ASSESSMENT OF RELATIONSHIP BETWEEN BODY WEIGHT AND MORPHOLOGICAL TRAITS OF SOUTH AFRICAN NON-DESCRIPT INDIGENOUS GOATS USING DIFFERENT DATA MINING ALGORITHM

by

MADUMETJA CYRIL MATHAPO

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SUPERVISOR: Dr TL TYASI

CO-SUPERVISOR: Dr TJ MUGWABANA

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DECLARATION

I declare that the full dissertation hereby submitted to the University of Limpopo for the degree of Master of Agricultural Management (Animal Production) is my own work and it has not been submitted for any other purposes or to any other University, and that all materials contained herein has been acknowledged.

Signature…………………. Date………………………………

Mathapo MC

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DEDICATION

This dissertation is dedicated to my family for their love, support, motivation and for always being there for me throughout this study.

ABSTRACT

Modern analytical techniques such as data mining algorithms are used to create a model that accurately estimates continuous dependent variable from independent variables of a given set of data. The present study used different data mining algorithms to assess the association between body weight (BW) and morphological characteristics such as body length (BL), heart girth (HG), withers height (WH), rump height (RH), and rump length (RL) of South African non-descript indigenous goats. The research was carried out in the Lepelle-Nkumbi Local Municipality, Capricorn District in the Limpopo province of South Africa. The study used 700 non-descript indigenous goats which include 283 bucks and 417 does with age ranged from one to five years old. The morphological characteristics were taken with a tailor measuring tape and a wood ruler calibrated in centimetres (cm), while the BW was taken with a balanced animal scale calibrated in kilograms (kg). Before the goats were allowed to go for grazing, the following body measurements (BW, BL, HG, WH, RH and RL) was taken once in the morning. Data was analyzed using descriptive statistics, Pearson correlation, various data mining algorithms (Chi-square automatic interaction detector, Classification, and regression tree), analysis of variance and goodness of fit equations (Coefficient of determination (R^2), adjusted coefficient of determination (Ajd.R^2), root mean square error (RMSE), relative approximate error (RAE), standard deviation ratio (SD. ratio) and coefficient of variance (CV)). The result showed that, BW and HG had higher mean values in does than bucks, BL and WH had higher mean values in bucks than does, and RH and RL had equal mean values in bucks and does, according to descriptive statistics. Furthermore, our findings showed that the BW of does had positive significant correlation ($P < 0.01$) with BL ($r = 0.65$), and positive significant correlation ($P < 0.05$) with HG ($r = 0.28$), but non-significant correlation ($P > 0.05$) with WH ($r = 0.21$), RH ($r = 0.23$) and RL ($r = 0.23$). However, the result for bucks indicated that BW had positive significant correlation ($P < 0.01$) with BL ($r = 0.65$) but non-significant correlation with HG ($r = 0.22$), WH ($r = 0.07$), RH ($r = 0.14$) and RL ($r = 0.12$). The chi-square automatic interaction detector and classification and regression tree results indicated that BL in bucks and does had statistical significance ($P < 0.01$) on BW followed by age, HG, and villages where the animals were raised. Goodness of fit results indicated there was high $R^2 = 0.58$, Adj. $R^2 = 0.58$, and low SD. Ratio = 0.65, RAE = 0.02, RMSE = 5.53) and CV = 14.49 in

CHAID model and low R^2 = 0.51, Adj. R^2 = 0.46 and high SD. Ratio = 0.70, RAE = 0.20, RMSE = 5.95 and CV = 15.49 in CART model. Analysis of variance results indicated that age had significant difference ($P < 0.01$) on BW and some morphological traits including BL, HG, WH and RH. Sex only revealed significant difference ($P < 0.01$) in RL. It was concluded that BL alone in both sexes can be used as a selection criterion when determining body weight of goats. Both CHAID and CART suggest that BL alone can be used as a predictor of body weight in goats. Goodness of fit calculations suggest that CHAID is the best model due to its high R^2, Adj. R^2 and low RAE and RMSE. Findings suggest that age can be used as deciding factor for the measured traits including BW, BL, HG, WH and RH in both does and bucks. Findings suggest that sex can only be used as a deciding for RL only in the current study.

Keywords: morphological traits, data mining algorithm, indigenous goats, body weight

TABLE OF CONTENT

Contents Page

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

CART	Classification and regression tree
CHAID	Chi-square Automatic interaction detector
ANOVA	Analysis of variance
BL	Body length
HG	Heart girth
WH	Withers height
RH	Rump height
RL	Rump length
R^2	Coefficient of determination
Adj.R^2	Adjusted coefficient of determination
SDratio	Standard deviation ratio
RAE	Relative approximate error
RMSE	Root mean square error
CV	Coefficient of variance
PPI	Permanent pair of incisors

CHAPTER ONE

INTRODUCTION

1.1 Background

Goats are mostly found in rural areas and are primarily used to produce milk and meat (Mpebe et al., 2018). They are one of those hardy animals that can withstand extreme weather conditions such as high temperatures, humidity, and drought (ARC, 2006; Tyasi et al., 2020a). Goats are disease-resistant and can thrive in poor pasture environments. They are also known to be non-selective browsers (Lehloenya et al., 2005; ARC, 2006). In rural areas, goats are an important livestock species for the poorest of the poor (Atoui, 2017). Goats are a fascinating animal that, due to their unique adaptive features to environmental conditions, they require little input skills to maintain them by their owners (Temoso et al., 2017).

