones. The juveniles had higher tick reduction percentages than the rest of other groups. This is in line with the study conducted by Soundararajanl *et al*. (2003) who reported 100% efficacy in hoggets treated with ivermectin. The results of the current study which showed that Rhipicephalus had not been eradicated in all sheep age groups are in agreement with some reports from other parts of the world which reported that although overall levels of control with avermectin (ivermectin) compounds were high, the levels of control during the first few days after treatment were relatively low (Nolan *et al*., 1981; Cramer *et al*., 1988; Bridi *et al*., 1992; Kumar *et al*., 1992; AFPMB., 1998; Cramer *et al*. 1988.). In agreement with the findings. of current study, Jongejan (1994) and Uilenburg (2004) indicated that effective and complete tick eradication has not yet been completely successful, with an exception to the first complete eradication of Boophilus species. The results of current study of low tick reduction in young sheep might be low immunity of lambs as might be their first time of infestation so their immunity had not well developed against tick infestation.

CHAPTER 5

5.0 CONCLUSION AND RECOMMENTATION

5.1 CONCLUSION

Based on the findings of current study it is concluded that:

- The level of farmers' awareness on tick infestation is low.
- High proportion of farmers are middle aged males with lower education level.
- Reluctance of farmers to use extension service is the main cause of lack of knowledge which influence the manner in which they administer the drugs against parasites including ticks and these could lead to parasites being resistant to drugs.
- Agro-ecological zones and age of an animal have effect on the prevalence and abundance of ticks.
- Rhipicephalus prevalence and concentration was higher than other tick genera identified with highest infestation in the Lowlands and the prevalence was higher in juvenile sheep.
- Most infested predilection site with ticks was found to be under tail-around anus.

5.2 RECOMMENTATIONS

- Extension service needs to apply more effort in training farmers on proper ivermectin administration to avoid resistance of ticks to drug.
- Farmers should be encouraged to practice the biosecurity measures as a way of controlling ticks.
- Current study was just based on tick genera so there is a need for a study aimed at identifying ticks down to species level for its effective control.

REFERENCES

Abbott W. S.1925. A method for computing effectiveness of an insecticide. *J. Econ. Entomol.*18: 265–267.

Abera, M., Mohammed, T., Abebe, R., Aragaw, K. and Bekele, J., 2010, 'Survey of ixodid ticks in domestic ruminants in Bedelle district, southwestern Ethiopia', Tropical Animal Health and Production 42, 1677–1683.

Abunna, F., Kasasa, D., Shelima, B., Megersa, B., Regassa, A. and Amenu, K., 2009, 'Survey of tick infestation in small ruminants of Miesso district, west Harergie, Oromia region, Ethiopia', Tropical Animal Health and Production 41, 969–972. http://dx.doi.org/10.1007/s11250-008-9286-3, PMid:19082757.

AFPMB., 1998. Tick –Borne Diseases: vector surveillance and control. United States Armed Forces Pest Management Board Naval Technical Guide Number 26; U.S.A, Pp. 45.

Ahammed, M. Ali, Ehsan,M. Mostafa. Bang. 2016. Efficacy of Evermectin against Gastrointestinal Nematodiasis and Ectoparasites in Crossbred Cattle in Bangladesh.. Journal of Veterinary Medicine : 191-197

Ajala MK. 2004. Household decision-making in the production of small ruminants in Giwa Local Government Area of Kaduna State of Nigeria. In: Proceedings of the 29th Annual Conference of the Nigerian Society of Animal Production, 21st – 25th March, 2004. Sokoto, Nigeria. pp. 399-402.

Alekaw, S. 2000. Distribution of ticks and tick borne diseases at Metekel ranch. *Ethiopian Journal of Ethiopian Veterinary Association* 4: 40 - 60.

Amaral, N.K., Benitz - Usher, C., Cramer, L.G. and Bridi, A.A. 1983. proceedings of the MSD AGVET Symposium XXll. *World Veterinary Congress*, pp. 199.

