ASSESSMENT OF BREEDING PRACTICES, TRAIT PREFERENCES OF SHEEP FARMERS AND SHEEP MORPHOMETRIC CHARACTERIZATION IN MAKURUNG AND LENTING VILLAGES OF LEPELLE-NKUMPI LOCAL MUNICIPALITY, LIMPOPO PROVINCE, SOUTH AFRICA

By

ABIGAIL MMAPASEKA PHALADI

[redacted]

A MINI-DISSERTATION

Submitted in (partial) fulfillment of the requirements for the degree of

Master of Science in Agriculture

In

Animal production

In the

FACULTY OF SCIENCE AND AGRICULTURE

(School of agricultural and environmental sciences)

at the

UNIVERSITY OF LIMPOPO, SOUTH AFRICA

SUPERVISOR: Prof TL TYASI

CO-SUPERVISOR: Prof O TADA

DECEMBER 2023

DECLARATION

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

Signature……………………. Date………………

Student name: PHALADI AM

ACKNOWLEDGEMENT

First and foremost, I would like to express my biggest gratitude to the Almighty God for constantly providing me with strength, protection, guidance, knowledge and perseverance throughout my life and this degree.

To my supervisors, Prof TL Tyasi and Prof O Tada, I would like to extend my greatest thanks for accepting me as one of their students and for their unwavering patience, support and guidance throughput the study. Truly, they have been there for me through out and I appreciate that.

Special thanks to my mentor (Mr Madumetja Cyril Mathapo) and Tyasi Research Team for their guidance throughout this study.

To my parents (Jeanet Rangoato and David Thopane), I would like to say thank you for the unwavering support and encouragement throughout my life. To my sisters (Lucia, Precious and Lehlogonolo), brother (Thabang), nephews (Bopaki Malaysia and Lethabo Jayden) and friends (Dineo Mogadime and Nombulelo Shongwe), thank you for always cheering and believing in me.

My gratitude also goes to the National Research Funding (NRF) for making this study possible by providing financial support from the beginning to the end.

Lastly, I would like to thank the sheep farmers at Makurung and Lenting villages for allowing me to use their animals for this study, as well as Dr Stanley Mogashoa, who is an extension officer in the Lepelle-Nkumpi Local Municipality, for assisting me in reaching other several sheep farmers he works with.

DEDICATION

I dedicated this dissertation to myself and my parents for their love, support, and motivation and for always being there for me throughout my studies.

ABSTRACT

Sheep farming is practiced country wide, including in dry areas of Northern Cape, Western Cape and Limpopo Province. This study assessed the existence of production objectives, breeding practices, trait preferences of sheep farmers and morphometric characterization of sheep in two selected villages (Makurung and Lenting) of Lepelle-Nkumpi local municipality of Limpopo Province. Using 306 sheep of different classes, morphometric measurements were taken to characterize and predict body weight. Data was analyzed using Chi-square tests, descriptive statistics, rank index, Pearson's correlation, analysis of variance (ANOVA) and various data mining algorithms such as Multivariate Adaptive Regression Spline (MARS) and Classification and Regression Tree (CART). Furthermore, MARS and CART were employed as data mining algorithms to determine the goodness of fit in body weight prediction from morphometric measurements. Socio-economic status results indicated that the majority of sheep farmers in the two surveyed villages were males, and there was no significant difference ($P>0.05$) observed between the villages. All the sheep farmers from Makurung village had tertiary education as their highest level of education, while in Lenting village majority of farmers had secondary education as their highest level of education, and there was a highly significant ($P<0.01$) difference between the villages. Majority of the sheep farmers from the two selected villages had their age range from 41 - 49, with only Lenting village having few farmers (36.70 %) greater than 60 years of age. Production objectives indicated that Majority of the sheep farmers in Makurung and Lenting villages kept sheep for savings & investment (55.00 %) and meat (41.70 %). However, there was no significant difference ($P>0.05$) between the surveyed villages. Breeding practices indicated that a large proportion (90.00%) of sheep farmers in both villages practiced uncontrolled mating, and a highly significant difference ($P<0.01$) was observed between the villages. A larger proportion of sheep farmers knew about castration and culling practice, with few (36.70 %) having no knowledge about it. Rank and indices in selection of trait preferences of breeding rams looked at mating ability (0.291), body size (0.250) and growth rate ($P >0.05$), while for breeding ewes, twinning ability (0.289), mothering ability (0.181), and lambing interval (0.168). Correlation results of rams in Makurung village showed that BW had a highly significant correlation with RH, HG, RL, WH and BL, While with rams of Lenting village, BW had a positive highly significant correlation with HG, WH, and BL. With ewes in Makurung village, BW had a highly significant correlation with RH, HG, WH and BL. While in Lenting village, BW had a highly significant correlation with RH, HG, RL, WH and BL. MARS and CART results indicated that HG had a significant effect (*P<0.01*) on WH, followed by BL, RH and the village. Goodness of fit criteria results indicated there was a high r (0.953), Rsq (0.900), ARsq (0.887) and low SDR (0.306) in MARS model, showing that this model was the best as compared with CART. The findings of this study imply that sheep farmers in Makurung and Lenting villages can read and write effectively and, therefore, can make decisions based on the design of CBBP. It was concluded that farmers in the two selected villages had household heads as male, who were married with education level of secondary and higher with ages ranging from 41-49. Sheep were kept mainly for saving and investment, with farmers having shown their highest preference for mating ability in rams and twinning ability in ewes. Most sheep farmers were not controlling the mating, with majority practicing culling and castration. In both sexes, BL, WH and HG can be used as a selection criterion when determining BW of sheep. Furthermore, both MARS and CART suggest that HG alone can be used as a predictor of BW in sheep. The goodness of fit calculations suggests that MARS was the best model. This study recommended that farmers, researchers, agricultural extension workers and other stake holders must collaborate in designing and implementing a community-based breeding programme by considering the production objectives, trait preferences and breeding practices.

Keywords: Community-based breeding programme, heart girth, data mining algorithms, linear body measurements and live body weight

TABLE OF CONTENT

Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AIC	Akaike's coefficient criterion
ARsq	Adjusted coefficient of determination
BL	Body length
CART	Classification and regression tree
CBBP	Community based breeding programme
CV	Coefficient of variation
HG	Heart girth
MAD	Mean absolute deviation
MAPE	Mean absolute percentage error
MARS	Multivariate adaptive regression spline
ME	Mean error
PI	Performance index
R	Pearson's correlation coefficients
RAE	Relative approximation
RH	Rump height
RL	Rump length
RMSE	Root mean square error
RRMSE	Relative root mean square error
Rsq	Coefficient of determination
SDR	Standard deviation ratio
WH	Withers height

CHAPTER 1

INTRODUCTION

1.1 Background

Sheep farming is practiced country wide, including dry areas of Northern Cape, Western Cape and Limpopo Province (DAFF, 2011). This is due to their short generation interval, high fertility, and their ability to adapt to harsh environments while also being able to produce in a limited feed supply (Tsedeke, 2007). Sheep are mostly found in rural areas and are used to produce milk and meat, among other products. They are resilient to diseases and are mostly grazers (Bolowe *et al.,* 2021). In rural areas, they have social value, economic and cultural values; hence, they are kept by smallholder farmers (Getachew *et al.,* 2010; Mekuriaw *et al.,* 2012; Dagnew *et al.,* 2017).

1.2 Problem statement

In Limpopo Province, the diverse sheep population is necessary for the present and future livelihoods of the rural farmers and is considered to be advantageous when compared to other types of farm animal's criteria (Abegaz *et al.,* 2010; Hemacha *et al.,* 2022). Among the other various factors, lack of ways to make profit from sheep farming has been recognized as a serious constraint among the sheep farmers (Gizaw *et al.,* 2008). According to Verma *et al.* (2016), linear body measurements are very important as they show the breed standards and help describe the morphological structure and developmental ability of the animal. These measurements are very important and helpful when it comes to developing an acceptable model, especially in the rural areas where there is lack of weighing scales (Maiwashe *et al.,* 2002). They have also been used in predicting body weight and carcass traits in sheep (Sowande *et al.,* 2008; Tadesse *et al.,* 2010; Birteeb *et al.,* 2012) and thus form an important aspect of phenotypic characterization (FAO, 2012).

Regardless of the existence of a large sheep population and their multiple purposes, the average sheep productivity is generally low (Dagnew *et al.,* 2017). The cause of low productivity is known to be numerous factors; however, it is largely related to the limited knowledge of livestock genetic improvements (Gizaw *et al.,* 2013; Dagnew *et al.,* 2017). Several studies indicated that sheep production might be improved by the development of community-based breeding programmes (CBBPs) (Gizaw *et al.,* 2008; Edea *et al.,* 2012; Wurzinger et al., 2021; Hemacha *et al.,* 2022). Community-based breeding programmes are organized breeding activities that are planned, designed and implemented by smallholder farmers individually or together with agricultural extension workers (Wurzinger et al., 2021). The aim was to initiate systematic breeding at the community level, which is achieved when the sheep farmers recognize and understand the production challenges they have so they can be assisted in designing an improvement programme (Nandolo *et al.,* 2016).

1.3 Rationale

The concept of community-based breeding programs (CBBPs) is not new. It has been used as a tool in agricultural research since 1970 (Omore *et al.,* 2008). CBBPs have been shown to be an effective approach to genetic improvement while building its local position and ownership and can be sustainable with the right level of organization and support from the farmers participating in it (Gutu *et al.,* 2010). To design and implement an effective animal improvement program, a thorough investigation of farmers' knowledge is required (Abraham *et al.,* 2018), and according to the FAO (2011), phenotypic and molecular characterizations are important tools for recording the breeds, which is the first step towards the development of strategies for their management, conservation and sustainable usage. Several studies have been conducted in other countries on smallholder sheep farmers to recognize their production objectives, practices, trait preferences and selection criteria to design, implement and review community based breeding programs (Sölkner *et al.,* 2006; Haile *et al.,* 2011; Wurzinger *et al.,* 2011; Mueller *et al.,* 2015). Thus, production objectives, breeding practices and trait preferences of sheep farmers at Lenting and Makurung villages for the development of CBBP are not yet known. To date, the morphometric characterization of sheep population in the two villages (Makurung and Lenting) of Lepelle-Nkumpi Local Municipality has not been covered in depth. Therefore, the current study was conducted to assess the breeding practices, traits preferences and morphometric characterization of sheep farmers with implications for the design and development of the breeding programme.

1.4 Aim

The aim of the study was to document the existence of production objectives, breeding practices and trait preferences of sheep farmers and morphometric characterization at Makurung and Lenting villages of Lepelle-Nkumpi Local Municipality for implementation of designing community-based breeding programme.

1.5 Objectives

The objectives of the study were to identify:

i. Socio-demographic and economic status of sheep farmers at Makurung and Lenting villages of Lepelle-Nkumpi Local Municipality.
ii. Production objectives of sheep farmers at Makurung and Lenting villages of Lepelle-Nkumpi Municipality
iii. Breeding practices of sheep farmers at Makurung and Lenting villages of Lepelle-Nkumpi Municipality
iv. Traits preferences of sheep farmers at Makurung and Lenting villages of Lepelle-Nkumpi Local Municipality.
v. To determine the association between live body weight and morphometric traits of sheep in Makurung and Lenting villages of Lepelle-Nkumpi Local Municipality.
vi. To establish a model to predict live body weights using morphometric traits of sheep in Makurung and Lenting villages of Lepelle-Nkumpi Local Municipality.

1.6 Research questions

The research questions of the study were as follows:

i. What are the socio-economic status of sheep farmers at Makurung and Lenting villages of Lepelle-Nkumpi Municipality?
ii. What are the production objectives of sheep farmers at Makurung and Lenting villages of Lepelle-Nkumpi Municipality?
iii. What are the breeding practices of sheep farmers for breeding stock at Makurung and Lenting villages of Lepelle-Nkumpi Local municipality?
iv. What are the trait preferences of sheep farmers at Makurung and Lenting villages of Lepelle-Nkumpi Municipality?

v. What is the association between live body weight and morphometric traits of sheep in Makurung and Lenting villages of Lepelle-Nkumpi local municipality?

vi. Which model can predict live body weights using morphometric traits of sheep in Makurung and Lenting villages of Lepelle-Nkumpi local municipality?

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter focused on presenting an overview and brief information on the origin, domestication and distribution of sheep. Moreover, it explored the socio-economic importance of sheep. It also looked at the importance of breeding practices in livestock farming and using morphometric traits to predict body weight.

2.2 Origin, domestication and distribution of sheep

There are a number of theories regarding the origin of domestic sheep. However, most sources do agree that sheep originated from the mouflon (Ensminger, 2002). There are two wild population of mouflons that are still present: namely, the Asiatic mouflon, which is found in the Asia Minor mountains, and the European mouflon, also found on the islands of Sardinia and Corsica (Ensminger, 2002). According to Ryder (1984), sheep and goats evolved about 2.5 million years ago in western Asia and southeast Asia and were the first ruminants to be domesticated by man around 11,000 years ago in the countries of the fertile crescent. Ryder (1984) mentions that the following three major groups of Eurasian wild sheep, Asiatic mouflon (*O. musimon or O. orientalis*), urial (*O. vignei*) and argali (*O. ammon*), are proposed as the ancestors of modern domestic sheep.