Goats provide good nutrition to rural families, they are important in the rural economy, and they are used to alleviate poverty (Slayi et al., 2014). They are also known as poor man's cow because they can survive on natural pastures (Rumosa-Gwaze, 2009). Goats have social and cultural value, which is why they are kept by smallholder farmers (Mdladla et al., 2017). Goats are used for traditional ceremonies and religious rituals aside from their use for meat, milk, and skin purposes (Pakpahan et al., 2016).

1.2 Problem statement

In the livestock industry, live body weight is an important economic trait. Its predictions help farmers to make the best choices for breeding animals, determining the proper feed portion, administering medical treatment, and determining the correct farm animal market price (Eyduran et al., 2017). Smallholder goat farmers in rural areas, on the other hand, find it difficult to estimate the live body weight of their animals due to lack of weighing scales, which may be expensive to purchase due to financial constraint. This situation, however, puts them at a disadvantage position when considering selecting their animals for breeding during the breeding season, and estimating prices for their animals (Berhe, 2017). In other parts of the world (Northern Ethiopia), morphological traits have been used to estimate the live body weight of Abergelle goat breeds (Alemayehu et al., 2012). Farmers in rural areas can use the morphological trait to predict live body weights of small ruminants, which is an important tool for animal management purposes such as dosing, adjusting feed supply, observing growth, and breeding selection (Mahieu et al., 2011).

1.3 Rationale

According to Nor et al. (2011), some morphological traits (body length and height at wither) are used to estimate live body weight in Boer goats, which can help to save farmers money and time. The morphological traits and live body weight of West African Dwarf goats were also found to be significantly correlated, with heart girth being the most correlated trait to live body weight when compared to other traits (Sam et al., 2016). In Hararghe highland there was significant association between live body weight and most morphological traits, with heart girth being the best correlated trait in both male and female goats (Tsegaye et al., 2013). In addition, Tyasi et al. (2020b) reported a significant correlation between live body weight and some morphological characteristics in Dorper sheep, with the most significant correlations being rump height and heart girth in rams and ewes, respectively. Data mining algorithms are a collection of heuristics and calculations that produces a data mining model from data (Microsoft, 2016). According to Eyduran (2016), data mining algorithms can assist farmers in identifying the trait that is most accurate in determining the live body weight of their animals. There is a lot of findings on the effectiveness of data mining algorithms in sheep and goat breeding (Eyduran et al., 2017). Unlike traditional models, such as simple and multiple linear regression models, that provide inaccurate live body weight estimation when strong correlation is found between independent variable which are morphological traits in our case (Ali et al., 2015). Researchers will be able to develop better models for estimating live body weight from morphological trait measurements with the help of data mining algorithms (Huma and Iqbal, 2019).

The use of morphological traits to estimate the live body weight of indigenous goats is still a rare practice among smallholder indigenous goat farmers in South Africa and especially in the Capricorn district in the Limpopo province where this study was conducted. As a result, this study aims to assess the live body weight of indigenous goats using morphological traits and various data mining algorithms. This study aims to identify morphological traits that will assist smallholder indigenous goat farmers to accurately estimate the live body weights of their animals for the purpose of good breeding program, effective vaccinations, feeding regime, marketing price, and slaughter weights.

1.4 Aim

The main aim of the current study was to establish the association between live body weight and morphological traits of South African non-descript indigenous goats.

1.5 Objectives

The objectives of the study were to:

i. determine the association between live body weights and morphological traits of South African non-descript indigenous goats.
ii. establish a model to predict live body weights using morphological traits of South African non-descript indigenous goats.
iii. determine the effect of sex on live body weights and morphological traits of South African non-descript indigenous goats.
iv. determine the effects of age on live body weights and morphological traits of South African non-descript indigenous goats

1.6 Hypotheses

The hypotheses of this study were as follows:

i. There is no relationship between live body weight and morphological traits of South African non-descript indigenous goats.
ii. Data mining algorithm cannot be used to determine a model to estimate the live body weight of South African non-descript indigenous.
iii. Sex has no effect on live body weights and morphological traits of South African non-descript indigenous goats.
iv. Age has no effect on live body weight and morphological traits of South African non-descript indigenous goats.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Human beings kept goats as one of the first domesticated animals to produce meat, milk, skins, and fiber (Visser, 2019). Capra aegagrus was the common ancestor of goats who were moved to human homes for domestication (Amills et al., 2017). South Africa is one of the small goats producing country and hold about 3% of Africa's goats and less than 1% of the world's number of goats (DAFF, 2019). Goats have been identified as one of the cheapest livestock to be raise by humans when compared to other livestock such as cattle (Van Marle-Koster et al., 2016). They are one of the livestock that have been undervalued in comparison to other livestock, despite their contribution to society and food security (Meissner et al., 2013).