Anitha A, Rao S, Rao J, Ravi A. 2013. Analysis of Sheep Production Systems.*Journal. Of Agricultural.Science.and Vet. Medicine*.VOL. 1, NO.3. PP.132

Ayalew, T., B. Duguma, and T. Tolemariam, 2013.Socio-economic and farm characteristics of smallholder cattle producers in Ilu Aba zone of Oromia regional state, South Western Ethiopia. Global Veterinaria, 10(5): 607-613

Bala,A. Abkar, A. Mohammed,s. , Bukhari,S. Sidig, E. 2018. Eisa5Estimation of hard Ticks prevalence among sheep and goats in Sennar state, Sudan. Volume 3; Issue 3; Page No. 19-23.

Bekele, J., Tariku, M. and Abebe, R., 2011, 'External parasites infestation in small ruminants in Wolmera district of Oromia region, central Ethiopia', Journal of Animal and VeterinaryAdvances 10, 518–532.

Bell-SakyI, L.N., Koney, E.B.M., Dogbey, O. and Walker, A.R. 2004. Incidence and prevalence of tick-borne haemoparasites in domestic ruminants in Ghana. *Journal of Veterinary Parasitology* 124: 25 - 42.

Bembridge T.J. 1989. Aspects of small production in Ciskei. South Africa .*Journal Animal Science* 19:1-3.

Ben S.H, Smith T. 2008. Feeding strategies to increase small ruminant production in dry environments. *Small Rum. Res*. 77:174-194.

Benz G.W., Roncalli R.A., Gross S.J. 1989. Use of Ivermectin in Cattle, Sheep, Goats, and Swine. In: Campbell W.C. Ivermectin and Abamectin. Springer, New York, NY.Journal of vet parasitology: 4612-3626-9_15

Bowman, A.S., Dillwith, J.W., Sauer, J.R. 1996.Tick salivary prostaglands; presence, origin and significance.Parasitol. Today, 12(10): 388 – 395.

Braker MJE, Udo HMJ, Webb EC. 2002. Impact of intervention objectives in goat production within subsistence farming systems in South Africa. *South Afr. J. Anim. Sci*. 32:185-191.

Bureau of Statistics (BOS).2011. Report on Family Farming Knowledge Platform by officials Maseru.

Carruthers, G., and Vanclay, F. 2007. Enhancing the social content of Environmental Management Systems in Australian agriculture.*International Journal of Agricultural ResourcesGovernance and Ecology*, 6(3), 326-340.

Cauley, M., 1986. Benchmark soils of Lesotho: their classification, interpretation, use and management. Office of Soil Survey, Soil Conservation Division Ministry of Agriculture: Maseru.

Chanie, M., Negash, T. andSirak, A., 2010, 'Ectoparasites are the major causes of various types of skin lesionos in small ruminants in Ethiopia', Tropical Animal Health and Production 42, 1103–1109.

Clark, R., and Timms, J. (2001).Achieving and Enabling Continuous Improvement and Innovation, the Better Practices Process, Brisbane: QueenslandDepartment of Primary Industries. Tehran provinces, Iran, Tropical Animal Health and Production 41, 397–401

Cole, H.E., 1986, Veterinary clinical pathology, 4th edn., W.B. Saunders Company, Philadelphia.

Costales A, Delgado C, Catelo MA, Lapar ML, Tiongco M, Ehui S and Bautista AZ. 2007. Supporting smallholder pig farmers in the Philippines. id2 1 natural resource highlights 5: Agriculture.Institute of Development Studies, Brighton, UK.

Cramer L. G. Carvalho L.A.F. Bridi A. A. Amaral N. K. Barrick R. A.1988. Efficacy of topically applied ivermectin against *Boophilusmicroplus* (Canestrini, 1887) in cattle. *Vet. Parasitol.* 29: 341–349.