The indigenous sheep in Africa are derived from Asia or Europe as no wild sheep were domesticated in Africa. However, both goats and sheep appeared in tomb and cave paintings as per archaeological evidence. Not long after their domestication in Western Asia, sheep entered the African continent and according to Epstein (1971), there were three waves of migration of precursor populations from Asia, namely: thin-tailed, fat-tailed and fat-rumped sheep, respectively. The earliest sheep in Africa were thin-tailed and hairy and were introduced to East Africa via North Africa (Marshal, 2000). The second wave of sheep introduced constituted fat-tailed sheep entering North Africa via the Isthmus of Suez and East Africa via straits of Bab-el-Mandeb (Ryder 1984). Fat-rumped sheep entered East Africa much late. Accordingly, African sheep have been described and classified based on their tail type (Epstein 1971; Ryder 1984). The Mouflon (*O. musimon* or *O. orientalis)* had several characteristics, such as a lack of aggression, a manageable size, early sexual maturity, social nature and high reproduction rates, which made them particularly suitable for domestication. Today, the *Ovis aries,* family Bovidae and the subfamily Caprinae is are entirely domesticated animals that are largely dependent on humans for their health and survival.

2.3 Socio-economic importance of sheep

Livestock production is the key to food security for many smallholder farmers in most developing countries, and an increase in livestock production is associated with an increase in livestock numbers (Salem and Smith, 2008). It can directly contribute to food security, mainly by slaughtering the sheep for meat, selling or battering the sheep and using the money to buy food.

Ouma *et al.* (2003) highlighted that the rate of returns a farmer gets on livestock investment is higher than that obtained from cash (savings), which are invested in formal financial institutions (banks). This is very important in developing countries, where financial markets function poorly and opportunities to manage risk using formal insurance are generally absent, and most farmers cannot read nor write (Moll *et al.,* 2007). Therefore, farmers keep sheep as a form of insurance against such and also crop loss.

Reflecting on the social importance, in the rural areas, sheep are considered as a common display of wealth and social ranking and also used to settle local disputes, where the chief council decides the number of sheep to be used as fines (Ouma *et al.,* 2003). South Africa is made of diverse traditions. As such, during traditional gatherings, ancestral ceremonies, chieftaincy inaugurations and weddings, sheep are slaughtered to appease the ancestors and give thanks as a form of celebration. According to the findings from local people (folklore), “sheep do not bleat like goats when they are slaughtered,” so it is not encouraged to use them when cleansing someone traditionally but rather be used to remove ancestors from a household in preparations for further rituals. There are further mentioning of the traditional calming effect of the fat when administered to those suffering from over-aggression or hyperactivity.

2.4 Importance of breeding practices in livestock farming

Breeding practices are largely related to checking the farmer's objective about his livestock, as this affects the productivity of the farm (Bebe *et al.,* 2003). The breeding practices mainly consist of mating practice, castration, and culling, among other factors. According to Abera *et al.* (2014), mating is predominantly uncontrolled in rural areas. This is mainly because most livestock farming is extensive, and as such, they have a common grazing place in which animals from different families graze together (Lombebo, 2022). This is consistent with the findings of Abebe *et al.* (2020) and Bolowe *et al.* (2022), who found that farmers share grazing places in Ethiopia and Botswana. Mthi *et al.* (2020) on cattle in the Eastern cape province. This is because of the extensive farming that the sheep farmer's practice. Culling is when farmers remove unproductive livestock from the herd. The reason for removal is because of old age, the animals being unproductive, and fertility problems. Most of the time, farmers cull male animals as opposed to female animals (Nguluma *et al.,* 2020). According to Gudeto *et al.* (2021), the animals are culled, for selling them for extra cash, castration and others by slaughtering them for home consumption. This was in agreement with the findings of a study by Getachew *et al.* (2010) on sheep in a mixed crop-livestock and pastoral system of Ethiopia and Tyasi *et al.* (2020) on goats in the Lepelle-Nkumpi municipality, who found that sheep and goats that are identified as not being suitable to be in the herd, they are sold or slaughtered. Nevertheless, this is a good practice as it allows the farmers to use limited resources such as feed and water for productive animals only. According to Gudeto *et al.* (2021), castration is a common practice used by farmers in rural areas to avoid unwanted breeding bulls and also to minimize the chances of inbreeding within a herd. The same author also highlighted that bull castration in the mid-rift valley of Oromia, Ethiopia it, is also done with the aim of bringing about docility of the bulls, improving draft power and increasing weight gain. Mthi *et al.* (2020), advise that castration of young calves needs to be done at a younger age, as it helps to prevent unwanted mating and transfer of unfavorable genes and also it is less painful to the animals. In addition, Dossa *et al.* (2015) and Kunene *et al.* (2020) highlighted that goat farmers castrate their buck to decrease the body odor and smell of goat meat.

2.5 Using morphometric traits to predict body weight

Body weight is a very important characteristic in meat animals, especially ruminants, because of its direct relation to generating income (Abera *et al.,* 2014). It is also an important economic trait yet is hardly ever measured in rural village areas; this is mainly because of the lack of weighing scales. Therefore, the sale and purchase of animals is done on the basis of their physical appearance; as such, the farmers do not actually get the actual price per the animal worth (Kumar *et al.,* 2018). Hence, information about body measurements are important as they reflect the breed standards (Riva *et al.,* 2004; Verma *et al.,* 2016) while giving information about the developmental ability of the animal.

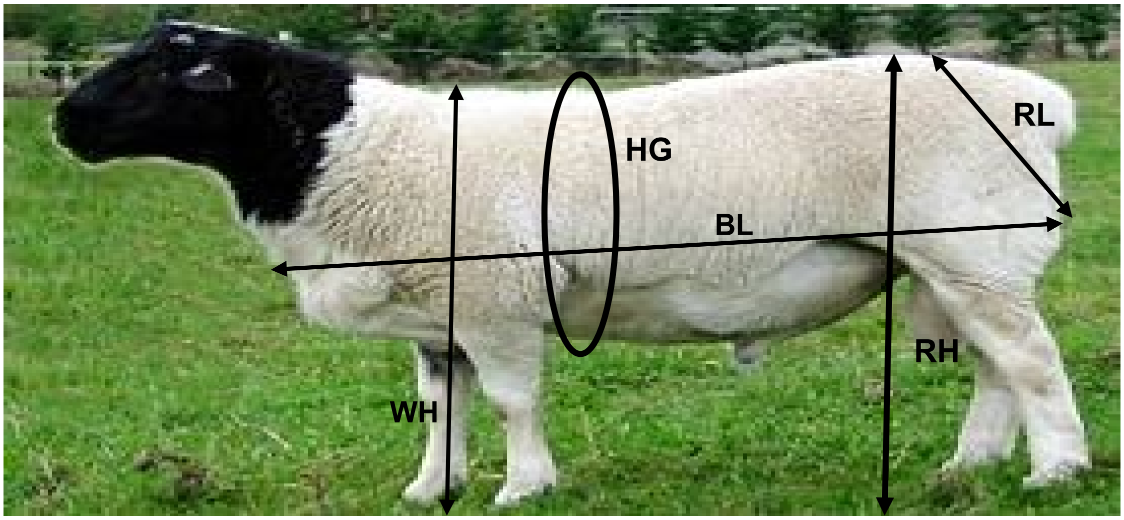

Figure 1: Illustration of linear body measurements discussed in detail below

2.5.1 Body length

Body length is a morphological trait that is measured from the humerus part of the head to the distal end of pubic bones (Yakubu, 2009). Mohammed *et al.* (2017) in their study reported that body length had a high significant correlation (indicate value) with body weight in male and female indigenous sheep in South Wollo districts (Wogide, Borena, and Legambo) of Ethiopia, even though it was not significantly affected by age and sex. Melaku *et al.* (2019) found that dentition significantly affects body length and that it increases as the age increased from the youngest (0 permanent pair of incisors) to the oldest (≥ 2 permanent pair of incisors). These findings are consistent with the results of Gebreyowhens and Tesfay (2016) in highland sheep population in Tigray, who found that as the age of an animal increase the average values for body length increases.

On the other hand, Jannah *et al.* (2023) observed that body length had the highest correlation (indicate value) with body weight in female Sukab sheep in Brebes district of Indonesia as such Abera *et al.* (2014) and Bireda *et al.* (2016) have indicated that the strong correlation of different measurements with body weight would imply that increasing this trait would mean an increased body weight.

2.5.2 Withers height

One of the most commonly used morphological traits to estimate body weight in small ruminants is withers height, which is often referred to as the height from the ground to the top of the withers and vice versa (Bello and Adama, 2012). On the other hand, Alemayehu *et al.* (2011) discovered that withers height was highly significant (indicate value) with body weight in indigenous sheep types in Dawuro zone of Ethiopia, and this was consistent with the findings of Abera *et al.* (2016) on indigenous sheep type of East Gojam zone, Ethiopia.

Kunene *et al.* (2006) found that withers height differed significantly between genders, with rams having higher values in Nguni (Zulu) sheep in KwaZulu Natal province. This was consistent with the findings of Getachew *et al. (*2016), who discovered that withers height varied significantly among males and female indigenous sheep breeds in Ethiopia. However, Chang'a *et al.* (2023) found that sheep gender did not significantly affect wither height in red Massai sheep of Arumeru and Mondluli districts in Tanzania. The variation could be due to the biological differences in growth between males and females.

Withers' height had a significant correlation (r = 0.7*) with body weight, indicating that it could be indirectly used in selection criteria (Michael *et al.,* 2016). Furthermore, a regression analysis revealed that a combination of heart girth, body length and wither height best suits the prediction of body weight, especially when there is difficulty when restraining an animal during field conditions (Bolowe *et al.,* 2021).

2.5.3 Heart girth

Heart girth refers to the circumference of the chest posterior to the forelegs at right angles to the body axis (Melaku *et al.,* 2019). A general linear model found heart girth to be the most important in accounting for a large proportion of the changes in body weight, this measurement was reported for Afar and Menz sheep breeds (Getachew *et al.,* 2009) and for Bonga and Horro sheep breed (Edea *et al.* 2008). Heart girth was found to be more dependable when it came to predicting body weight than other linear body measurements at the farmer's level when there are no facilities to take the whole measurements (Mohammed *et al.,* 2017). Even though the heart girth of Tswana sheep in the Southern district was higher than the heart girth of sheep in Wogide, Borena and Legambo districts of Ethiopia (Mohammed *et al.,* 2017) and Sinan and Hulet eju sheep of Ethiopia (Michael *et al.,* 2016), It was recognized that heart girth was among the variables that are least affected by the animal posture and are easy to measure than other measurements. Hence, under field conditions, heart girth alone can be used to estimate live weight as compared to combinations with other linear body measurements because of the difficulty of proper animal restraint during measurement. Through the adjusted coefficient of determination of a multiple linear regression model, it was discovered that heart girth was the best estimator of live weight for both male and female on Simien sheep in Simien Mountain region, Ethiopia (Maleku *et al.,* 2019). These findings are in agreement with the findings of Tesfaye et al. (2008) on indigenous sheep breeds, including Afar, Menz, and Washera.

2.5.4 Rump height

Rump height is referred to as a morphological trait that is found in relation to the level of the hind legs, mainly from the top of the pelvic girdle to the ground surface (Yakubu, 2009). In a study by Mohammed *et al.* (2017) on local crossbred and pure Dorper sheep in South Wollo Amahara in Ethiopia, it was found that rump height was significantly correlated with body weight (indicate value). The findings are consistent with the results of Bolowe *et al.* (2021), who found that rump height was significantly correlated with body weight (indicate value). The genetic correlation of body weight with rump height and all other body measurements in cross-bred sheep indicate that these traits were genetically linked (Mohammed *et al.,* 2018).

2.5.5 Rump length

According to Birteeb *et al.* (2012), rump length refers to the distance from the hip to the pin of the animal. A study by Mohammed *et al.* (2018) found that rump length was highly and significantly correlated with body weight (indicate value) in Dorper and local sheep of North Amhara, Ethiopia. However, Michael *et al.* (2016) found a different result from Mohammed *et al.* (2017), where rump length was significantly correlated with body weight in indigenous sheep types of Northern Ethiopia. Similarly, these findings are consistent with the finding of Abera *et al.* (2014) in indigenous sheep types in Selale area, in Central Ethiopia.

2.6 Conclusion

The findings of the above literature revealed the origin, domestication and pathway of sheep into Africa and even though sheep is among the first ruminants to be domesticated the origin of the sheep we have in South Africa originated from Asia. It revealed that sheep has multipurpose importance to farmers on a daily basis. The literature also demonstrated how important breeding practices are in livestock as they shape the productivity of the herd or farm. Lastly, the literature revealed that there is a positive relationship between these traits, meaning they can be useful in predicting body weight at the village level when there are no weighing facilities.

CHAPTER 3

METHODOLOGY AND ANALYTICAL PROCEDURES

3.1 Study area

The study was conducted in two villages: Makurung and Lenting of Lepelle-Nkumpi Local Municipality in the Capricorn District of Limpopo Province, South-Africa. The municipality is found at 24.2585° S latitude and 29.6499° E longitude. The climate is primarily subtropical, having mild winters, frost-free free and very hot, mostly dry summers (CDM, 2009). It has a mean annual rainfall ranging from 453mm to 474mm with a rainfall coefficient variation of 30.78%. The rainfall coefficient variation shows the rainfall variability. Hence, the higher the value, the more the rainfall varies yearly. The mean annual temperature for Lepelle-Nkumpi Local Municipality is around 20°C, with the average temperature in summer at 23°C and in winter at 20°C (Kuyamandi Development Services, 2006). The municipality is under savannah biome, with vegetation such as northeastern mountain grasslands plant species and grass species such as the *Panicum maximum* (Mphafa) and *Cynodon dactylon* (Mohlwa) that are often food for sheep (ASCDM, 2009; Matlebyane *et al.,* 2010).