Smallholder farmers in developing countries commonly own goats to supplement their income in impoverished areas (FAO, 2012; Hossain et al., 2015; Ouchene-Khelifi et al., 2015). The value of goats varies by region and cultural group and can be used to generate source of income to meet emergency social and financial needs of smallholder farmers (Boogaard et al., 2012; Boogaard and Moyo, 2015). South Africa goat breeds include unimproved indigenous, Boer, Kalahari Red, and Savanna goats among others (Mpebe et al.,2018). Goats have a high biological value and lipid soluble vitamins, which are beneficial to pregnant women, nursing mothers, and children (Durawo et al., 2017). According to Qekwana et al. (2017), goats are reared in South Africa not only for meat and milk consumption, but also for traditional and religious ceremonies. According to statistics, 65 percent of goats in South Africa are unimproved, while 35 percent are commercial goats (DAFF,2015).

The following major subtopics are covered in this literature review: the origin and importance of indigenous goats, live body weight and its importance, morphological traits (rump height, rump length, body length, body depth, and withers height) as predictors of live body weight, and different data mining algorithms for animal breeding (classification and regression trees, chi-square automatic interaction detector) in different animals in livestock farming.

2.2 Origin and importance of South African indigenous goats

Indigenous goats came from various parts of Southern Africa and were brought to South Africa by various ethnic groups (Tyasi et al., 2020a). These goats were registered as a breed in 2006 and were divided into four ecotypes: Nguni Type (Mbusi), Northern Cape Speckled, Eastern Cape Xhosa, and Kunene Type (Kaokoland) according to Snyman (2014). Indigenous goats are hardy breeds that are resistant to certain parasites like tapeworms, biting lice and ticks, and diseases such as heart-water and paratuberculosis found in the area (Mohlatlole et al., 2015). They can feed on bushes and trees as browsers and grazers, and they are also efficient users of high-fiber, low-quality roughage (Mirkena et al., 2010).

They are used in breeding programs to pass on genetic materials such as hardiness and disease resistant traits from one generation to another (Mpebe et al., 2018). These animals are very fertile at a young age, have a long breeding season, and can give offspring all year round (Tyasi et al., 2020a). Smallholder farmers generate income from these indigenous goats by selling their milk and meat for human consumption, as well as their skin and manure for local use (Leketa et al., 2019).

2.3 Live body weight and its importance

Live body weight is an important trait that can help farmers choose animals to use during breeding season (Ashwini et al., 2019). Live body weight of livestock is also linked to management practices such as determining feed levels to avoid overfeeding or underfeeding, which can be stressful to the animal. It also aids in determining nutrient requirements and the appropriate dose of treatment to use on animals (Putra et al., 2014). Live body weight is also important in determining slaughter weight, growth rate, and responsiveness to environmental factors in livestock.

Body weight also indicates fair ideas about the future production of the young ones and plays an important role in dairy animal reproductive performance (Khan et al., 2020). It also allows farmers to determine the potential value of the animal's life in relation to the market price. According to Yakubu and Mohammed (2012), the live body weight of goats can help farmers determine animal health status and weaning time. The major components that determine profitability in goat enterprises are reported to be live body weight and conformation (Norris et al., 2015). According to Afolayan et al. (2006), knowing the live body weight of livestock would ensure that farmers received fair market value for their livestock rather than using middlemen to know market prices of their animal. Live body weight is also useful in assessing farm animal body development (Rotimi et al., 2020).

2.4 Morphological traits as predictor of live body weight

Morphological traits are continuous characters that describe features of body shape (Habib et al., 2019), e.g., body length, withers height, heart girth and rump length. In animal breeding, animal selection necessitates precise estimation to increase livestock production (Sam et al., 2016). Animal body weight is typically measured using a weighing scale (Shirzeyli et al., 2013). Due to the scarcity of scales in rural areas, animal weighing is done through virtual judgement (Chinchilla-Vargas et al., 2018). This causes communal farmers to receive less returns in terms of monetary value from what they have worked for and makes it difficult for them to improve their animals because of their lack of knowledge of their animal body weight (Walugembe et al., 2014). Morphological traits were reported to be an easy and accurate method of estimating the live body weight of animals in rural areas where weighing scales are not available (Younas et al.,2013).

Morphological traits are genetically correlated with live body weight, which is known as the target trait due to its importance in livestock production (Birteeb and Ozoje, 2012). According to Olawumi and Farinnako (2017), morphological traits are critical parameters for measuring growth, feed utilization, and carcass characteristics in animals. In sheep farming, morphological traits are becoming increasingly important for determining sheep breeds, standards, and selecting more productive sheep in terms of modifying sheep meat yield levels (Jahan et al., 2013). According to Norris et al. (2015), body weight can be estimated from morphological traits because there is a positive relationship between those traits, and it is easy for smallholder farmers to use. These morphological characteristics can provide a high level of satisfaction when selecting and predicting an animal's body weight without the use of a weighing scale (Mohammad et al., 2013). The morphological traits covered in the present study are discussed below.

2.4.1 Body length

Body length is a morphological trait measured from the humerus head to the distal end of the pubic bones (Yakubu, 2009). Moela (2014) in their study reported a significant positive correlation between body length and body weight in South African indigenous goats. In the absence of weighing scales, the coefficient of determination confirmed that body length can be used to estimate body weight of Beetal goats (Iqbal et al., 2013). Body length of West African Dwarf goats had a strong significant correlation with body weight in Ekiti state, which had a higher correlation coefficient than those from Osun state of Nigeria (Olawumi and Farinnako, 2017). Body length was found to be the second most correlated trait and demonstrated that when combined with heart girth in Female Ettawa Grade Goats and it provided the best estimates for body weight (Dakhlan et al., 2020).