CSA, 2008, Ethiopian agricultural sample survey report on livestock and livestock characteristics, vol II, 2007/08, Addis Ababa, Ethiopia.

Dantankwa, A. and K. Asafu-Adjei, 2001.Policies for improving the competitiveness of smallholder livestock producers in Ghana challenges and opportunities. Ghana.

Dautel, H. and Kahl, O. 1999. Ticks (acari: ixodoidea) and their medical importance in the urban environment.*In Proceedings of the Third International Conference on Urban Pests*: 19 - 22 July 1999, Czech Republic: 73 - 82).

Davey, R. Miller, J. George, J. Miller R.,2005.. Therapeutic and persistent efficacy of a single injection treatment of ivermectin and moxidectin against Boophilus microplus (Acari: Ixodidae) on infested cattle. Journal of Vet Parasitology. 35(1-2):117-29.

Day, M.J., 2011. One health: the importance of companion animal vector-borne diseases. *Journal ofParasites Vectors* 4: 49.

Dercon S, Krishman S. 1996. Income portfolios in rural Ethiopia and Tanzania: Choices and constraints. J. Dev. Stud. 32 (6):850-875.

Department of Agriculture, Forestry and Fisheries (DAFF). 2012. Statistics and Economic Publications and Reports. Available online at: Statistical-Information/Livestock).

Diseko L.J., 2018. Ticks and tick-borne haemoparasites from domestic animals in Lesotho Thesis at North-West University.SA.

Drummond, R.O. 1983. Tick-borne livestock diseases and their vectors. Chemical control of ticks. World Animal Review (FAO) 36: 28 - 33.

Ermias, Y., 2000, 'A Study on ectoparasites of fresh sheep pelts and assessment of pickled skin defects processed at Sebeta Tannery', DVM thesis, Faculty of Veterinary Medicine, Addis Ababa University, Debre Zeit, Ethiopia.

Estrada-Pena, A. 2015.*Ticks as vectors: taxonomy, biology and ecology*. Scientific and Technical Review of the Office International des Epizooties (Paris) 34 (1): 53 - 65.

Estrada-Pena, A. and DE LA Fuente, J. 2014.*The ecology of ticks and epidemiology of tick-borne viral diseases.* Antiviral Research 108: 104 - 128.

Fayemi PO, Muchenje V.2014. Farmers' preference for mutton and lamb from natural veld in the Eastern Cape Province of South Africa. J. Food Agric. Environ. 12(2):15-19.

Feldman BM and S Borut, 1983. Some observations on two East Mediterranean species of Haemaphysalis ticks parasiting domestic stocks. *Journal of Vet Parasitol,* 13: 171-181.

Flannery, R.D., 1977. Erosion phenomenon in Lesotho. Lesotho Agricultural College: Maseru.

Food and Agricultural Organization of United Nations (FAO) 2009. The State of Food and Agriculture.Livestock, Food Security and Poverty Reduction.

Food and Agricultural Organisation of United Nations (FAO). 2010. National Gender Profile of the Agricultural Households, Vietnam.

Gizaw S, Tegegne A, Berhanu G, Hoekstra D. 2010. Sheep and goat production and marketing systems in Ethiopia: Characteristics and strategies for improvement. IPMS (Improving productivity and market success) of Ethiopia farmers Project Working Paper 23. Nairobi J. Anim. Sci. 19:1-3. J. Food Agric. Environ. 12(2):15-19.

.

Hamito, D., 2010. Control of External Parasites in Sheep and Goats. Ethiopia Sheep and Goat Productivity Improvement Program (ESGPIP). *Technical Bulletin* NO. 41. Pp.3.

Hoogstraal, H. 1956. Ticks of the Sudan. United States Naval Medical Unit Number 3

Hillyard, P.D. 1996. In: Barns RSK. Crothers, J.H. ed. *Ticks of north-west Europe.* Shrewsbury, UK: Field Studies Council.