3.2 Experimental animals and management

According to Molabe *et al.* (2021), the Dorper sheep is a fat-tail breed, an adaptable commercial breed with a high growth rate associated with large body size, good meat yield, carcass weight and dressing percentage. Meanwhile, Meat Master sheep is a composite breed between mainly the Dorper and Damara sheep breeds. It is a low input/high input, mutton, hair and non-fat tailed sheep breed (Becker *et al.,* 2021). The animals are raised under extensive farming systems, whereby they are kept in the kraal at night and in the morning, they go out as a flock and graze on natural vegetation of grasses, clover and forbs at one part of the pasture at a time (Admasu *et al.,* 2017). Clean water from community taps were provided at home when they leave in the morning to go graze and when they came back in the afternoon.

For herd health management, the sheep received routine inspection and dipping, whereby the sick or injured ones were removed. Physical restrain was sometimes applied to limit movement, as described by (FAO, 2012). The animals were in a standing position with their head raised for a period of approximately 10 minutes when all the body measurement traits were taken.

3.3 Study design

The study was conducted using the cross-sectional observational design, where the data was collected from the sheep and sheep farmers in Makurung and Lenting villages of Lepelle-Nkumpi Local Municipality at once.

3.4 Sampling procedure

The study used a multi-stage sampling procedure for sampling. According to Heeringa et al. (2017), a multi-stage sampling procedure is defined as a sampling method that divides the population into groups. Stage 1: Lepelle-Nkumpi Local Municipality was purposively chosen due to the substantial number of sheep population found. Stage 2: Two villages namely Makurung and Lenting villages, were purposively selected due to the presence of enough sheep farmers that are working with agricultural extension officers of the local municipality. Stage 3: Sheep farmers at Lenting and Makurung villages in Lepelle-Nkumpi Local Municipality were selected to participate in study with a census research approach. Stage 4: Sheep rams that are at least two years old and sheep ewes of at least two years and multiparous (at least two lambing) were randomly selected, described and phenotypically characterized as per a study done by Whannou *et al.* (2021). The age of the animals was verified by examining their teeth according to the procedure described in (FAO, 2013).

3.5 Sample size of the sheep and farmers

The sheep sample size of the study were calculated using Yamane formula (Yamane, 1967) as follows:

The following is Yamane's formula for estimation of sheep sample size:

$$n = \frac{N}{1+N\,(e)^{2}}$$

Where:

n is the required sample size

N is the population size

e is the acceptable error of estimation (0.05)

The sheep population size of sheep at Makurung and Lenting villages of the Lepelle-Nkumpi local Municipality is 1300. Therefore, the study used a sample size of 306 sheep, which was 153 per village (78 Dorper and 75 Meat master sheep per village).

$$N = \frac{1300}{1+1300\,(0.05)^{2}}$$

$$= 305.88 \approx 306 \text{ sheep}$$

The study used all the farmers farming with sheep at Makurung and Lenting villages of the Lepelle-Nkumpi local Municipality since they had a small population of 80 farmers. According to Admasu *et al*. (2017) the sample size of the cross-sectional study design of sheep farmers must be more than 70 farmers. Hence, the current study used all the sheep farmers.

3.6 Data collection

The data was collected using a semi-structured questionnaire (Annexure B). The questionnaire was pre-tested for validation. The questionnaire was given to the heads of individual households as they are responsible for sheep farming, but the other members of the households did add additional data/information. The questionnaire was translated into local language (Sepedi) so that the farmers could understand the questions. The data/information collected by the questionnaire included socio-economic statuses such as gender, age, marital status, purpose of keeping sheep, sheep farmer's breeding practices such as whether they practice castration or not and lastly ranking of their trait preferences in their farm.

The morphological traits such as: Body length, Rump height, Heart girth, Rump length and Withers height were measured following the procedure of Yakubu (2009). Body length (BL) was taken from the head of humerus to the distal end of the pubic bone. Rump height (RH) was measured from the top of the pelvic girdle to the ground surface in relation to the level of hind legs. Heart girth (HG) was measured by measuring the circumference of the chest. Rump length (RL) was measured from the hip to the pin.

Withers height (WH) was measured from the highest point of the shoulder to the ground surface in relation to the level of the fore legs. All the measurements were taken using tailor measuring tape and wood ruler that is calibrated in centimeters to ensure accuracy and also using one person to take the measurements as a way to avoid variation. In addition, the measurements were taken at around 8 am before the animals go grazing. This was done to avoid biases on certain traits due to feeding.

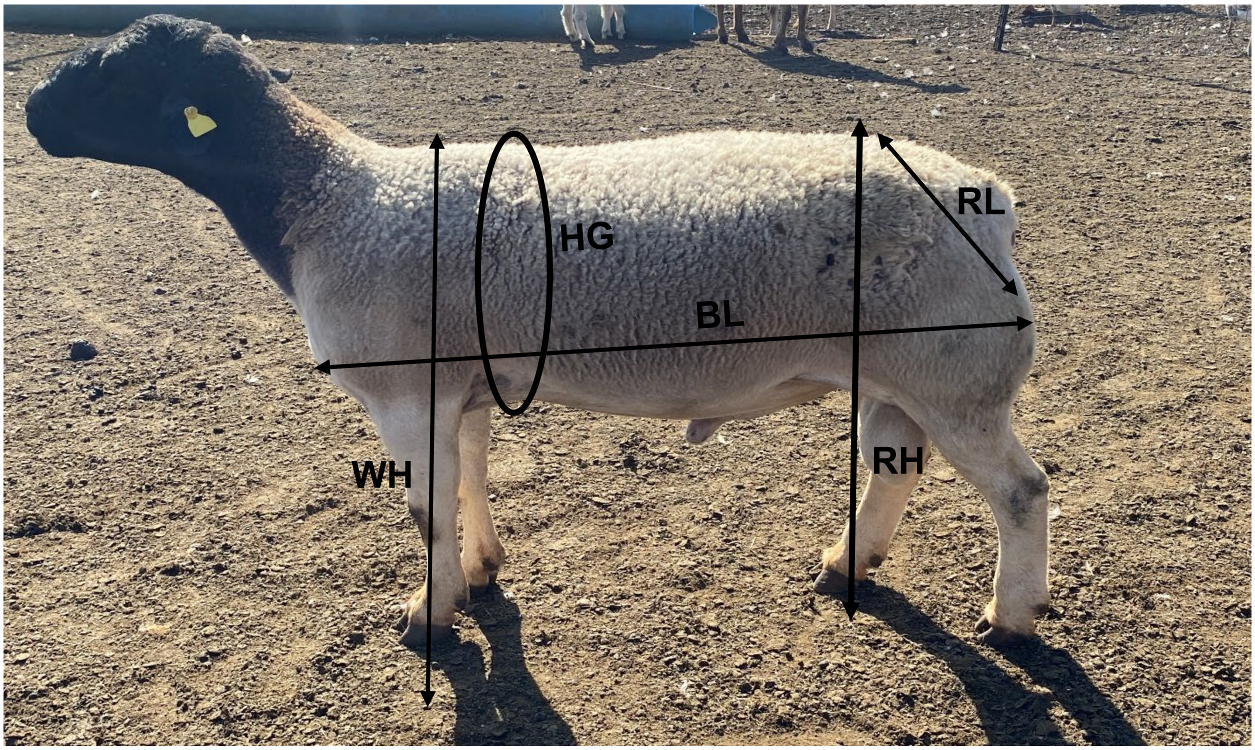

Figure 2: Illustration of linear body measurements taken on each sampled sheep.

3.7 Statistical analysis

The data was analyzed using Statistical Package for the Social Sciences (IBM SPSS 2022) version 27. Descriptive statistics such as frequency and percentage was used to achieve objective 1, 2 and 3. The index of ranking of preferred traits was used to achieve objective 3, as described by Zewdu *et al.* (2018). Index = sum (3 × rank1 + 2 × rank2 + 1 × rank3) for individual trait/sum (3 × rank1 + 2 × rank2 + 3 × rank1). A Chi-square ($\chi 2$) statistics was used to contrast the categorical variables between the two villages as well as the animal classes.

Classification and regression tree (CART) and Multivariate adaptive regression spline (MARS) was carried out to generate equations to determine the traits that can be used to estimate the live body weight of sheep.

3.7.1 Classification and regression tree tree (CART)

The Classification and Regression Tree (CART) algorithm was proposed by Breiman *et al.* (1984). With the CART algorithm, a binary split tree structure created by splitting a variable homogeneously includes the two sub-nodes. In the CART algorithm, the process began from the root node, including the initial data set, and continued until many homogeneous sub-nodes are gotten, which supplied the minimum error variance. This is general description, write in the context of your research data.

3.7.2 Multivariate adaptive regression spline (MARS)

MARS is a non-parametric regression method developed by Friedman (1991). The MARS algorithm was conducted as explained by Sengül *et al.* (2020a), and its prediction equation can be written as follows:

$$f(x) = \beta_0 + \sum_{m=1}^{m} \beta_m \lambda_m(x)$$

where $f(x)$ is the expected response, β_0 and β_m are parameters that are calculated to give the best data fit, and m is the number of BFs in the model. In the MARS model, the basis function is composed of a single univariable spline function or a combination of more than one spline function for diverse predictor inputs. The spline BF, $\lambda_m(x)$, is defined as:

$$\lambda_m(x) = \prod_{k=1}^{k_m} \left[S_{km}\left(X_{v(k,m)} - t_{k,m} \right) \right]$$

where $t_{k,m}$ denotes the knot location; s_{km} denotes the right/left regions of the corresponding step function, taking either 1 or −1; $v(k, m)$ denotes the predictor variable's label; and k_m is the number of knots. Following the procedure of Sengül *et al.* (2020b). The pruning process was used to remove the basic functions that had a low contribution to the model fitting performance following the generalized cross-validation error (GCV):

$$GCV(\lambda) = \frac{\sum_{i=1}^{n}\left(y_i - y_{ip}\right)^2}{\left(1 - \frac{M(\lambda)}{n}\right)^2}$$

where n represents the number of training cases, y_i shows the observed value of the responsible variable, y_{ip} as the estimated value of the response variable, and $M(\lambda)$ represents the penalty function for the complex of the model with λ terms.

The following goodness of fit test criteria were computed for training and test datasets:
Pearson's correlation coefficient (r):

$$r = \frac{cov(y_i\,, y_{ip}\,)}{S_{y_i} S_{Y_{ip}}}$$

Relative root mean square error (RRMSE):

$$RRMSE = \frac{\sqrt{\frac{1}{n}{,}\sum_{i=1}^{n}(y_i - \text{y}) \times 2}}{\bar{\text{y}}}$$

Mean error (ME):

$$ME = \frac{1}{n}\sum_{i=1}^{n}(y_i\, - y_{ip}\,)$$

Coefficient of determination (Rsq):

$$Rsq = 1 - \frac{\sum_{i=1}^{n}(y_{1\,-\,\hat{\text{Y}}_1})^2}{\sum_{i=1}^{n}(\,y_1 - \bar{\text{y}})^2}$$

Coefficient of determination is used to measure the proportion of variation explained by the independent variables for the dependent variable, where r represents the correlation coefficient between the fitted and observed body weight. Adjusted coefficient of determination ($ARsq$):

$$ARseq = 1 - \frac{\frac{1}{n-k-1}\sum_{i}^{n}(y_i - \hat{y}_i)^2}{\frac{1}{n-k-1}\sum_{i}^{n}(y_i - \bar{y})^2}$$

Root-mean-square error (RMSE):

$$RSME = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}$$

Where n shows the total number of samples used; y_i and $\hat{y}_i$ represent the observed and fitted weights of the ith animal, respectively. Standard deviation ratio (SDR): This is an evaluation measure that is used in assessing the performance of fitted models by taking the ratio of the observed to the fitted model's values.

$$SD_{ratio} = \sqrt{\frac{\frac{1}{n}\sum_{i=1}^{n}(\varepsilon_i - \bar{\varepsilon})^2}{\frac{1}{n-1}\sum_{i=1}^{n}(\varepsilon_i - \bar{\varepsilon})^2}}$$

Akaike information criteria (AIC): The method, AIC, is used in evaluating how good a model fits the data. It is used to choose the best for the data by comparing its fit to the data.

$$AIC = N\ Ln\left(\frac{SSE}{N}\right) + 2p$$

Mean absolute percentage error (MAPE): MAPE is another popular measure used to predict error. It is easy to understand and interpret as it measures the size of the error in percentage terms.

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{Y_i - \hat{Y}_i}{Y_i}\right| \times 100$$

Mean absolute deviation (MAD): MAD is used to avoid the issues of negative and positive errors cancelling each other out from the MAE. The smaller the MAD, the better the fit.

$$MAD = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{Y_i - \hat{Y}_i}{Y_i}\right|$$

Global relative approximation error (RAE):

$$RAE = \sqrt{\frac{\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)^2}{\sum_{i=1}^{n} Y_i^2}}$$

Coefficient of variance (CV):r g

$$CV = \sqrt{\frac{\frac{1}{n-1}\sum_{i=1}^{n}(\varepsilon_i - \bar{\varepsilon})^2}{\bar{Y}}} \times 100$$

where Yi is the observed live body weight (kg) of ith sheep; $\hat{Y}_i$ is the predicted live body weight value of the i^{th}sheep; $\bar{Y}$ is an average of the actual live body weight values of the Animals 2023, 13, 1146 5 of 11 sheep; ε_i is the residual value of the i^{th} sheep; an average of the residual values; k is the number of significant independent variables in the model, and n is the total number of sheep. The residual value of each goat is expressed as $\varepsilon_i = Y_i - \hat{Y}_i$.