Body length was reported to be a vital body measurement yardstick that can be used to improve body weight of goats (Babale et al., 2018). When there are no weighing scales, the correlation coefficient and coefficient of determination show that body length is more reliable when estimating the body weight of Assam Hill goats (Khargharia et al., 2015). Body length had the highest correlation, followed by heart girth, implying that these traits can be used to improve body weight in West African Dwarf goats (Dudusola et al., 2019). Body length was found to be one of the zoometric traits that farmers in Southern Mexico use to estimate body weight of local goats in the absence of weighing scales (Derantes-Coronado et al., 2015). According to Abd-Allah et al. (2019), body length is a more reliable predictor of body weight in female Shami goats raised in Egypt. When compared to other traits, body length alone explained a greater variation in body weight of female Afar goats (Tekle, 2014).

2.4.2 Heart girth

One of the most commonly used morphological traits to estimate body weight in small ruminants is heart girth (Bello and Adama, 2012). It was indicated that heart girth might be used to estimate body weight of Maefu goats due to its high coefficient of determination (Berhe, 2017). According to Kamarudin et al. (2011) Pearson correlation and simple linear regression results indicated that heart girth can be used to improve or estimate body weight of Boer goats reared in a private farm (De Kebun Enterprise) in Kg Pulau Meranti, Mukim Dengkil, Puchong, Selangor. Amane et al. (2014), reported that heart girth alone can be used to estimate body weight of West Highland goats with great precision. In female Ettawa Grade goats, heart girth showed a high correlation and coefficient of determination when compared to other traits, which implies that it can provide a good estimate of body weight without being combined with other traits (Dakhlan et al., 2020).

According to Chitra et al. (2012), heart girth alone can provide a good estimate of body weight in adult female Malabari goats because it has a high coefficient of determination and correlation coefficient. Habib et al. (2019) discovered that predicting body weight based on heart girth can provide an accurate estimation of body weight in Black Bengal goats. Heart girth was discovered to be the best predictor of goat body weight (Yaekob et al., 2015). The correlation coefficient and path analysis revealed that heart girth can be used to predict body weight of goats raised on communal rangelands in Botswana (Temoso et al., 2017). Furthermore, Ibrahim et al. (2014), reported that heart girth was found to be one of the traits that can accurately predict body weight among the linear body measurements of Red Sokoto bucks. Heart girth was also reported to be a highly probable trait for predicting body weight in Begait goats (Hagos, 2016).

2.4.3 Withers height

Withers height is a morphological trait found from the highest part of the body to the ground perpendicularly (Kusminanto et al., 2020). In the absence of weighing scales, withers height was reported to be the most appropriate morphological trait for estimating body weight of WAD goats (Huma and Iqbal, 2019). Tyasi et al. (2020a) in their study stated that withers height can be used by farmers as a selection criterion to predict body weight of their does because it plays a larger role in their body weight than other traits. Conversely, as a result of its highly significant correlation, withers height was judged to be the second trait that might be employed to improve BW of commercial goats in Pakistan (Eyduran et al., 2013). Rotimi et al. (2020) in their study advised that farmers without weighing scales can use withers height to select and estimate the body weight of Sahelian goats because of its significant correlation with body weight of the animal.

Withers height in Mandya Local goats of Karnataka showed a highly significant correlation with body weight, suggesting that these two traits may be controlled by the same set of genes (Siddalingamurthy et al., 2017). The regression analysis in West

African Dwarf goats revealed that female goat body weight can be estimated using withers height (Ofori et al., 2021). Conversely, Valsan et al. (2020) reported that, there is a link between withers height and body weight in Malabari goats from India, implying that these two traits may be influenced by the same genes. The contribution of withers height, heart girth, and shoulder width to the model developed to estimate body weight of female and male indigenous Tswana kids' goats was found to be significant (Sebolai et al., 2011). Raja et al. (2015) demonstrated that wither height is a better predictor of body weight in male and female goats aged 0-3 months. According to Khorshidi-Jalali et al. (2019), withers height can accurately predict body weight of Raini Cashmere's.

2.4.4 Rump height

Rump height is a morphological trait found in relation to the level of the hind legs from the top of the pelvic girdle to the ground surface (Yakubu, 2009). According to Norris et al. (2015), rump height was included in a regression equation, and the equation can be used as the simplest tool to estimate and select goat body weight. When considering age as a factor, rump height was highly significantly correlated to BW in male West African Dwarf goats, and it was the second option chosen as a selection criterion in determining body weight (Sam et al., 2016). The best body weight estimation formula developed for goat farmers was rump height (Perez et al., 2016). Berhe (2017) found that rump height had a significant effect on body weight in Maefur goats, though it was lower than the other traits that was studied. Rump height and other traits, according to Seifemichael et al. (2014), can be used to estimate Afar goat body weight. Rump height, according to Yakubu et al. (2011), was the best predictor of body weight in non-descript goats from North Central Nigeria.