Hillyard, P.D. 1996. In: Barns RSK. Crothers, J.H. ed. Ticks of north-west Europe. Shrewsbury, UK: Field Studies Council.

Hoogstraal, H. 1956. African Ixodoidea. I. Ticks of the Sudan. Bureau of Medicine and Surgery, Department of Navy. Washington: US Govt. Print. Of (USGPO).

Horak, G., Nyangiwe, N., Matos, D. Neves, l. 2009. Species composition and geographic distribution of ticks infesting cattle, goats and dogs in a temperate and in a subtropical region of south-east Africa. *Onderstepoort Journal of Veterinary Research*, 76:263–276

Howden, P., and Vanclay, F. 2000. Mythologization of farming styles in Australian broad acre cropping, *Rural Sociology*, 65(2), 295-310.

Hunt W, Vanclay F, Birch C, Coutts J, Flittner N, and Williams B,2011 RURAL SOCIETY Volume 20, Issue 2.

Hunt, W., Vanclay, F., and Coutts, J. 2008. How Universities can function to fill an emerging knowledge and skills gap in agricultural industries. Paper presented to the Annual conference of Australian Universities Community Engagement Alliance Conference, University of the Sunshine Coast.

Jameel, G.H. et al. 2014. Hematological and histopathological effects of ivermectin in treatment of ovine dermatophytosis in Diyala Province-Iraq. IJSR, vol. 3, pp. 1389–1394.

James-Rugu, N.N. and Iwuala M.O.E., 1998. Studies on the prevalence of factors conditioning Tick infestation of dogs, sheep and goats in Plateau state. West Afri.J.Biol. Sci. 8:70 – 80.

Jongejan,F and Uilenberg.G. 2018. Vectors: Ticks; Infectious Diseases of Livestock. Onderstepoort, Pretoria.

Karimuribo ED, Chenyambuga SW, Makene VW, Mathias S. 2011. *Characteristics and production constraints of rural-based small-scale pig farming in Iringa region*, Tanzania.Livest.Res. Rural Dev. 23(172).

Khan MN, CS Hayat, Z Iqbal, B Hayat and A Nadeem, 1993. Prevalence of ticks on livestock in Faisalabad kl(Pakistan). Pak Vet J, 13: 182-184.

Kuma A. Sharma S. D. Joshi B. P.1992. Therapeutic evaluation of ivermectin and pestoban against common bovine ticks. *Indian Vet. J.* 69: 62–64

Kumsa, B., Tamirat, H., Tadesse, G., Aklilu, N. andCassani, R., 2012, ‘Prevalence and species composition of ixodid ticks infesting horses in three agroecologies in central Oromia, Ethiopia’, Tropical Animal Health and Production 44, 119–124.

Kunene NW, Fossey A. 2006.A survey on livestock production in some traditional areas of Northern KwaZulu-Natal in South Africa.Livest. Res. Rural Dev. 18(113):30-33.

Kusina NT, Kusina J. 1999. Goat productivity in Zimbabwe: Opportunities and constraints- A review. Proceedings of the Association of Institutions of Tropical Veterinary Medicine in association with Zimbabwe Veterinary Association..

Latha BR, Aiyasami SS, Pattabiraman G, Sivaraman T, Rajavelu G. 2004. Seasonal activity of ticks on small ruminants in Tamil Nadu state. Trop Anim Health Production 36:121–133.

Latif, A.A. 2013. *Illustrated guide to identification of African tick species.* 1st ed, AGRI Connect (PTY) LTD, Pretoria, South Africa.

Latif, A.A. and Walker, A.R, 2004. An introduction to the biology and control of ticks in Africa. U.K

Lespine, A. et al. 2005. Influence of the route of administration on efficacy and tissue distribution of ivermectin in goat. Vet Parasitol, vol. 128, pp. 251–260.