CHAPTER 4

RESULTS

4.1 Socio-economic status of sheep farmers

Table 4.1 shows a description of the socio-economic status of sheep farmers in two villages of Lepelle-Nkumpi Local Municipality. The observed results indicated that the majority of sheep farmers from both villages were males, and there was no significant difference (P > 0.05) observed across gender between the villages. All the sheep farmers from Makurung village had tertiary background as their highest level of education, while in Lenting village majority (80.00%) of the sheep farmers had secondary education as their highest level of education, and there was a highly significant (P < 0.01) difference between the villages. All the interviewed sheep farmers from Makurung village were married, while in Lenting village, majority of the sheep farmers are married 24 (80%), and few 6 (20%) are single. However, there is a significant difference (P < 0.05) observed between the two villages in terms of marital status. Majority of the sheep farmers from the two selected villages, had their age range from 41 - 49, with only Lenting village having few farmers greater than 60 years of age. The majority of the sheep farmers in the two surveyed villages had 6-10 years' experience of farming with sheep. Furthermore, there was a highly significant (P < 0.01) difference between the villages on both age and years of farming with sheep.

Table 4.1: Socio-economic status of sheep farmers

	Villages			
	Makurung	**Lenting**		
Characteristics	**N %**	**N %**	**Chi-square**	**P-value**
Categorical variables				
Gender				
Male	31(77.00%)	18 (60.00%)		
Female	9 (22.00%)	12 (40.00%)	2.500	0.114
Marital status				
Single	0 (0.00%)	6(20.00%)		
Married	40 (100.00%)	24 (80.00%)		

Widow	0 (0.00%)	0 (0.00%)	8.750	0.003
Level of education				
Primary	0 (0.00%)	6 (20.00%)		
Secondary	0 (0.00%)	24 (80.00%)		
Tertiary	40 (100.00%)	0 (0.00%)	70.000	< 0.001
Age				
≤ 30	0 (0.00%)	0 (0.00%)		
31- 39	16 (40.00%)	0 (0.00%)		
41-49	24 (60.00%)	12 (40.00%)		
50-59	0 (0.00%)	7 (23.30%)		
> 60	0 (0.00%)	11 (36.70%)	37.333	< 0.001
Source of income				
Yes	32 (80.00%)	24(80.00%)		
No	8 (80.00%)	6 (80.00%)	0.000	1.000
What is the source of income?				
No source of income	0 (0.00%)	6 (20.00%)		
Salaries or wages	40 (100.00%)	0 (0.00%)		
Social grant	0 (0.00%)	24 (80.00%)	70.000	< 0.001
Belief system				
Christian	39 (97.50%)	18 (60.00%)		
African tradition	0 (0.00%)	6 (20.00%)		
Not religious	1 (2.48%)	6 (20.00%)	16.211	< 0.001
Years of farming with sheep				
≤ 5	13 (32.50%)	12 (48.00)48.0		
6-10	27 (67.50%)	13 (43.30%)		
11-19	0 (0.00%)	5 (16.70%)		
> 20	0 (0.00%)	0 (0.00%)	8.690	< 0.001

Continuous variable				
	Mean±SE	**Mean±SE**	F-value	P-value
Household size	7.60±0.31	6.60±0.53	2.910	0.090

4.2 Production objectives of sheep farmers

Table 4.2. shows the production objectives of sheep farmers at Makurung and Lenting villages. It is crucial to note that there were no significant differences (*p>0.05*) in the breeding objectives between the two villages. Majority of sheep farmers in Makurung village highlighted that the main objectives for keeping sheep was for meat (25.00%). Other reason for keeping sheep were for savings & investment (25.00%), ceremony/rituals (17.50%) and income (17.5%), While in Lenting village, the main reasons were for savings & investment (30.00%), income (20.00%) and meat (16.70%). However, there was no significant difference (P > 0.05) between the surveyed Villages.

Table 4.2: Purpose of keeping sheep

Purpose	**Villages**			
	Makurung N (%)	**Lenting N (%)**	**Chi-square**	**P-value**
Meat	10 (25.00)	5 (16.70)		
Savings & investment	10 (25.00)	9 (30.00)		
Dowry payment	2 (5.00)	4 (13.30)		
Ceremony/cultural rites	7 (17.5)	2 (6.70)		
Income	7 (17.5)	6 (20.00)		
Hides	2 (5.00)	1 (3.30)		
Manure	2 (5.00)	3 (10.00)	4.436	0.618^{ns}

4.3 Breeding practices of sheep farmers

Table 4.3 shows the breeding practices of sheep farmers in the two selected villages. The results indicated that the main breed kept in both villages was the Dorper followed by the

Dorper and Meat master, no household kept the Meat master breed only. The results indicated a significant difference (P < 0.05) between the villages in terms of the breed they are keeping. Majority of the farmers at Makurung and Lenting villages practiced uncontrolled mating with percentage values of 100.00% and 76.60%, respectively, and a highly significant difference (P < 0.01) was observed between the villages. There was a highly significant difference (P < 0.01) on the knowledge on inbreeding and method of castration between the surveyed villages. A larger proportion of farmers in both villages knew about inbreeding, with few 11 (36.70%) farmers in Lenting village having no knowledge about it. The results further discovered that majority of the farmers in both villages knew about the practice of castration and culling, whereby in Makurung village the most preferred method of castration was both rubber and burdizzo (60.00%) and while in Lenting village, only burdizzo (56.70%) was the most preferred method.

Table 4.3: Breeding practices of sheep farmers in the two villages

	Villages			
	Makurung	**Lenting**		
Characteristics	**N (%)**	**N (%)**	**Chi-square**	**P-value**
What sheep breeds do you farm with ?				
Dorper	32 (80.00%)	17 (56.70%)		
Both Dorper and Meat masters	8 (20.00%)	13 (43.30%)	4.444	0.035
Do you practice breeding prior to mating?				
Yes	40 (100.00%)	26(86.70%)		
No	0 (0.00%)	4 (0.00%)	5.657	0.017

What breeding methods do you use ?				
Improving indigenous	40 (100.00%)	30 (100.00%)		
Importing exotic	0 (0.00%)	0(0.00%)		
How do you improve breed ?				
Crossbreeding	16 (40.00%)	13 (43.30%)		
Pure breeding	24 (60.00%)	17(56.70%)	0.078	0.779
Mating system used				
controlled	0 (0.00%)	7 (23.30.%)		
Uncontrolled	40 (100.00%)	23 (76.70%)	10.370	0.001
Do you know about inbreeding ?				
Yes	40 (100.00%)	19 (63.30%)		
No	0 (0.00%)	11 (36.70%)	17.401	<0.001
Source of knowledge of inbreeding				
Books	16 (40.00%)	14 (46. 70%)		
Farming experiences	16 (40.00%)	4 (13.30%)		
From other farmers	8 (20.00%)	12 (40.00%)	37.333	<0.001
Do you practice culling?				
Yes	40 (100.00%)	26 (86.70%)		
No	0 (0.00%)	4 (13.30%)	5.360	0.464
The reasons for culling ?				
Low production	0 (0.00%)	4 (13.30%)		

Old age	24 (60.00%)	22 (73.30%)		
Both old age and low production	16 (40.00%)	4 (13.30%)	10.064	0.007
Do you practice castration?				
Yes	32 (80.00%)	26 (26.70%)		
No	8 (20.00%)	5 (16.70%)	0.013	0.723
The method of castration				
Rubber	8 (20.00%)	8 (26.70%)		
Machine	8 (20.00%)	17 (56.70%)		
Both rubber and machine	24 (60.00%)	5 (16.70%)	14.557	<0.001
The breeding season?				
Spring	40 (100.00%)	30 (100.00%)		

4.4 Trait preference of sheep farmers on breeding rams

Table 4.4 represents the rank and indices of trait preferences in breeding rams. The index was used for computing the importance of the preferred traits. The findings showed that mating ability (0.291) was ranked first from both villages, then followed by body size (0.250), growth rate (0.181), coat color (0.161), scrotal circumference (0.085), disease resistance (0.028) and sexual maturity (0.013).

Table 4.4: Rank and indices of trait preference in breeding rams

Traits	**Makurung (n = 40)**				**Lenting (n = 30)**				
	Rank 1	**Rank 2**	**Rank 3**	**Index**	**Rank 1**	**Rank 2**	**Rank 3**	**index**	**Overall index**
Mating ability	7	21	7	0.303	10	10	0	0.278	0.291
Body size	13	6	0	0.221	10	10	0	0.278	0.250

Growth rate	20	0	0	0.250	0	0	20	0.111	0.181
Coat color	0	13	13	0.154	10	0	0	0.167	0.161
Disease resistances	0	0	0	0.000	0	0	10	0.056	0.028
Scrotal circumference	0	0	14	0.058	0	10	0	0.111	0.085
Sexual maturity	0	0	6	0.025	0	0	0	0.000	0.013
temperament	0	0	0	0.000	0	0	0	0.000	0.000
Fighting ability	0	0	0	0.000	0	0	0	0.000	0.000

Index = sum (3 × rank1 + 2 × rank2 + 1 × rank3) for each individual preferred trait divided by sum (3 × rank1 + 2 × rank2 + 3 × rank1) for all preferred traits

4.5 Trait preference of sheep farmers on breeding ewes

Table 4.5 shows the rank and indices of trait preferences in breeding ewes. The index was used for computing the importance of the preferred traits. The findings showed that mothering ability (0.289) was ranked first then, followed by mating ability (0.181), lambing interval (0.168) and growth rate (0.113), body size (0.289) and disease resistance (0.028).

Table 4.5: Rank and indices of trait preferences in breeding ewes

Traits	**Makurung (n = 40)**				**Lenting (n = 30)**				
	Rank 1	**Rank 2**	**Rank 3**	**Index**	**Rank 1**	**Rank 2**	**Rank 3**	**Index**	**Overall index**
Twinning ability	13	6	21	0.300	10	10	0	0.278	0.289
Mothering ability	20	0	0	0.250	0	10	0	0.111	0.181
Lambing interval	7	20	6	0.279	0	0	10	0.056	0.168

Body size	0	7	13	0.113	10	0	0	0.167	0.140
Growth rate	0	7	0	0.058	0	10	10	0.167	0.113
Milk production	0	0	0	0.000	10	0	0	0.167	0.084
Disease resistance	0	0	0	0.000	0	0	10	0.056	0.028
Temperament	0	0	0	0.000	0	0	0	0.000	0.000
Mature body weight	0	0	0	0.000	0	0	0	0.000	0.000
Coat color	0	0	0	0.000	0	0	0	0.000	0.000

Index = sum (3 × rank1 + 2 × rank2 + 1 × rank3) for each individual preferred trait divided by sum (3 × rank1 + 2 × rank2 + 3 × rank1) for all preferred traits

4.6 Descriptive statistics of body weight and linear body measurements of sheep

Table 4.6 shows the descriptive statistics of body weight and linear body measurements of sheep based on sex. . The results indicated that from the two selected villages, BW in rams had a mean range of 31.76±SE to 46.67±SE and 35.60±SE to 46.18±SE in ewes, respectively.

Table 4.6: Descriptive statistics of body weight and linear body measurements of sheep

	Makurung		Lenting	
Traits	**N**	**Mean±SE**	**N**	**Mean**±SE
	Male (rams)			
Body weight	33	46.67±3.52	37	31.76±1.71
Rump height	33	66.94±01.48	37	61.78±0.49

Heart girth	33	81.97±2.72	37	70.22±1.37
Withers height	33	67.82±1.98	37	63.24±0.85
Body length	33	74.91±1.77	37	60.22±0.85
Female (ewes)				
Body weight	120	46.18±0.58	116	35.60±0.70
Rump height	120	68.80±0.40	116	65.81±0.27
Heart girth	120	83.09±0.52	116	72.95±2.00
Withers height	120	65.43±0.52	116	63.57±0.36
Body length	120	71.55±0.55	116	60.17±0.52

4.7 Correlation between body weight and linear body measurements at Makurung village

Table 4.7 shows the phenotypic correlation between body weight and linear body measurements, where the above diagonal represents the males, and the below diagonals is for females. In males (rams), BW had a highly significant correlation (P < 0.01) with RH, HG, RL, WH and BL. While in female (ewes), BW had a highly significant correlation (P < 0.01) with RH, HG, a significant correlation with WH and BL but a negatively non-significant correlation (P > 0.05) with RL.