2.4.5 Rump length

Rump length is a morphological trait measured from hips (Tuber coxae) to pins (Tuber ischii) (Ozkay and Bozkurt, 2008). This trait showed a strong positive association with body weight, indicating that when combined with other traits, it created a strong model to predict body weight in male and female goats (Tsegaye et al., 2013). According to Tyasi et al. (2020a), rump length has the potential to be a selection criterion in South African non-descript indigenous does to improve body weight, despite having a lower correlation coefficient than other traits. In adults Assam Hill goats, rump length showed a high positive significant correlation, and its combination with other traits on the prediction equation showed a very high coefficient of determination (Khargharia et al., 2015). Furthermore, Dorantes-Coronado et al. (2015) found a significant relationship between rump length and body weight, though its variation to body weight was low when compared to other goat traits. According to Zergaw et al. (2017) rump height could be used to estimate body weight of Central Highland and Woyto-Guji goats.

2.5 Data mining algorithm

Data mining algorithm is a collection of heuristics and calculations that produces a data mining model from data (Microsoft, 2016). Data mining, according to Bavisi et al. (2014), absorbs knowledge from large datasets and transforms it so that people can understand it for future use. Data mining is used by researchers in science, security, health, and informatics to find patterns and associations in raw data (Massaro et al., 2017). In animal breeding, data mining algorithms were used to develop a trait that can be used to estimate body weight of Commercial Goat in Pakistan (Eyduran et al., 2013). In addition, Aslam and Ashraf (2014), indicated that data mining algorithm can also be used in education to improve educational results and to make better educational strategies for future decision making.

Several studies have been published on the use of Classification and Regression Trees (CART), Chi-square Automatic Interaction Detection (CHAID) and Multivariate Adaptive Regression Spine (MARS) to determine model that will estimate BW of sheep (Olfaz et al., 2018) goats (Eyduran et al., 2017) and cattle (Aksahan and Keskin, 2015). However, this study used only two algorithms in different livestock farming which were: Classification and Regression Tree (CART) and Chi-square Automatic Interaction Detection (CHAID) to determine a model to estimate the live body weight of South African non-descript indigenous.

2.5.1 Classification and regression tree

A classification and regression tree are statistical technique that can create an understandable model to predict an event on both an ordinal and nominal scale (Olfaz et al., 2018). Classification and regression trees are used to identify morphological traits e.g., BL, WH and HG that have significant effect on dependent variables e.g., BW (Mathapo and Tyasi, 2021). According to Speybroeck (2012), this technique can be used to analyse complex, unbalanced, and missing-value data, as well as categorical (resulting in a classification tree) or continuous data (resulting in regression trees). Classification and regression tree are binary decision tree structure formed by recursively partitioning a node into two child nodes, beginning with the root node that contains the entire data set, until many similar nodes are obtained from a learning sample data set by ensuring minimum error variance using cross-validation training and test sets (Tyasi et al., 2021).

The goal of this technique is to have terminal nodes to increase the proportion of differences between nodes (Koc, 2017). According to Oguntunji (2017), classification and regression tree (CART) was used to develop a trait that can predict body weight of Nigerian Muscovy ducks. CART demonstrated predictive accuracy in predicting live body weight from morphological characteristics in sheep and goats (Yakubu, 2012; Eyduran et al., 2017). The technique of using CART is non-parametric, and so, it has no assumptions about the underlying distribution of the independent variables are required (Zaborski et al., 2019).

2.5.2 Chi-square automatic interaction detector

Chi-squared Automatic Interaction Detector (CHAID) is a statistical technique that can effectively predict dependent variables from ordinal, continuous, and nominal independent variables in a tree form (Khan et al., 2014). According to Eyduran (2016), the CHAID algorithm can provide accurate estimation of dependent variables and handle multi-collinearity issues that arise as a result of very strong Pearson correlation coefficients between independent variables as predictors of dependent variables. Chi-squared Automatic Interaction Detector uses many ways of splitting in regression tree construction for the strongest Pearson coefficient as a model quality criterion (Ali et al., 2015).

According to Orhan et al. (2016), the CHAID algorithm builds a regression tree diagram by merging, splitting, and stopping stages, and it converts continuous variables to ordinal variables. Furthermore, it generates similar subgroups by repeatedly splitting nodes to maximize the difference in dependent variables between nodes, and it uses the form F significance test when the response variable is continuous (Akin et al., 2016; Eyduran et al., 2016). The CHAID algorithm automatically prunes unnecessary structures in the regression tree diagram, unlike the CART algorithm, which requires analysts to activate the pruning option and aims to reduce the difference within nodes in the response variables during regression tree construction (Celik and Yilmaz, 2017). CHAID has been used to predict body weight in a variety of animal species, including sheep (Karabacak et al., 2017), goats (Altay, 2021), and cattle (Karadas et al., 2017).

2.6 Conclusion

There have been studies on association between BW and morphological characteristics of goats using data mining algorithms, but base on our knowledge no study on South African non-descript indigenous goats have been conducted. The findings of the above literatures revealed a link between body weight and morphological traits in various goat breeds from various countries. They demonstrated how these morphological traits benefited non-resourceful farmers in rural areas. Furthermore, the literatures also revealed the importance of knowing the body weights of animals in livestock farming. Many studies revealed the importance of data mining algorithms in assisting in the development of a model that may help breeders advise farmers on which morphological traits can be used to estimate the body weight of their animals.