Lorusso,V. Picozzi,K. Bronsvoort,B. Majekodunmi,A. Dongkum,C. Balak,G. Igweh,A. Welburn,S. 2013. Ixodid ticks of traditionally managed cattle in central Nigeria: where Rhipicephalus (Boophilus) microplus does not dare. Journal of Parasitology 41: 1323–1333.

Mafisa, T., 1993.*Wool and Mohair Productioin Lesotho.*Future of livestock production industries in East and Southern Africa. International Livestock Centre for Africa, FAO,Roma, Italy.

Mahmoud, T.U., Khalil, N.S., Marwa S. A. 2018. Acute behavioral and biochemical responses of sheep to Subcutaneous, ivermectin injection. Report: Slovak University of Agriculture in Nitra. Pp.1.

Martin,A., O. Tolf, Conny; Tamba, Paula; Stefanache, Mircea; Gabriel,R. Dimitrios,F. Herbert,T. ; Jonas,W. Gerhard,D. Dobler,C, Lidia. 2018. Molecular survey of neglected bacterial pathogens reveals an abundant diversity of species and genotypes in ticks collected from animal hosts across Romania.Journal of Parasite Vectors (1):144.

Marufu, M.C., Chimoyo, M., Mapiye, C. and Dzama, K. 2011. Tick loads in cattle raised on sweet and sour rangelands in the low-input farming areas of South Africa. Tropical Animal Health and Production 43: 307 - 313.

Mapiliyao L, Muchenje V, Dumisani P, Chiruka R, Marume U. 2012. Production practices and constraints to sheep productivity in two ecologically different resource poor communal farming systems of South Africa. *Sci. Res. Essays* 7(37):3209-3217.

Marinda, P., Bangura, A., and F. Heidhues, 2006. Technical efficiency analysis in male and female managed farms, a study of maize production in West Pokot district, Kenya; Gold Coast, Australia, August: 12-18.

Mekonnen, S., Hussein, I. and Bedane, B., 2001, 'The distribution of ixodid ticks (Acari: Ixodidae) in central Ethiopia', Onderstepoort Journal of Veterinary Research 66, 243–251.

Mekonnen, S., Pegram, R.G., Gebre, S., Mekonnen, A., Jobre, Y. andZewde, M., 2007, 'A synthesis of ixodid (Acari: Ixodidae) and argasid (Acari: Argasidae) ticks in Ethiopian and their possible roles in disease transmission', Ethiopian Veterinary Journal 11, 1–17.

Mengesha M, Tsega W. 2012. Indigenous sheep production in Ethiopia: A Review. Iran J. Appl. Anim. Sci. 2(4):311-318.

Mestorino, N. et al. 2003. Pharmacokinetics in plasma of ivermectin after its oral (solution and tablets) administration to sheep. *Journal of Vet Pharmacology*, vol. 26, pp. 307–309.

Miao ZH, Glatz PC, Ru YJ. 2005. Free-range poultry production-A review. Asia-Australian J. Anim. Sci. 18(1):113-132.

Mohammed, Y. and Ali, H., 2006, 'Prevalence of ectoparasites of sheep and goat flock in Urmia Subrub, Iran', Veterinary Parasitology 76, 431–442.

Mohr C.O. 1961. Relation of Ectoparasite load to host size and standard range. J. Parasit. 47 (6): 978 – 984.

Moshaverinia, A., Dini, I.M. and Azizzadeh, M. 2012. Prevalence of ixodid tick infestation of sheep in the Arasbaran region of Iran. Journal of Parasitology 36(2): 230–233.

Mthi.S, A. Skenjana and P. O. Fayemi. 2017. Characteristics of small-scale sheep production systems in some communal areas of the Eastern Cape Province, South Africa. International Journal of Livestock Production. Vol. 8(12), pp. 199-206.

Mulugeta, Y., 2008, 'A study on ectoparasites of small ruminants in selected sites of Tigray regional state and their impact on the tanning industry', MSc thesis, Faculty of Veterinary Medicine, Addis Ababa University, Debre Zeit, Ethiopia.