Table 4.7: Phenotypic correlation for male above diagonal and female below diagonal

	BW	RH	HG	RL	WH	BL
BW	-	0.88**	0.99**	0.78**	0.84**	0.98**
RH	0.58**	-	0.87**	0.70**	0.791**	0.87**
HG	0.74**	0.55**	-	0.73**	0.82**	0.99**
RL	-0.15^{ns}	0.08	0.22	-	0.76**	0.68**
WH	0.29*	0.57**	0.06	-0.09	-	0.79**
BL	0.39*	0.34*	0.61**	-0.27*	-0.15^{ns}	-

BW: body weight, RH: rump height, HG: heart girth, RL: rump length, WH: withers height, BL: body length, ** : correlation is significant at the 0.01 level, * : correlation is significant at the 0.05 level, ^{ns} : no significant

4.8 Correlation between body weight and linear body measurements at Lenting village

Table 4.8 shows the phenotypic correlation between body weight and linear body measurements, where the above diagonal represents the males, and the below diagonals is for females. In males (rams), BW had a highly significant correlation ($P < 0.01$) with HG, RL, WH, and BL but a non-significant correlation ($P > 0.05$) with RH. In females (ewes), BW had a highly significant correlation ($P < 0.01$) with RH, HG, RL, WH and BL.

Table 4.8: Phenotypic correlation for male above diagonal and female below diagonal

	BW	RH	HG	RL	WH	BL
BW	-	0.32^{ns}	0.92**	0.75**	0.73**	0.81**
RH	0.57**	-	0.11	0.30	0.51**	0.25
HG	0.88**	0.60**	-	0.71**	0.76**	0.84**
RL	0.53**	0.51**	0.54**	-	0.77	0.78**
WH	0.65**	0.56**	0.66**	0.43**	-	0.79**
BL	0.64**	0.46**	0.52**	0.55**	0.61**	-

BW: body weight, RH: rump height, HG: heart girth, RL: rump length, WH: withers height, BL: body length, ** : correlation is significant at 0.01 level, * : correlation is significant at 0.05 level, ^{ns} : not significant

4.9 Classification and regression model

Figure 2 indicates the regression tree diagram constructed by CART algorithm in prediction of body weight from linear body measurements. The algorithms produced an optimal tree structure of seven terminal nodes (node 6, 7, 8, 9, 10, 11 and 12). The influential predictors of LBW as a responsible variable were HG and WH. At the top of the regression diagram, the overall live body weight of sheep was recorded as 40 kg. At the first tree depth, LBW average (53 kg) of sheep with HG ≥ 81 cm was heavier by 18 kg than the average (35 kg) of sheep with HG ≤ 81 cm. At the second tree depth, LBW (51 kg) of sheep with 102 cm < HG ≥ 81 cm was found to be lighter by 29 kg than the average (80 kg) of sheep with 102 cm ≥ HG ≥ 81 cm at the fourth tree depth. LBW average (55 kg) of sheep with 81 cm ≥ HG < 102 cm and HG ≥ 89 cm was found to be heavier by 6 kg than the average (42 kg) sheep with 81 cm < HG < 102 cm and HG < 89 cm. LBW average (26 kg) of sheep with 71cm < HG < 81 cm. Sheep with 71 cm < HG < 81 cm and WH < 60 cm gave the lightest LBW of 22 kg, but the heaviest LBW average was obtained from sheep with 71 cm < HG < 81 cm and HG ≥ 78 cm.

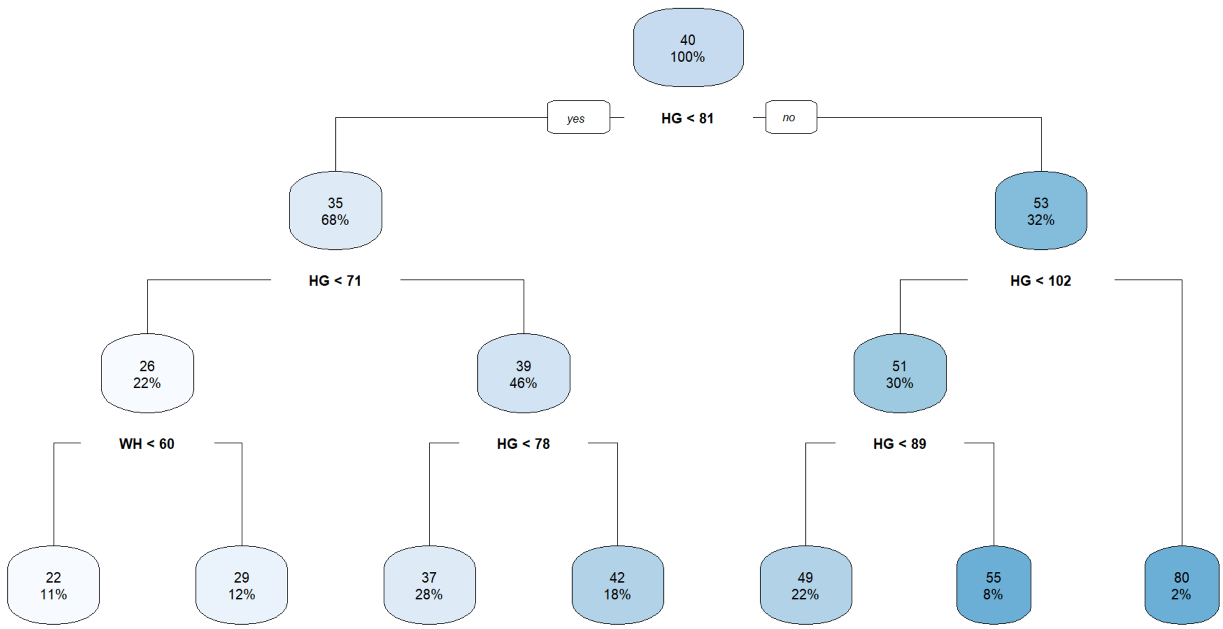

Figure 3: CART algorithm model

4.10 Multivariate adaptive regression splines model

Table 4.9 represents the model established by the MARS data mining algorithm. The results showed that HG, WH, BL, RH and Village were involved in the model. The findings discovered eight basic functions from the MARS model, with five single-order term variables ,four orders of interactions and an intercept of 46.215. MARS described the influence of linear body measurements with the negative and positive coefficients on BW. Briefly, the influence on BW of non-descript sheep was in the positive direction when HG > 80 cm with model coefficient of 1.456 and negative direction with a model coefficient of 0.550 when WH > 62, < 62cm, BL was < 77 and >77cm, with coefficient values of (-1.02), (-0.55), (-0.933) and (-1.241), respectively. Additionally, the model revealed the effect of linear measurement interactions on BW. The influence on BW was positive when the interaction of village Makurung and HG > 65 cm ,HG > 65cm and BL< 73cm, RH > 68cm, HG > 65cm and WH > 60cm with coefficient values of 0.225, 0.057 and 0.002, respectively. The influence on BW was negative when interaction RH < 68cm, HG > 65cm and WH > 65cm with a coefficient value of -0.008.

Table 4.9: Multivariate adaptive regression splines algorithm

BF	Equations	Coefficients
Intercept		46.215
BF1	max (0; HG - 80)	1.456
BF2	max (0; 62 -WH)	-1.021
BF3	max (0; WH - 62)	-0.550
BF4	max (77- BL)	-0.933
BF5	max (0; BL - 77)	-1.241
BF6	(Villages-Makurung)*max (0; HG - 65)	0.225
BF7	Max (0; HG-65)* max (0; 73 - BL)	0.057
BF8	Max (0; 68- RH)*max (0; HG-65)*max (0; WH - 60)	-0.008
BF9	Max (0; RH-68)*max (0; HG- 65)*max (0; WH-60)	0.002

BF: basic functions, max: max, HG: heart girth, WH: withers height, BL: body length, RH: rump height

4.11 Predictive performance of data mining algorithms

Table 4.10 represents the goodness of fit criteria used for measuring predictive performance between MARS and CART data mining algorithms. Among the statistical algorithms, the MARS algorithm had the maximum estimation precision compared to CART algorithms. Although the two algorithms could estimate the actual and predicted BW, MARS had better goodness of fit with the r ranging from 0.966 to 0.931.

MARS shows higher predictive performance in the criteria than CART algorithm (Table 4.10)

Table 4.10: Goodness of fit criteria for MARS and CART algorithm

CRITERIA	MARS		CART		
	Training	Test	Training	Test	Decision
Root mean square error (RMSE)	2.958	3.464	3.470	4.053	Smaller is better
Relative root mean square error (RRMSE)	7.337	8.477	8.608	9.918	Smaller is better
Standard deviation ratio (SDR)	0.259	0.306	0.304	0.366	Smaller is better
Coefficient of variation (CV)	7.350	8.280	8.630	9.890	Smaller is better
Person's correlation coefficients (r)	0.966	0.953	0.953	0.931	Greater is better
Performance index (PI)	3.732	4.340	4.408	5.136	Smaller is better
Mean error (ME)	0.000	0.826	0.000	0.516	The expected value is zero
Relative approximation error (RAE)	0.005	0.007	0.007	0.009	Smaller is better
Mean absolute percentage error (MAPE)	6.502	7.767	7.662	9.183	Smaller is better
Mean absolute deviation (MAD)	2.258	2.729	2.755	3.291	Smaller is better
Coefficient of determination (Rsq)	0.933	0.900	0.908	0.864	Greater is better
Adjusted coefficient of determination(ARsq)	0.930	0.887	0.908	0.864	Greater is better
Akaike's information criterion (AIC)	488.519	243.658	537.497	251.906	Smaller is better

CHAPTER 5

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Discussion

Community-based breeding programs (CBBP) attempt to achieve genetic improvement of livestock populations by directly involving the farmers from the design of such programs to the actual breeding actions (Nandolo *et al.,* 2016). The first part of this study looked at the socio-economic status of sheep farmers at Makurung and Lenting villages using frequencies and means. The results discovered that majority of the households in both villages were male headed. The findings are consistent with the study of Abebe *et al.* (2020) on smallholder sheep farmers in Northwest Highlands of Ethiopia, who found that majority of the sheep farmers who are heads of households are males. This is mainly because of the traditional and cultural customary patterns that exist in the rural areas where men are considered the head of the family (Tyasi *et al.,* 2022). The results showed that the majority of the sheep farmers in the two selected villages were aged between 41-49, with few above 60 years. The findings are consistent with the findings of De Aguiar *et al.* (2020), who found that majority of the sheep farmers in Hamus's region, Ceara, Brazil, had an age range of 40 to 50 years old. However, a study by Abera *et al.* (2014) recorded majority of the farmers having their age ranging from 51- 70, in Ethiopia (Selale area). Farmers in both villages had their highest level of education, which was secondary to tertiary level, with few farmers in Lenting having primary education. However, Kefale *et al.* (2017), Bolowe *et al.* (2022) and Hassen *et al.* (2022) on farmers in South Wollo zone of Ethiopia, four districts of Botswana and Somali regional state of Ethiopia, reported a different result with a higher proportion of farmers having primary education and being illiterate. This could be due to old farmers engaging in farming, with age ranges of 51 to 60 and some greater than 70 years. Furthermore, the results showed that there is a higher proportion of married farmers, and this is consistent with the findings of Yakubu *et al.* (2020), who found that in sub-humid tropical environment of Ethiopia, a large proportion of sheep farmers who are household heads were married. Bolowe *et al.* (2022), on the other hand, reported that many farmers in four districts of Botswana were not married. This could be due to social reasons, as it is easier to farm with small stock than cattle farming as a way to sustain their lives. The findings of this study imply that sheep farming in Makurung and Lenting is practiced by farmers who are able to read and write effectively; as such, it will be easier to engage and adopt the community-based breeding program that will be developed. Having documented the socio-economic status of sheep farmers at the two selected villages, it is important to derive the knowledge for keeping small ruminants as it is a prerequisite for deriving operational breeding goals (Jainter *et al.,* 2001). The study looked at the purpose of keeping sheep in the two selected villages, using frequency, percentages, and chi-square. The primary reason for keeping sheep in the two selected villages was for savings and investment, followed by meat, income and ceremony/cultural. The high dependency of sheep farmers on keeping sheep for savings & and investment observed in this study was attributed to their proximity to urban or peri-urban areas (Lebowakgomo) where they have other means of income other than agricultural activities. Furthermore, the majority of the farmers in both villages are educated and, therefore, have formal employment. As such, they invest the money in sheep farming. A similar observation was made by Monau *et al.* (2017), who reported that indigenous Tswana goat farmers in the Southern region of Botswana preferred having work as a major source of income over livestock sales. However, Kosgey *et al.* (2008) and Garcia (2013) found that Gambian livestock owners and sheep farmers in Kenya owners kept their sheep primarily for income. It must be recognized that the different roles that sheep played in the livelihoods of farmers in this study are a direct reflection of the farmer's various objectives for sheep production. Furthermore, Mthi *et al.* (2020) found contradicting results to the current study whereby wool production, meat and donation were the main production of sheep farmers in Eastern Cape Province South Africa. The differences in the results found by different authors could be due to the different geographical areas that the farmers occupy and the different living conditions. Furthermore, the farmers do not keep for milk and wool; this may be due to lack of knowledge and how uncommon it is in South Africa to consume sheep milk and in most cases, the sheep breeds used in rural areas are meat breeds. Despite the different ranking priorities, the farmers in both villages reported that they kept sheep for multipurpose. This is in agreement with Jimmy *et al.* (2010) and Tesfaye *et al. (*2008), who reported that sheep were reared for multiple reasons so as to maximize output from an animal that can survive on low resource input. As such, the current findings suggest that keeping sheep for income and meat for household consumption was a common reason and a great alternative source of income for farmers in village settings. This is supported by Welday *et al.* (2019), who highlighted that sheep and goats are relatively cheap and often the first assets acquired by the community; as such, the farmers find it easier to keep them for savings/investment, meat and income. The current findings imply that sheep can be kept as a great alternative source of income and meat for household consumption, especially at a village level. This is supported by Mengesha *et al.* (2012), who highlighted that sheep and goats are relatively cheap and often the first assets acquired by the community; as such, the farmers find it easier to keep them for savings and investment, meat and income. Given the broadness of the purposes that farmers have for keeping sheep, much care is also needed when choosing the trait preferred by farmers since they help to achieve their purposes (Kosgey *et al.,* 2008 and Jimmy *et al.,* 2010). As such, the study looked at the trait preferences for breeding rams and ewes using index of ranking. In rams, it was discovered that mating ability was ranked first by the sheep farmers in the two surveyed villages, followed by body size, growth rate, coat color and scrotal circumference. This finding are consistent with the findings of Kebede *et al.* (2008) who indicated that mating ability was a preferred trait for breeding bucks in central Rift Valley of Ethiopia. However, the findings of the current study were consistent with those of Getachew *et al.* (2010) in cool highland (Menz) and arid and semi-arid lowland (Afar region) of Ethiopia, who found that the primary pertaining criteria for the selection of breeding ram was appearance. The difference in the ranking and preferred traits suggest that sheep farmers in the areas wanted more production hence they chose mating ability over coat color. With regard to the trait preferences of sheep farmers in breeding ewes in the two selected villages, the main preferred trait was twinning ability, followed by mothering ability, lambing interval, and body size. The results are consistent with the findings of Welday *et al.* (2019), who found that the main preferred ewe trait by sheep owners in selected zones of Tigray, Northern Ethiopia, was twinning ability. Similarly, Getachew *et al.* (2010) found that mothering ability was ranked second by Menz sheep owners in Ethiopia's mixed crop-livestock system. However, Bolowe *et al.* (2022) reported different results from the current study, with body size ranked second in terms of preferred traits for ewe by Indigenous Tswana sheep farmers in Southern districts of Botswana. Similarly, a study by Zewdu *et al.* (2012) in Western (Adiyo haka) and South-Western districts (Horro) Ethiopia indicated that the top preferred traits was body size, which got ranked first and coat color, which got ranked second. The heterogeneity of traits preferred by farmers is mainly on the level of how much one trait is preferred over the other. Subsequently, Abebe *et al.* (2020) and Hemacha *et al.* (2022) reported a different result from the current study with body size and coat color as among the most preferred traits by sheep farmers in Northwest highland and Hadiya zone of Ethiopia. The findings of this current study imply that sheep farmers preferred mating ability in rams as this can increase the size of the herd. Physical traits such as body size/appearance and growth rate are associated with high carcass output and a higher selling price. Furthermore, the high preference for twinning ability, mothering ability and lambing interval is a way to get more production and have lambs that are well nourished; as such, they have an increased chance of survival.