CHAPTER THREE

METHODOLOGY AND ANALYTICAL PROCEDURE

3.1 Study site

The study was conducted in four villages of the Lepelle-Nkumbi Local Municipality in the Capricorn District of Limpopo Province, South Africa (-24º 14’60.00” S 29 º39’59.99” E). Lepelle-Nkumpi Local Municipality is a Category B Municipality in the Limpopo Province's Capricorn District. The municipality is located 55 kilometres south of Polokwane City and the district municipality. It is the smallest of the four district municipalities, accounting for 16% of its total land area (Stats SA, 2012). The municipality is mostly rural. It is divided into 29 wards, four of which are Lebowakgomo townships and one of the Capricorn District's growth points. All Provincial Legislature sessions are held at the former homeland's Lebowakgomo Old Parliament. The climate in Lepelle-Nkumbi is favorable for agricultural production, including goat farming. The climate is primarily subtropical, with mild winters, mostly frost-free, and very hot, often dry, summers. The average high temperature is 26.02^{o}C, and the average low temperature is 12.10^{o}C. (CDM, 2009). The vegetation found in the municipality is savannah biome (North-eastern Mountain grasslands and sour lowveld bushveld) (ASCDM, 2009).

3.2 Experimental animal and management

In the study, non-descript indigenous goats of different sexes (Buck and Does) from South Africa aged 1 to 5 years were used. The age of the animals was determined using a dentition chart. Non-descript indigenous goats in South Africa are named after the areas where they are kept, such as Pedi and Xhosa ear ecotypes, and they are kept for meat, hides, and even milk for children (Mohlatlole et al., 2015). Animals were subjected to a traditional management grazing system, which allows them to move and feed on communal land during the day and returns them to the kraal before sunset, where they were given water. The study used healthy and non-pregnant animals that were chosen at random for participation (Yakubu et al., 2011).

3.3 Study design

Cross-sectional study design was employed. A cross-sectional design is a type of observational study design in which the researcher simultaneously measures the results and the exposure in the study contributors (Maninder, 2016). As a result, selected indigenous goat farmers from four villages within the Lepelle-Nkumpi Local Municipality were visited to measure all the morphological traits of interest on each non-descriptnindigenous goat once without being administered with any treatment.

3.4 Sampling procedure

The study used a multi-stage sampling procedure for sampling. According to Sedgwick (2015), multi-stage sampling is the process of taking samples in stages, with the sample size decreasing at each stage. Stage 1: The municipality of Lepelle-Nkumbi was chosen on purpose because the Department of Agriculture, Land Reform, and Rural Development in Limpopo indicated that Lepelle-Nkumbi has a higher population of indigenous goats. Stage 2: Three villages (Morotse, Linting, and Sepitsi) were purposefully chosen due to the presence of smallholder indigenous goat farmers who collaborate with the Lepelle-Nkumbi Municipality's extension officer. Stage 3: From each selected village, a minimum of 30 smallholder indigenous goat farmers with at least 7 goats on their herd were randomly selected. This is in line with the study of Louanrath and Sutanepong (2019). Stage 4: A minimum of 7 non-descript indigenous goats of different sexes (buck and does) and ages were randomly selected for morphological traits measurements from each of the selected farmers' herd. (Norris et al., 2015) suggested that 613 indigenous goats might be a suitable sample size for measuring morphological traits in this type of study. This study used a sample size of 700 goats which include 283 bucks and 417 does, which is greater than the sample size (613) recommended by Norris et al. (2015).

3.5 Data collection

Ethical approval was granted by the University of Limpopo Animal Research Ethics Committee (AREC) with the number AREC/12/2020:PG before the commencement of the study. A weighing scale was employed to measure body weight of goats in kilograms (kg). To ensure accuracy, morphological traits measurements were taken with a tailor measuring tape as well as wooden ruler calibrated in centimetres (cm). The goat handler ensured that the goats stood still on the ground when taking measurements to avoid anatomical distortions that could lead to false results (Okpeku et al., 2011). The morphological traits including Body length, Rump height, Heart girth, Rump length, and Wither's height were measured using the procedure of Yakubu

(2009). Body length (BL) of the goats were taken from the humerus head to the distal end of the pubic bones. Rump height (RH) was measured in relation to the level of the hind legs from the top of the pelvic girdle to the ground surface. The circumference of the chest was used to calculate heart girth (HG). Rump length (RL) was determined by measuring from the hip of the goats to the pin. Wither's height (WH) was calculated by measuring the distance between the highest point of the shoulder and the ground surface in relation to the level of the forelegs. In order to avoid errors, all the measured traits were taken by a single person. Furthermore, to avoid getting inaccurate measurements due to the effects of water and feeds on the structure and size of animals, the traits were measured before releasing the goats for grazing. The figure below depicts the position of the morphological traits collected in the study.