Musemwa L, Mushunje A, Chimonyo M, Fraser G, Mapiye G, Muchenje V. 2008. Nguni cattle marketing constraints and opportunities in the communal areas of South Africa: Review. Afr. J. Agric. Res. 3(4):239- 245.

Nava, S., Gugulielmone, A.A. and Mangold, 2009. An overview of systematics and evolution of ticks. Frontiers in Bioscience 14: 2857 - 2877.

Nsoso SJ, Madimabe MJ. 2003. A review of sheep industry in Botswana: Promoting the Karakul sheep industry. South Afr. J. Anim. Sci. 29:258-262.

Opasina, B.A., Dipeolu, l., and Fabemi, B.O. 1983. Some ectoparasites of Veterinary importance on dwarf sheep and goats under traditional system of management in the humid forest and derived savanna of Nigeria. Rev. Elev. Med. Vet. Pays Trop. 36(4): 387 – 391.Parasitology Blackwell Science. London.

Ogunmefun, S.O. and A.I. Achike, 2015. Profitability analysis of selecting informal insurance measures for selected enterprises by rural farmers in Odogbolu local government area. Russian Journal of Agricultural and Socio-Economic Science, 3(39):25-37.

Parola, P.and Pault, D. 2001. Ticks and tick-borne diseases in humans: an emerging infection threat. Clinical Infectious Diseases 32: 997 - 928.

Pegram, R.G., Hoogstral, H. and Wassef, H.Y., 1981, 'Ticks (Ixodidae) of Ethiopia: Distribution, ecology and host relationship of tick species affecting livestock', *Bulletin of Entomological Research* 71, 339–359.

Pegram R.G. and Preston, PM. 2014. Ticks of Domestic Animals in Africa: a Guide to Identification of Species. Bioscience Reports, Edinburgh Scotland, U.K.

Perret SR, Mercoiret MR. 2003. Supporting Small-scale Farmers and Rural Organisations: Learning from Experiences.In West Africa. Pretoria: Protea Book House, Ifas and Cirad.

Pushpa P. 2006.A study on livestock production system of rural and per-urban livestock owners. M.Sc. (Agric.) Thesis, Univ. Agric. Sci., Dharwad.

Rahbari, S., Nabian, S. and Bahohar, A.R., 2009, 'Some observations on sheep sarcoptic mange in Tehran provinces, Iran', Tropical Animal Health and Production 41, 397–401

Randolph, S.E. 2004. Tick ecology: processes and patterns behind the epidemiological risk posed by ixodid ticks as vectors. Parasitology 129: S37 - S65.

Rashid. M, Godara. R.,.Yadav.A and. Katoch. R. 2018. Prevalence of Ticks in Sheep and Goats of Jammu region. Indian Journal of Small Ruminants, 24(1): 183-186.

Rehman WU, IA Khan, AH Qureshi and S Hussain, 2004. Prevalence of different species of ixodidae (hard ticks) in Rawalpindi and Islamabad. *Pak Journal of Med Res*, 43: 1-4.

Rehman, A. Nijhof,A.M, Sauter-Louis, C. Birgit Schauer,B. Staubach,C. Franz J. and Conraths,F. J. 2017. Distribution of ticks infesting ruminants and risk factors associated with high tick prevalence in livestock farms in the semiarid and arid agro-ecological zones of Pakistan. Germany.

Rugu, N.N. and Jidayi. 2004. A survey on the ectoparasites of some livestock from some area of Borno and Yobe State Nigeria. Nigerian Vet. J. 125 (2): 48 - 55.

Saari.S, Näreaho.A, Nikander.S. 2017. Parasitic Skin Disorders In Small Animal Dermatology (Fourth Edition).Journals and Books of ScienceDirect.P187-228.

Serste, T. andWossene, A., 2007, 'A study on ectoparasites of sheep and goats in eastern part of Amhara region, northeast Ethiopia', Small Ruminant Research 69, 62–67.