According to Kosgey *et al.* (2004), characterizing the current production systems and breeding practices of sheep breeds in their habitat is the first step to improving the small ruminant sector. Therefore, the study focused on the breeding practices of sheep farmers at Makurung and Lenting villages of Lepelle-Nkumpi Local Municipality, using frequencies and means. The findings demonstrated that in the two study areas, mating was mainly uncontrolled, with little report of controlled mating in sheep farmers from Lenting village. The results are consistent with the findings of Adimasu *et al*. (2019), Getachew *et al.* (2010) and Abera *et al.* (2014), who reported that the mating system of small ruminants under smallholder farmers are predominantly uncontrolled. The sheep farmers who practiced uncontrolled mating have highlighted that they try to identify the sire of the lamb after birth by using color and appearance. Rams ran together with ewe throughout the year, and castration was a common practice, with few sheep farmers in both villages not practicing it. The results of this current study are consistent with the findings of Hemacha *et al.* (2022), who found that a larger proportion of respondents in Duna and Misha districts of Ethiopia have practiced ram castration. However, Dossa *et al.* (2015) found a different result from the current study with low practice of castration, especially among sheep and goat farmers in Kano (Nigeria), Bobo Dioulasso (Burkina Faso) and Sikasso (Mali). This is mainly due to the small flock size. Another experience that the sheep farmers in both villages had been the practice of culling. The reasons for culling were due to both low production and old age. These findings are in agreement with the findings of Ejlesten *et al.* (2012), who reported culling of inferior and old animals. However, Abebe *et al.* (2020) reported different results from the current study, with reasons for culling their sheep being small body size, unfavorable coat color, old age, and fertility problems in both male and female sheep.

The majority of the sheep farmers in the two selected villages knew inbreeding, with only a few farmers in Lenting village not having any knowledge about it. This is consistent with a study by Edea *et al.* (2012), who found that in a household owning greater than 10 animals, seven of the one respondents reported knowing about inbreeding Furthermore, Ejlesten *et al.* (2012) indicated that keepers who have been keeping sheep for long time may have more knowledge when it comes to issues relating to inbreeding as compared to the ones who just started, however this does not automatically translate into a difference in practices. The findings imply that the sheep farmers are aware and are practicing castration and culling methods, not necessarily to improve productivity, but rather as ways to get rid of the sheep that are considered not productive and not aligning with the production objectives. Hence, the current study looked at the association between body weight and some morphometric characteristics of Dorper and Meat master sheep in the Lepelle-Nkumpi Local municipality.

The study used phenotypic correlation to determine the association between body weight and some morphometric traits in the two selected villages. With rams in Makurung village, body weight had a highly significant correlation with rump height, heart girth, rump length, wither height and body length. While with rams of Lenting village, body weight had a positive, highly significant correlation with heart girth, withers height and body length but a non-significant correlation with rump height. The findings of the current study were consistent with those of Mavule *et al.* (2013), Ebadu *et al.* (2022), and Kuthu, (2023), who found that body length, heart girth and heart width had the highest correlation with body weight in Zulu sheep in rural communities of KwaZulu-Natal province, Gumer sheep in Gumer district Ethiopia and Pahari sheep in Azad Jammu & Kashmir region of Pakistan, respectively. Subsequently, Okpeku *et al.* (2011) reported that there was a positive and significant correlation between live body weight, height at withers, neck length, heart girth and body length in Red Sokoto and West African Dwarf goats. In contrast to the current findings, Mohammed *et al.* (2017) discovered that rump height was strongly correlated with body weight in male indigenous Ethiopian sheep in three districts in South Wollo, Ethiopia. With ewes in Makurung village, body weight had a highly significant correlation with rump height, heart girth, but a negatively non-significant correlation with rump length. While in Lenting village, body weight had a highly significant correlation with rump height, heart girth, rump length, withers height and body length. The findings of the current study were consistent with those Jannah *et al.* (2023), who found that body length had the highest correlation with body weight in female sukab sheep in Brebes district of Indonesia and Asefa *et al.* (2017), who found that body weight was strongly correlated with chest girth, body length, rump height in indigenous sheep types in Bale zone and Oromia Regional state, Ethiopia. However, Gebreyowhens and Tesfay (2016) found different results in indigenous highland sheep population of Tigray, Ethiopia, where body weight was strongly correlated with rump length. This could be due to the different environmental conditions and also the breed type.

The correlation results of the current study imply that increasing heart girth, withers height and body length will increase body weight of sheep, and farmers may use these results as indirect selection criterion during breeding to improve body weight. The relationship found that morphometric traits (heart girth, withers height and body length) and body weight might be controlled by a single gene (Maiwashe *et al.,* 2002). The phenotypic correlation of the linear body measurement does not provide the prediction of body weight; as such, the study used Multivariate Adaptive Regression Splines (MARS) and Classification and Regression Tree (CART) algorithms to establish a model to estimate body weight from morphometric traits. MARS model showed that heart girth, withers height, body length, rump height, and village (where the Dorper and Meat master sheep were bred and raised) can be used to predict body weight of Dorper and Meat master sheep. The findings discovered that heart girth is the best explanatory variable for the prediction of body weight. The findings are consistent with the findings of Rashijane *et al.* (2023), who found that heart girth was the best explanatory variable in savanna goats.

In contrast to the current findings, Agyar *et al.* (2022) found that from the MARS model results, body length is the best explanatory variable in Anatolian buffaloes in Turkiye. Similarly, Fatih (2021) found that shoulder height was the best explanatory variable in Marecha (Camelus dromedaries) camels in Pakistan. This might be due to different environmental conditions and species used in the study. CART model findings indicate that heart girth and withers height can be used as influential predictors of body weight in Dorper and Meat master sheep. The findings discovered that heart girth is the best explanatory variable for prediction of body weight. The findings of the current study were consistent with the study of Tirnink *et al.* (2023), who discovered that from the CART model, heart girth was the best explanatory variable in Polish Merino and Suffolk rams. Similarly, Yakubu *et al.* (2012) found results that are in agreement with the current study, where result from the current one with chest circumference as the best explanatory variable in Uda sheep in Nasarawa state, north central Nigeria. Likewise, Faraz *et al.* (2021) found different results from the current study, with body length as the best explanatory variable in Thalli sheep under tropical conditions in Pakistan. The findings of this study suggest that farmers can use heart girth to estimate the body weight of their sheep.

The study further looked at the performance of the MARS and CART models using goodness of fit criteria. The results discovered that the performance of the MARS and CART algorithms were nearly identical. However, MARS performed well, showing higher values on Pearsons's correlation coefficient (r), coefficient of determination (Rsq), adjusted coefficient of determination (ARsq), and lower standard deviation ratio (SDR). The findings of the current study are consistent with the findings of Fazaz *et al.* (2021) where MARS model was found to be the best model for the estimation of body weight in Thalli sheep under tropical conditions of Pakistan. However, Celik *et al.* (2017) found different results from the current study, where CART model performed the best when predicting the body weight of Mangali rams of Pakistan. The findings were consistent with the findings of Sengül et al. (2020), where MARS was found to be the best model when predicting body weight of Kivircik lambs at Bursa Uladag University Animal Agricultural

Application and Research Center in Turkiye. The difference could be due to the variation in age, breed and environmental factors.

5.2 Conclusion

In conclusion, this study provides insight into socio-demographic and economic status, production objectives, traits preferences, breeding practices encountered in sheep farming while determining the relationship between linear body measurements and using data mining algorithms to determine body weight in the selected study area. The majority of the sheep farmers' households are male-headed and between the ages of 41 and 49, with a few sheep farmers over 60 years old. A large proportion of the sheep farmers are married with secondary to tertiary as their highest level of education. Sheep in the surveyed villages were mainly kept for saving and investment, followed by meat, income and ceremony/cultural rites. Sheep farmers have shown the highest preference for mating ability for rams, followed by body size, growth rate and coat color, while the highest preference in ewes was shown for twinning ability, followed by mothering ability, lambing interval and body size.

Mating usually occurred everywhere as the majority of the farmers practiced an uncontrolled mating system. Culling was very common in the study areas, with old age being the primary reason. The majority of sheep farmers in the study areas used rubber and burdizzo to castrate their sheep. Body length, withers height and heart girth were found to be highly correlated with body weight in the present study, as such, it may be used as a selection criterion in both sexes (rams and ewes) when selecting sheep for breeding. The variation in the findings of this current study could be used by South African Dorper and Meat master sheep farmers in the Lepelle-Nkumpi to improve and estimate body weight from morphometric traits so that they can make good decision such as selecting good rams and ewes for breeding as well as implementing a vaccination programme.

Furthermore, The MARS and CART models revealed that heart girth, wither height, body length and village can be used to estimate body weights in sheep. The two models suggested that heart girth alone could be used to predict body weight in rams and ewes of Dorper and Meat master sheep. Although the results discovered that the performance of the MARS and CART algorithms were nearly identical, MARS performed well, where it showed higher values on Pearsons's correlation coefficient (r), coefficient of determination (Rsq), adjusted coefficient of determination (ARsq) and lower Standard deviation ratio (SDR), coefficient of variation (CV), Relative root mean square error (RRMSE) and Standard deviation ratio (SDR). Furthermore, the usage of MARS algorithms may be useful tool when it comes to estimating live body weight and help in increasing the productivity of sheep in South Africa.

5.3 Recommendation

Based on the findings of the present study, recommendations are:

- The level of productivity is low, and less attention is given to husbandry and breed improvement. Therefore, to increase productivity, it is important to involve farmers, researchers, agricultural extension workers and other stakeholders in designing to implement a community based breeding programme by considering the existing production objectives, trait preferences and breeding practices that have been documented in this study.
- Researchers and extension officers must organize workshops to educate the farmers about the influence of qualitative traits such as coat color on the selling and buying of sheep at a community level and quantitative traits such as scrotal circumference on sheep productivity since, as seen in the study it was received the lowest ranking.
- Researchers need to research more about the on-farm performance evaluation so as to understand the uniqueness of the two breeds to improve their production sizes.
- Selecting breeding rams using HG so they can have easier copulation for mating.

CHAPTER 6

REFERENCES

6.1 References .

Abebe, A.S., Alemayehu, K., Johansson, A.M and Gizaw, S. 2020. Breeding practices and trait preferences of smallholder farmers for indigenous sheep in the northwest highlands of Ethiopia: Inputs to design a breeding program. *Public library of science one*, *15*(5): 23.

Abegaz, S., Van, W and Olivier J. 2010. Estimates of (co) variance function for growth to yearling in Horro sheep of Ethiopia using random regression model. *Archives Animal Breeding*, 53(6): 689-700.