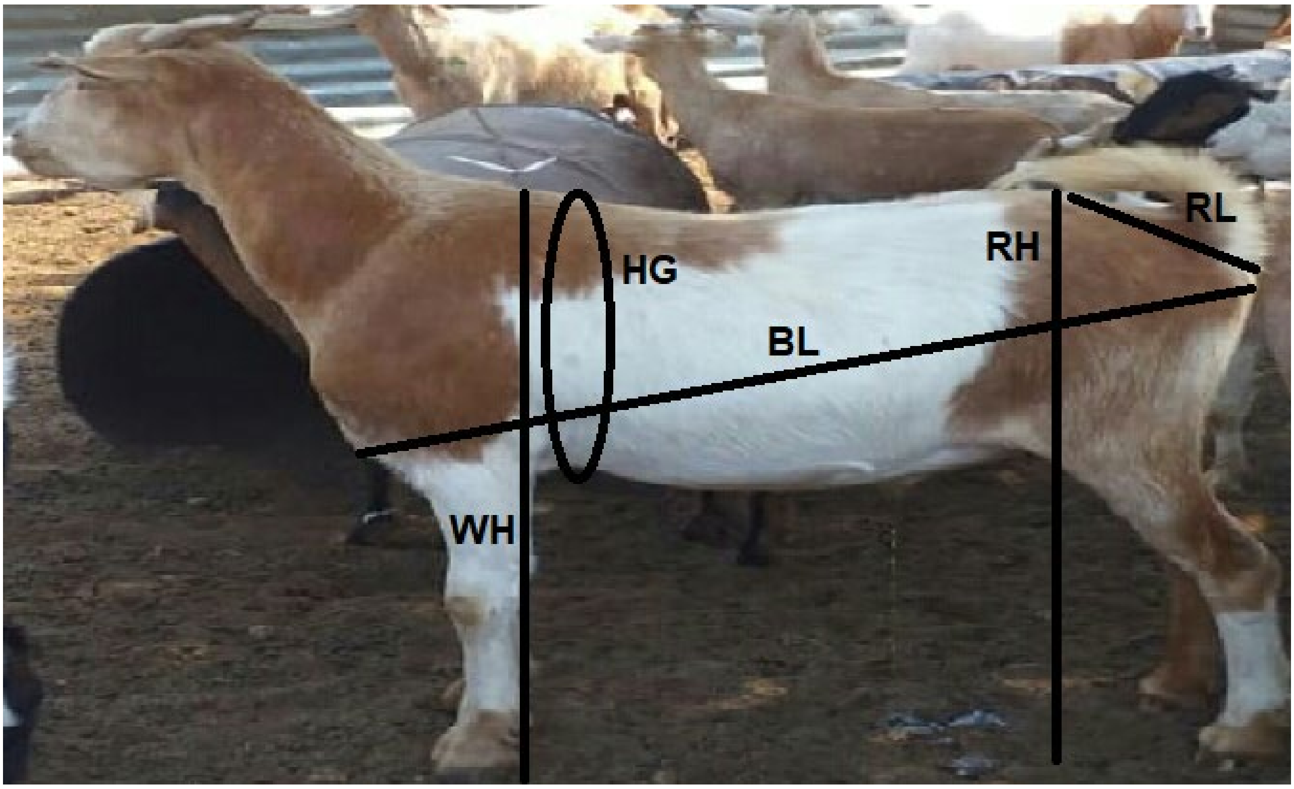

Figure 3.01: Goat showing anatomical parts that were measured during the study

3.6 Statistical analysis

Statistical Package for Social Sciences (IBM SPSS, 2019) version 26 software was used. Pearson correlation was used to determine the association between BW and some morphological traits of the selected goats. A probability of 5% was used for significant difference and 1% for highly significant difference between the traits. The effect of sex and age on live body weight and morphological traits of the indigenous goats was studied using analysis of variance (ANOVA). Classification and regression tree (CART) and Chi-square automatic interaction detector (CHAID) analyses were used to create an equation for determining traits that might be utilized to estimate BW.

The following is an equation for the analysis of variance that was used:

$Y_{ij} = u + G_j + e_{ij}$

Where: Y_{ij} is the observation of the i^{th} goats on the j^{th} sex/age

U is the mean

G_j is the fixed effect of the j^{th} sex/age

e_{ij} is the random residual error

The following goodness-of-fit formulas were used to compare the predictive performance of the Classification and regression tree (CART) and the Chi-square automatic interaction detector (CHAID) Algorithms in the study.

Coefficient of Determination

$$R^2 = \left[1 - \frac{\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2}{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}\right] \times 100$$

Adjusted Coefficient of Determination

$$R^2_{Adj} = \left[1 - \frac{\frac{1}{n-k-1}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2}{\frac{1}{n-1}\sum_{i=1}^{n}(Y_i - \bar{Y})^2}\right] \times 100$$

Standard Deviation Ratio

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

Relative Approximation Error

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

Root Mean Square Error

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

Coefficient of Variation

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

Where, Y_i is the observed live body weight (kg) of i^{th} goats;

$\hat{Y}_i$ is the predicted live body weight value of the i^{th} goats;

$\bar{Y}$, an average of the actual live body weight values of the goats;

ε_i is the residual value of the i^{th} goats; an average of the residual values;

k is the number of significant independent variables in the model;

and n is the total number of goats.

The residual value of each goat is expressed as $\varepsilon_i = Y_i - \hat{Y}_i$.

CHAPTER FOUR

RESULTS

4.1 Descriptive statistics of measured traits

Table 4.01 shows the summary of body weight and morphological traits. The mean BW value of does was found to be 36.05kg while that of bucks was 35.19kg. The summary of morphological traits showed that bucks had mean values of 68.43cm, 72.27cm and 63.81cm for BL, HG and WH, respectively. While does had mean values of 67.92cm, 73.34cm and 63.49cm for BL, HG and WH, respectively. The Coefficient of variance was found to range from 2.24% - 8.07% in bucks while that of does was found to range from 2.41% - 8.84%.