Sajid MS, Z Iqbal, MN Khan and G Muhammad, 2008. Point prevalence of hard ticks (Ixodids) infesting domestic ruminants of lower Punjab, Pakistan. Int J Agri Biol, 10: 349-351.

Senthilkumar T, Sudeepkumar N K and Subramania R. 2005.Profile of urban dairy farmers utilising mobile artificial insemination services in Tamil Nadu. J. Ext. Educ. 16(1and2):3745-3748.

Sissay B. Mekbib. Adesola O. Olaleye. Motlatsi N. Mokhothu. Masia Johane. Spirit .B. Tlali. Taddese W. Godeto. 2011. Assessment on the Adaptive Capacity of the Machobane Farming System to Climate Change in Lesotho Journals of RearchGate.

Sonenshine D.E. 1991. Biology of Ticks, volumes 1 and 2. Oxford University Press, New York, United.

Soulsby EJL, 1982. Helminths, Arthropods and Protozoa of Domesticated Animals. 7th Ed, Bailliere Tindall, London, UK.

Soundararajanl, R.Kumar, R. Yue, M. 2003. Comparative Efficacy of Ivermectin and Deltamethrin, Against Otobius Megnini of Sheep.lndian Vet. Journal,; 80 : 733 – 735

Straten,M. Jongejan.F.1993. Ticks (Acari: Ixodidae) infesting the Arabian camel (Camelus dromedarius) in the Sinai, Egypt with a note on the acaricidal efficacy of Ivermectin. Journal of Experimental and Applied Acarology vol. 17: 605–616.

Teshome, W., 2002, ‘Study on skin diseases of small ruminant in Sidama zone, southern Ethiopia’, DVM thesis, Faculty of Veterinary Medicine, Addis Ababa University, Debre Zeit, Ethiopia.

Tiar. 2009. Technical Milestone Report 2 Sheep Connect-Tasmania, Launceston: Tasmanian Institute of Agricultural Research.

Tjomsland. 2013. Ticks kill sheep. Bioforsk - Norwegian Institute for Agricultural and Environmental Research.Science Daily.

Vanclay, F., Howden, P., Mesiti, L. and Glyde, S. (2006). The social and intellectual construction of Farming Styles: Testing Dutch ideas in Australian agriculture. *Sociologia Ruralis,* 46(1), 61-82.

Vanclay, F., Mesiti, L., and Howden, P. (1998). Styles of farming and farming subcultures: Appropriate concepts for Australian rural sociology.*RuralSociety*, 8(2), 85-107.

Vanclay, F., Silvasti, T., and Howden, P. (2007). Styles, Parables and Scripts: Diversity and conformity in Australian and Finnish agriculture. *Rural Society,* 17(1), 3-18.

Walker A.R., Bouattour A., Camicas J.-L., Estrada-Pena A., Horak I.G., Latif, A.A., Pegram R.G. and Preston P.M. 2003. Ticks of Domestic Animals in Africa: a Guide to Identification of Species. Bioscience Reports, Edinburgh, United Kingdom.

Walker, J.B., Keirans, J.E.andHorak, I.G. 2000. The Genus Rhipicephalus (Acari, Ixodidae): A Guide to the Brown Ticks of the World. Academic Press, Cambridge.

Walker, A.R., Bouattour, A., Camicas, J.L., Estrada-Pena, A., Horak, I.G., Latif, A.A. et al., 2003, ‘Ticks of domestic animals in Africa: A guide to identification of species, ICTTD-2’, Bioscience Reports, London.

Walker, J.B., Mehlitz, D., Jones, G.E. (1978). Notes on Ticks of Botswana. Eschborn Germany, Germany, Pp. 83.

Walker, J.B.,1974. The lxodid ticks of Kenya. (London: Commonwealth Agricultural Bureaux).

Wall, R. and Shearer, D., 1997, Veterinary entomology, 1st edn., Chapman and Hall, London.