Abera, B., Kebede, K and Gizaw, S. 2014. Indigenous breeding practices and selection criteria of sheep breed in Selale area, Central Ethiopia. *International journal of livestock research*, *4*(7): 49-56.

Abera, M., Kebede, K., Mengesha, Y. 2016. Phenotypic characterization of indigenous sheep types in Northern Ethiopia. *Journal of Natural Sciences Research*6 (15): 16-2.

Abraham, H., Gizaw, S and Urge, M. 2018. Identification of breeding objectives for Begait goat in western Tigray, North Ethiopia*. Tropical Animal Health and Production,* 50(8): 1887-1892.

Adimasu, E., Almayehu, K and Getachew, T. 2019. Breeding Objective, Breeding Practices and Selection Criteria of Indigenous Sheep in Western Amhara, Ethiopia. *International Journal of Sustainable Agricultural Research*, *6*: 172-182.

Admasu, L., Aberra, M and Sandip, B. 2017. Traditional sheep production systems and breeding practice in Wolayita Zone of Southern Ethiopia. *African Journal of Agricultural Research*,*12*(20): 1689-1701.

Agricultural Strategy for Capricorn District Municipality, 2009. Lepelle-Nkumpi LED Review: Annexure 2: Sectoral analysis.

Agyar, O.,Tırınk, C., Önder, H., ¸Sen, U., Piwczy ´nski, D., Yavuz, E. 2022. Use of Multivariate Adaptive Regression Splines Algorithm to Predict Body Weight from Body Measurements of Anatolian Buffaloes in Türkiye. Animals, 12: 2923.

Alemayehu, A. 2011. Phenotypic characterization of indigenous sheep types of Dawuro zone and Konta special woreda of SNNPR, Ethiopia. [Thesis]. School of Graduate Studies of Haramaya University, Dire Dawa, and Ethiopia. Available at https://www.researchgate.net/profile/Amelmal-Alemayehu/publication. 30 October 2022.

Alemayehu, T and Tikab, G. 2010. Application of Linear Body Measurements for Live Body Weight Estimation of Highland Sheep in Tigray Region, North-Ethiopia. Journal of the Drylands,3(2): 203-207.

Asefa, B., Abate, T and Adunga, E. 2017. Phenotypic characterization of indigenous sheep types in Bale Zone, Oromia Regional State, Ethiopia. *Journal of Veterinary Science and Technology*, *8*(4): 1-7.

Bebe, O.B., Udo, H.M.J., Rowlands, G.J andThorpe, W. 2003. Smallholder dairying systems in the Kenya highlands: cattle population dynamics under increasing intensification. *Livestock Production Science*, 3(2): 9-12.

Becker, S.J and Fourie, P.J. 2021. Phenotypic characterization of Meatmaster sheep using quantitative and qualitative trait analysis. *Tropical Animal Health and Production*, *53*(2): 326.

Bello, A.A and Adama, T.Z. 2012. Studies on body weight and linear body measurements of castrates and non-castrate savannah brown goats. *Asian Journal of Animal Sciences*, *6*(3): 140-146.

Bireda W, Kebede K, Mekasha Y, Bejano S. 2016. Phenotypic characterization of black head Somali sheep in Gode and Adadile Districts, Ethiopia. *Globa Veterinaria*,17 (3): 265-270.

Birteeb, P.T., Peters, S.O., Yakubu, A., Adeleke, M.A and Ozoje, M.O. 2012. Multivariate characterisation of the phenotypic traits of Djallonke and Sahel sheep in Northern Ghana. *Tropical Animal Health and Production, 45*(1): 267-274.

Bolowe, M.A., Thutwa, K., Kgwatalala, P.M., Monau, P.I and Malejane, C. 2021. On-farm phenotypic characterization of indigenous Tswana sheep population in selected Districts of Southern Botswana. *African Journal of Agricultural Research*, 17 (10): 1268-1280

Bolowe, M.A., Thutwa, K., Monau, P.I., Malejane, C and Kgwatalala, P.M. 2022. Production characteristics and management practices of indigenous Tswana sheep in southern districts of Botswana. *Animals*, *12*(7): 830.

Breiman, L., Friedman, J.H., Olshen, R.A and Stone, C.J. 1984. Classification and regression trees Belmont. *CA: Wadsworth International Group*.

Celik, S and Yilmaz, O.2017. Comparison of different data mining algorithms for prediction of body weight from several morphological measurements in dogs. *JAPS: Journal of Animal & Plant Sciences*, *27*(1).

Chang'a, E.P., Chasama, G.L. and Kifaro, G.C. 2023. Phenotypic Characteristics of Red Maasai Sheep in Arumeru and Monduli Districts in Tanzania. *Asian Journal of Research in Animal and Veterinary Sciences*, *6*(3): 295-305.

Dagnew, Y., Urge, M., Tadesse, Y and Gizaw, S. 2017. Sheep production and breeding systems in northwestern lowlands of Amhara region, Ethiopia: implication for conservation and improvement of Gumz sheep breed. *Open Journal of Animal Sciences*, *7*(02): 179.

De Aguiar, A.L., da Silva, R.R., Alves, S.M., da Silva, L.P., de Morais, O.R and Lobo, R.N.B. 2020. Breeding objectives and selection criteria of a participatory community-based breeding programme of goats and sheep. *Tropical Animal Health and Production*, *52*1: 933-1943.

Department of Agriculture, Forestry and Fisheries (DAFF). 2011. A profile of the South African mutton market value chain. *Department of Agriculture, Forestry and Fisheries, Pretoria*. Available at https:www.dalrrd.gov.za. 24 March 2022.

Dossa, L.H., Sangaré, M., Buerkert, A.C and Schlecht, E. 2015. Production objectives and breeding practices of urban goat and sheep keepers in West Africa: regional analysis and implications for the development of supportive breeding programs. *Springer Plus*, 4: 281.

Ebadu, A and Habtamu, E. 2022. Research Article Evaluation of Phenotypic and Morphometric Characteristics in Community Based Breeding Program of Gumer Sheep. *Asian Journal of Animal Sciences,* 16: 21-28.

Edea, Z. 2008. Characterization of Bonga and Horro Indigenous Sheep Breeds of Smallholders for Designing Community Based Breeding Strategies in Ethiopia An M.Sc. Haramaya University, Dire Dawa, Ethiopia. Available at https:core.ac.uk/download/pdf/132679007.pdf. 5 September 2022.

Edea, Z., Haile, A., Tibbo, M., Sharma, A.K., Sölkner, J and Wurzinger, M. 2012. Sheep production systems and breeding practices of smallholders in western and south-western Ethiopia: Implications for designing community-based breeding strategies. *Livestock Research for Rural Development*, *24*(7): 2012.

Ensiminger, M.E. 2002. Sheep and Goat Science 6th ed. Interstate publishers, Inc. U.S.A. p82.

Epstein, H. 1971. The origin of the domestic animals of Africa. African Publishing Corporation (APC), New York, U.S.A, 1: 670.

FAO (Food and Agriculture Organization of the United Nations). 2011. Draft guidelines on phenotypic characterization of animal genetic resources. FAO, Rome, Italy. Available at https://www.semanticscholar.org/paper/DRAFT-GUIDELINES-ON-PHENOTYPIC-CHARACTERIZATION-OF/98d6adebbbf26e88bb17eefcf05ed077085341af.pdf. 19 June 2022.

Faraz, A., Tirink, C., Eyduran, E., Waheed, A., Tauqir, N.A., Nabeel, M.S., Tariq, M.M. 2021. Prediction of live body weight based on body measurements in Thalli sheep under tropical conditions of Pakistan using CART and MARS. Trop. Anim. Health Prod, 53: 301.

Fatih, A., Celik, S., Eyduran, E., Tirink, C., Tariq, M.M., Sheikh, I.S., Faraz, A and Waheed, A. 2021. Use of MARS algorithm for predicting mature weight of different camel (Camelus dromedarius) breeds reared in Pakistan and morphological characterization via cluster analysis. *Tropical Animal Health and Production*, *53*: 1-14.

Food and Agriculture Organization (FAO). 2013.Caractérisation phénotypique des ressources génétiques animales. *Directives FAO sur la production et la santé animales . Rome, Italy* No. 11.

Food and Agriculture Organizations (FAO). 2012. Phenotypic characterization of animal genetic resources. Available at https://www.fao.org/3/i2686e/i2686300.pdf. 28 March 2022.

Friedman, J.H. 1991. Multivariate Adaptive Regression Splines. Ann. Stat. 119, 1–141.

Garcia, L.I.P. 2013. Production objectives and selection criterions of three endemic ruminant breeds in The Gambia and Senegal.. [Master's Thesis]. Faculty of Veterinary Medicine and Animal Science, Swedish University of Agricultural Sciences. Available at https://epsilon.slu.se. 15 November 2023.

Gebreyowhens, W and Tesfay, Y. 2016. Morphological characterization of indigenous highland sheep population of Tigray, Northern Ethiopia. *Journal of Natural Sciences Research*, *6*(1): 96-104.

Getachew T, Haile A, Tibbo M, Sharma A, Kifle A, Terefe E, Wurzinger M, Sölkner J. 2009. Morphological characters and body weight of Menz and Afar sheep within their production system. *Ethiopian Society of Animal Production,* 9(1). 1-12.

Getachew, T., Haile, A., Tibbo, M., Sharma, A.K., Sölkner, J and Wurzinger, M. 2010. Herd management and breeding practices of sheep owners in a mixed crop-livestock and a pastoral system of Ethiopia. *African Journal of Agricultural Research*, *5*(8): 685-691.

Getachew, T., Haile, A., Wurzinger, M., Rischkowsky, B., Gizaw, S and Abebe, A. 2016. Review of sheep crossbreeding based on exotic sires and among indigenous breeds in the tropics: An Ethiopian perspective. *African Journal of Agricultural Research*, *11*(11): 901-911.

Gizaw, S., Komen, H., Hanotte, O and Van Arendonk, J.A. 2008. Indigenous sheep resources of Ethiopia: types, production systems and farmers preferences. *Animal Genetic Resources/Resources génétiques animales/Recursos genéticos animals, 43*(4): 25-39.

Gudeto, A., Mirkena, T and Kebede, T. 2021. Traditional cattle breeding practices and rate of inbreeding in the mid rift valley of Oromia, Ethiopia. *International Journal of Veterinary Science and Research*, *7*(2): 077-082.

Gutu, Z., Haile, A., Rischkowsky, B., Mulema, A.A., Kinati, W and Kassie, G. 2010. Evaluation of community-based sheep breeding programmes in Ethiopia. Addis Ababa: ICARDA.

Haile, A., Wurzinger, M., Mueller, J., Mirkena, T., Duguma, G., Okeyo Mwai, A., Sölkner, J. and Rischkowsky, B.A. 2011. Guidelines for setting up community-based sheep breeding programs in Ethiopia: Lessons and experiences for sheep breeding in low-input systems. *ICARDA tools and guidelines.No.1. Aleppo, Syria. ICARDA.*

Haile, D., Gizaw, S and Kefelegn, K. 2015. Selection criteria and breeding practice of sheep in mixed crop-livestock farming system of North Shoa, Ethiopia. *Journal of Biology, Agriculture and Healthcare*, *5*(21): 168-174.

Hassen, M., Amentie, T., Abdimahad, K., Ma'alin, A and Mahamed, A. 2022. Hygienic Production and Post-Harvest Handling Practices of Raw Camel Milk in Degahbour District of Jarar Zone, Somali Regional State, Ethiopia. *Open Journal of Animal Sciences*, *12*(2): 303-316.

Heeringa, S.G., West, B.T and Berglund, P.A. 2017. *Applied survey data analysis*. CRC press.

Hemacha, S.A., Kebamo, M and Hailemeskel, D. 2022. Breeding practice, trait preferences and flock structure of local sheep in selected districts of Hadiya zone, Southern Ethiopia. *Journal of Livestock Science, 13*: 171-179.

Islam, M. R., Saadullah, A. R., Howlider, M.A.R and Huq, M. A. 1991. Estimation of live weight and dressed carcass weight from different body measurements in goats. *Indian Journal of Animal Sciences*, *61*(4): 460-461.

Jaitner, J., Sowe, J., Secka-Njie, E and Dempfle, L. 2001. Ownership pattern and management practices of small ruminants in The Gambia—implications for a breeding programme. *Small Ruminant Research*, *40*(2): 101-108.

Jannah, Z.N., Atmoko, B.A., Ibrahim, A., Harahap, M.A and Panjoho, P. 2023. Body weight prediction model analysis based on the body size of female Sakub sheep in Brebes District, Indonesia. *Biodiversitas Journal of Biological Diversity*, *24*(7).

Jimmy, S., David, M., Donald, K.R and Dennis, M. 2010. Smallholder goat breeding systems in humid, sub-humid and semi-arid agro-ecological zones of Uganda. *Global Veterinaria*, *4*(3): 283-291.

Kebede, T., Lemma, T., Dinka, H., Guru, M and Sisay, A. 2008. Growth performance and carcass characteristics of Arsi-Bale goats castrated at different ages. *Journal of Cell and Animal Biology*, 2: 187–194.

Kefale, A., Awoke, T., Getu, A and Abegaz, S. 2017. Herd management and breeding practices of holla sheep owners in south wollo zone, Ethiopia. *International Journal of Advanced Geosciences*, *5*(2): 41-47.