Wallaga, D., 1997, ‘Survey of ticks and tick-borne diseases in eight domestic animals in and around Debre Zeit, Eastern Showa Zone, Ethiopia’, DVM thesis, Faculty of Veterinary Medicine, Addis Ababa University, Debre Zeit, Ethiopia.

Yalew, T., 2007, ‘Study on the prevalence of ectoparasites in small ruminants in and Around. Tehran provinces, Iran’, Tropical Animal Health and Production 41, 397–401.

Yacob HT, Yalew TA, Dinka AA. 2008. Part I. Ectoparasitic prevalence in sheep and goats in around Wolatia soddo, Southern Ethopia. Revue Med Vet.;159: 450–454.

Yakhchali M, Hosseine A. 2006. Prevalence and ectoparasitic fauna of sheep and goats flocks in Urmia suburb, Iran. Vet Arh 76(43):1–442.

Yitayew A, Taye M, Amanie A, Zeleke G. 2013. Community-based improvement scheme for Washera sheep: Lessons from Yilmanadensa and Quarit Districts in Westren Amhara Region, Ethiopia. Afr. J. Agric. Res. 8(44):5485-549.

ANNEXES

Annex1: Survey questions summary

1. Respondents name
2. Name of the village
3. Name of district
4. Agro-ecological zone
5. Sex of respondents
6. Age of respondent
7. Farm size
8. Occupation of the respondents
9. What is your marital status?
10. Did you go to school?
11. What is the highest qualification you attained?
12. Are you a member of any small ruminants association?
13. If yes, do you get any benefit from such associations?
14. Have you attended any training sessions in the Wool industry?
15. If yes, how often do you attend training sessions in a year?
16. What source of income do you have?
17. Which one of the mentioned sources contributes more for the family?
18. What type of livestock do you currently own?
19. How many merino species do you have?
20. Do you get any extension services?
21. If yes, are the extension services from the government or private organization?
22. What are your sources of medication?
23. If is a shop, which shop it is?

24. Do you consider these medication to be effective?

25. What other problems do you encounter on the farm?

26. How do you treat those external parasites?

27. If answer is yes in question (D 6), Which measures do you use?

28. How do you maintain the hygiene of the kraal?

Annex 2: Strategies in place to improve knowledge and experience in sheep farming

Category	Senqu %	Foothills %	Highlands %	Lowlands%	X^2 Value	Sig.
Any training received in the sheep industry?						
Yes	30	4	25	13	27.91	0.00
No	70	96	75	87		
Membership of Associations in the sheep industry						
Yes	24	5	27	13	22.38	0.00
No	76	95	73	87		
Any benefit as a member of Association?						
Yes	23	5	26	13	23.06	0.00
No	3	0	2	1		
Are you accessible to any extension services?						
Yes	25	16	19	7	12.79	0.00
No	75	84	81	93		

X^2= chi square. df=degree of freedom. Sig = significance value. RV= Senqu River, N/A = not applicable

Annex 3: farmers' awareness of the presence ecto-parasites health problems in four agro-ecological zones of Lesotho

Category	Senqu	Foothills	Lowlands	Highlands

	%	%	%	R V%	X^2	Sig.
Biting lice	10.9	9.5	1.9	12.6		0.0
				1.20		
Sucking lice	19.1	7.4	7.8	2.1		
Mites	13.6	34.7	25.2	8.4		
Fleas	1.8	0.0	0.0	1.1		
Nose Bot Fly	0.0	2.1	0.0	0.0		
Fly Maggots	0.0	0.0	1.0	0.0		
Ticks	2.7	0.0	1.0	2.1		
sucking liceand mites	10.9	14.7	9.7	26.3		
biting and sucking lice	4.5	7.4	5.8	22.1		
biting lice and mites	7.3	2.1	1.0	1.1		
Mites and Fleas	1.8	0.0	0.0	0.0		

X^2 Value, degree of freedom (f) and significance value of (sig).