Kosgey, I.S. 2004. *Breeding objectives and breeding strategies for small ruminants in the tropics*. Wageningen University and Research. [Ph.D. Thesis]. Wageningen Universiteit. Available at https://core.ac.uk/download/pdf/132679007.pdf. 27 November 2023.

Kosgey, I.S., Rowlands, G.J., van Arendonk, J.A and Baker, R.L. 2008. Small ruminant production in smallholder and pastoral/extensive farming systems in Kenya. *Small Ruminant Research*, *77*(1): 11-24.

Kumar, S., Dahiya, S.P., Malik, Z.S and Patil, C.S. 2018. Prediction of body weight from linear body measurements in sheep. *Indian Journal of Animal Research*, *52*(9).

Kunene, N., Nesamvuni, E.A. and Fossey, A. 2007. Characterization of Zulu (Nguni) sheep using linear body measurements and some environmental factors affecting these measurements. *South African Journal of Animal Science*. 37 (1): 11–20.

Kunene, N.W and Fossey, A. 2006. A survey on livestock production in some traditional areas of Northern KwaZulu Natal in South Africa. *Livestock Research for Rural Development*, *18*(113): 30-33.

Kuthu, Z.H. 2023. Morphometric characterization and body weight correlations in Pahari sheep of Azad Jammu and Kashmir. *Pakistan Journal of Science*, *75*(2).

Kuyamandi Development Services., Goat meat production feasibility study. 2006. http://www.lepelle-nkumpi.gov.za/lepelle nkumpiadmin/pages/sites/lepellenkumpi/documents/strategies/GOAT%20FARMING%20FEASIBILITY.pdf. 13 May 2022.

Lakew, A., Melesse, A and Banerjee, S.2017. Traditional sheep production systems and breeding practice in Wolayita Zone of Southern Ethiopia. *African Journal of Agricultural Research*, *12*(20): 1689-1701.

Lakew, M., Haile-Melekot, M., Mekuriaw, G., Abreha, S and Setotaw, H. 2014. Reproductive performance and mortality rate in local and dorper× local crossbred sheep following controlled breeding in Ethiopia. *Open Journal of Animal Sciences*, *4*(05): 278.

Lombebo, W.,A. 2022. Characterization of local cattle husbandry practices in Hadiya zone, Southern region of Ethiopia. *Uttar Pradesh Journal of Zoology*, 43(3): 1-10.

Maiwashe, N., Bradfeld, M.J., Theron, H.E and Van Wyk, J.B. 2002. Genetic Parameter Estimates for Body Measurements and Growth Traits in South Africa Bonsmara Cattle. *Livestock Production Science,* 75(3): 293-300

Matlebyane, M.M., Ng'ambi, J.W.W. and Aregheore, E.M. 2010. Indigenous knowledge (IK) ranking of available browse and grass species and some shrubs used in medicinal and ethno-veterinary practices in ruminant livestock production in Limpopo province, South Africa. *Livestock Research for Rural Development*, *22*(3): 54.

Mavule, B.S., Muchenje, V., Bezuidenhout, C.C and Kunene, N.W. 2013. Morphological structure of Zulu sheep based on principal component analysis of body measurements. *Small Ruminant Research*, *111*(1-3): 23-30.

Mekuriaw, S., Mekuriaw, Z., Taye, M., Yitayew, A., Assefa, H and Haile, A. 2012. Traditional management system and farmers' perception on local sheep breeds (Washera and Farta) and their crosses in Amhara Region, Ethiopia. *Livestock research for rural development*, *24*(1).

Melaku, S., Kidane, A., Abegaz, S., Tarekegn, A and Tesfa, A. 2019. Phenotypic characterization of Simien sheep in Simien mountain region, Ethiopia. *International Journal of Agriculture and Biosciences*, *8*(4): 178-185.

Mengesha, M and Tsega, W. 2012. Indigenous sheep production in Ethiopia: a review. *Iranian journal of applied Animal science*, *2*(4): 311-318.

Michael, A., Kefelegn, K and Yoseph, M. 2016. Phenotypic characterization of indigenous sheep types in Northern Ethiopia. *Journal of Natural Sciences Research*, *6*(15): 16-27.

Mohammed, J., Abegaz, S., Lakew, M and Tarekegn, G.M. 2018. Evaluation on the Structural Indices Unveil Performance Variation among Dorper, Local and their F1 Crossbred Sheep Population in Ethiopia. *Journal of Genomics*, *1*(102): 2.

Mohammed, N., Alemayehu, K and Getachew, T. 2017. On-farm phenotypic characterization of indigenous sheep and its crossbreed with exotic Awassi in selected district of South Wollo, Amhara, Ethiopia. *International Journal of Tropical Drylands*, *1*(1):1-11.

Molabe KM and Tyasi TL, 2021. Application of Biometric traits for predicting weaning weight of Dorper sheep using path analysis. *International Journal of Veterinary Science,* 10(4): 335-339.

Moll, H.A., Staal, S.J. and Ibrahim, M.N., 2007. Smallholder dairy production and markets: A comparison of production systems in Zambia, Kenya and Sri Lanka. *Agricultural systems*, *94*(2), pp.593-603.

Monau, P.I., Visser, C., Nsoso, S.J and Van Marle-Köster, E. 2017. A survey analysis of indigenous goat production in communal farming systems of Botswana. *Tropical Animal Health and Production*, *49*: 1265-1271.

Mthi, S., Nyangiwe, N., Thubela, T., Nyalambisa, N., Madyibi, Z and Yawa, M. 2020. Cattle production and breeding practice in communal farming system in the Eastern Cape Province, South Africa. *African Journal of Rural Development*, 13: 13

Mueller, J.P., Rischkowsky, B., Haile, A., Philipsson, J., Mwai, O and Besbes, B. 2015. Community-based livestock breeding programmes: essentials and examples. *Journal of Animal Breeding and Gentics*,132:155–68.

Nandolo, W., Wurzinger, M., Mészáros, G., Van Tassell, C., Gondwe, T., Mulindwa, H and Sölkner, J. 2016. Identification of breeding objectives in community-based goat breeding programmes in Malawi. *Acta Agriculturae Slovenica*, *5*(104).

Nguluma, A.S., Hyera, E., Nziku, Z., Shirima, E.M., Mashingo, M.S.H., Lobo, R.N.B., Getachew, T., Rischkowsky, B and Haile, A. 2020. Characterization of the production system and breeding practices of indigenous goat keepers in Hai district, Northern Tanzania: implications for community-based breeding program. *Tropical Animal Health and Production*, *52*(6): 2955-2967.

Okpeku, M., Yakubu, A., Peters, S.O., Oozoje, M and Ikebi, O.A. 2011. Application of Multivariate Principal Component Analysis to Morphological Characterization of Indigenous Goats in South1ern Nigeria, *Acta Agriculture Slovenica*, 98(2): 101-109.

Omore, A., Kurwijila, L and Grace D. 2008. Improving livelihoods in East Africa through livestock research and extension: reflections on changes from the 1950s to the early twenty first century. *Tropical Animal Health and Production, 41*(7): 1051-1059.

Ouma, E.A. 2003. *An analysis of the economic value of cattle in smallholder livestock production systems in Western Kenya: Case of Kisii and Rachuonyo Districts* (Doctoral dissertation, Egerton University). Available at https://download/pdf/132632339.pdf. 5 September 2022.

Rashijane, L.T., Mokoena, K and Tyasi, T.L. 2023. Using Multivariate Adaptive Regression Splines to Estimate the Body Weight of Savanna Goats. *Animals*, *13*(7): 1146.

Riva, J., Rizzi, R., Marelli, S and Cavalchini, L.G. 2004. Body measurements in Bergamasca sheep. *Small Ruminant Research*, *55*(1-3): 221-227.

Ryder, M.L. 1984. Sheep In: Mason, I.L. Evolution of Domestic Animals, 1st edition. Longman, London, 85.

Salem, B.H and Smith, T. 2008. Feeding strategies to increase small ruminant production in dry environments. *Journal of Ruminant Research*, 77:174-194.

Şengül, T., Çelik, Ş and Şengül, Ö. 2020. Use of Multivariate Adaptive regression splines (MARS) for predicting parameters of breast meat of quails. *JAPS: Journal of Animal & Plant Sciences*, *30*(4).

Sölkner, J., Nakimbugwe, H., Valle-Zárate, A. 2006. Analysis of determinants for success and failure of village breeding programmes. In Proceedings of the 6th World Congress on Genetics Applied to Livestock Production, 1998 January 11–16. *Armidale, New England: University of New England*.

Sowande, O.S and Sobola, O.S. 2008. Body measurements of West African dwarf sheep as parameters for estimation of live weight. *Tropical Animal Health and Production, 40*(6):433-439.

SPSS (Statistical Packages for Social Sciences) (2009). SPSS (Version 20). Statistical Procedures for Social Sciences (SPSS) INC. Chicago, Illinois, USA.

Tadesse, A and Gebremariam, T. 2010. Application of linear body measurements for live body weight estimation of Highland Sheep in Tigray Region, North-Ethiopia. *Journal of Dryland Agriculture,* 3(2): 203-207.

Tesfaye, G. 2008. Characterization of Menz and Afar Indigenous Sheep Breeds of Smallholders and Pastoralists for Designing Community-Based Breeding Strategies in Ethiopia, M.S. thesis, Haramaya Univ., Haramaya, Ethiopia. Available at https://core.ac.uk/reader/132684800. 7 October 2022.

Tırınk, C., Eyduran, E., Faraz, A., Waheed, A., Tauqir, N.A., Nabeel, M.S., Tariq, M.M. and Sheikh, I.S. 2021. Use of multivariate adaptive regression splines for prediction of body weight from body measurements in Marecha (Camelus dromedaries) camels in Pakistan. *Tropical Animal Health and Production*, *53*(3): 339.

Tsedeke, K. 2007. Production and marketing of sheep and goats in Alaba, SNNPR. Hawassa University. Awassa, Ethiopia. Available at https://core.ac.uk.download/pdf/132631374.pdf. 17 August 2022.

Tyasi, T.L., Eyduran, E and Celik, S. 2021. Comparison of tree-based regression tree methods for predicting live body weight from morphological traits in Hy-line silver brown commercial layer and indigenous Potchefstroom Koekkoek breeds raised in South Africa. *Tropical Animal Health and Production*, *53*:1-8.

Tyasi, T.L., Mathye, N.D., Danguru, L.W., Rashijane, L.T., Mokoena, K., Makgowo, K.M., Mathapo, M.C., Molabe, K.M., Bopape, P.M and Maluleke, D. 2020. Correlation and path analysis of body weight and biometric traits of Nguni cattle breed. *Journal of Advanced Veterinary and Animal Research*, *7*(1): 148.

Tyasi, T.L., Mathye, N.D., Danguru, L.W., Rashijane, L.T., Mokoena, K., Makgowo, K.M., Mathapo, M.C., Molabe, K.M., Bopape, P.M., Maluleke, D. 2020. Correlation and path analysis of body weight and biometric traits of Nguni cattle breed. *Journal of Advanced Veterinary and Animal Research*, 7: 148–155.

Tyasi, T.L., Ng'ambi, J and Mogashoa, S. 2022. Breeding practices and trait preferences of goat keepers at Lepelle-Nkumpi Local Municipality, South Africa: implication for the design of breeding programmes. *Tropical Animal Health and Production*, *54*(1): 68.

Verma, S.K., Dahiya, S.P., Malik, Z.S., Patil, C.S and Patil, H.R. 2016. Biometrical characterization of Harnali sheep: A new synthetic strain. *Indian Journal of Veterinary Research, 25*(1):16-21

Welday, K., Urge, M and Abegaz, S. 2019. Sheep production systems and breeding practices for selected zones of Tigray, Northern Ethiopia. *Open Journal of Animal Sciences*, *9*(01): 135.

Whannou, H.R.V., Afatondji, C.U., Ahozonlin, M.C., Spanoghe, M., Lanterbecq, D., Demblon, D., Houinato, M.R.B and Dossa, L.H. 2021. Morphological variability within the indigenous sheep population of Benin. *Public Library of Science one 16*(10): 61.

Wurzinger, M., Gutiérrez, G.A., Sölkner, J and Probst, L. 2021. Community-Based Livestock Breeding: Coordinated Action or Relational Process?. *Frontiers in Veterinary Science, 8*: 3-7.

Wurzinger, M., Sölkner, J. and Iñiguez, L. 2011. Important aspects and limitations in considering community-based breeding programs for low-input smallholder livestock systems. *Small Ruminant Research*, *98*(1-3), pp.170-175.

Yakubu, A. 2009. Fixing collinearity instability in the estimation of body weight from morpho-biometrical traits of West African Dwarf goats. *Trakia Journal of Sciencesi*, *7*(2): 61-66.

Yakubu, A. 2012. Application of regression tree methodology in predicting the body weight of Uda sheep. *Animal Science and Biotechnologies*, *45*(2): 484-490.

Yakubu, A., Isa, S., Alabi, O., Shoyombo, A.J and Adeolu, A.I. 2020. Breeding practices and trait preferences of sheep farmers in a Sub-Humid tropical environment. *Tropical Animal Science Journal*, *43*(4): 377-384.

Yamane, T. 1967. Statistics, An Introductory Analysis, 2nd Ed., New York: Harper and Row.

Zewdu, A., Alemayehu, K. and Wondifraw, Z. 2018. Breeding practices and farmers trait preferences on indigenous dairy cattle production in East Gojja Zone, Ethiopia. *Asian Journal of Agriculture and Food Sciences*, *6*(1).