Table 4.01: Descriptive statistics of live body weight and morphological traits of bucks and doe goats

Traits	(Bucks = 283) Mean ± SE	CV (%)	(Does = 417) Mean ± SE	CV (%)
BW (kg)	35.19±0.48	8.07	36.05±0.43	8.84
BL (cm)	68.43±0.45	7.55	67.92±0.35	7.22
HG (cm)	72.27±0.43	7.30	73.34±0.35	7.11
WH (cm)	63.81±0.38	6.34	63.49±0.29	5.99
RH (cm)	64.19±0.35	5.95	64.15±0.28	5.68
RL (cm)	16.10±0.13	2.24	16.78±0.12	2.41

BW: Body weight; BL: Body length; HG: Heart girth; WH: Wither's height; RH: Rump height; RL: Rump length; SE: Standard error; CV: Coefficient of variation.

4.2 Phenotypic correlation between body weight and morphological traits

Table 4.02 shows the phenotypic correlation between body weight and biometric characteristics of does. The results showed that BW had a highly significant correlation ($P < 0.01$) with BL, but a significant correlation ($P < 0.05$) with HG, and non-significant correlation ($P > 0.05$) with WH, RH and RL. The results further showed that all the measured morphological traits including BL, HG, WH, RH and RL had non-significant correlation (P > 0.05) amongst each other.

Table 4.02: Phenotypic correlation between body weight and morphological traits of does

Traits	BW	BL	HG	WH	RH	RL
BW (kg)						
BL (cm)	0.65^{**}					
HG (cm)	0.28^{*}	0.11^{ns}				
WH (cm)	0.21^{ns}	0.18^{ns}	0.08^{ns}			
RH (cm)	0.23^{ns}	0.11^{ns}	0.11^{ns}	0.12^{ns}		
RL (cm)	0.23^{ns}	0.01^{ns}	0.10^{ns}	0.05^{ns}	0.20^{ns}	

BW: Body weight; BL: Body length; HG: Heart girth; WH: Wither's height; RH: Rump height; RL: Rump length; **: P < 0.01; *: P < 0.05; ^{ns}: non-significant.

Table 4.03 shows the phenotypic correlation between body weight and morphological traits of bucks. The results indicated that BW had a highly significant correlation (P < 0.01) with BL but non-significant correlation (P>0.05) with HG, WH, RH and RL. The results of the bucks further indicated that all the morphological traits including BL, HG, WH, RH and RL had non- significant correlation (P > 0.05) amongst each other.

Table 4.03: Phenotypic correlation between body weight and morphological traits of bucks

Traits	BW	BL	HG	WH	RH	RL
BW (kg)						
BL (cm)	0.65^{**}					
HG (cm)	0.23^{ns}	0.18^{ns}				
WH (cm)	0.07^{ns}	0.20^{ns}	0.13^{ns}			
RH (cm)	0.14^{ns}	0.08^{ns}	-0.04^{ns}	0.19^{ns}		
RL (cm)	0.12^{ns}	0.05^{ns}	0.01^{ns}	0.09^{ns}	0.09^{ns}	

BW: Body weight; BL: Body length; HG: Heart girth; WH: Wither's height; RH: Rump height; RL: Rump length; **: P < 0.01; ^{ns}: non-significant

4.3 CART modelling

Figure 4.01 showed the regression tree model constructed with CART. The model reflected factors that can affect body weight of South African non-descript indigenous goats from the three villages of Lepelle-Nkumbi Municipality. Node 0 with an overall body weight of 35.71±8.55kg with n = 700 was subdivided according to body length. Node 1 with body length less or equals to 65.50cm had an average body weight of 29.29±6.46kg with n = 240 and Node 2 with body length greater than 65.50cm had an average body weight 39.05±7.54kg with n = 460. Node 1 was be divided into Node 3 and 4 according to body length. Goats with body length less or equals to 59.50cm and those with body length greater than 59.50cm had an average body weight of 24.89±4.71kg with n = 91 and 31.99±5.89kg with n = 149, respectively. From Node 2, binary branching was developed into Node 5 and Node 6 according to age. Node 5 represented goats at one, two and three years old with an average body weight of 36.53±6.65kg with n = 291. Node 6 represented goats at four and five years old with average body weight of 43.40±6.98kg with n = 169. Node 4 was also split according to age into Node 7 and Node 8. Node 7 represented goats that are one and two years old while Node 8 represented goats that are three, four and five years old with average body weight of 28.88±4.48kg (n = 49) and 33.50±5.93kg (n = 100), respectively. Binary branching was observed from Node 5 according to body length to form Node 9 and Node 10. Node 9 showed goats with body length less or equals to 69.50cm while Node 10 showed goats with body length greater than 69.50cm with average body weight of 34.12±6.14kg (n = 131) and 38.50±6.41kg (n = 160), respectively. Node 9 was split into Node 11 and Node 12 according to the heart girth trait. Node 11 represented goats with heart girth less or equals to 72.50cm while Node 12 represented goats with heart girth greater than 72.50cm with average body weight 32.09±4.10kg (n = 68) and 38.50±6.41kg (n = 63), respectively. Node 10 showed binary branching of Node 13 and Node 14 according to villages. Node 13 showed goats from Morotse and Sepetsi while Node 14 showed goats from Lenting with average body weight 40.99±6.69kg (n = 71) and 36.52±5.46kg (n = 89), respectively. Node 6 which was split according to age of four and five years old was recorded to have the heaviest average body weight of 43.40kg in the model as compared to other nodes.

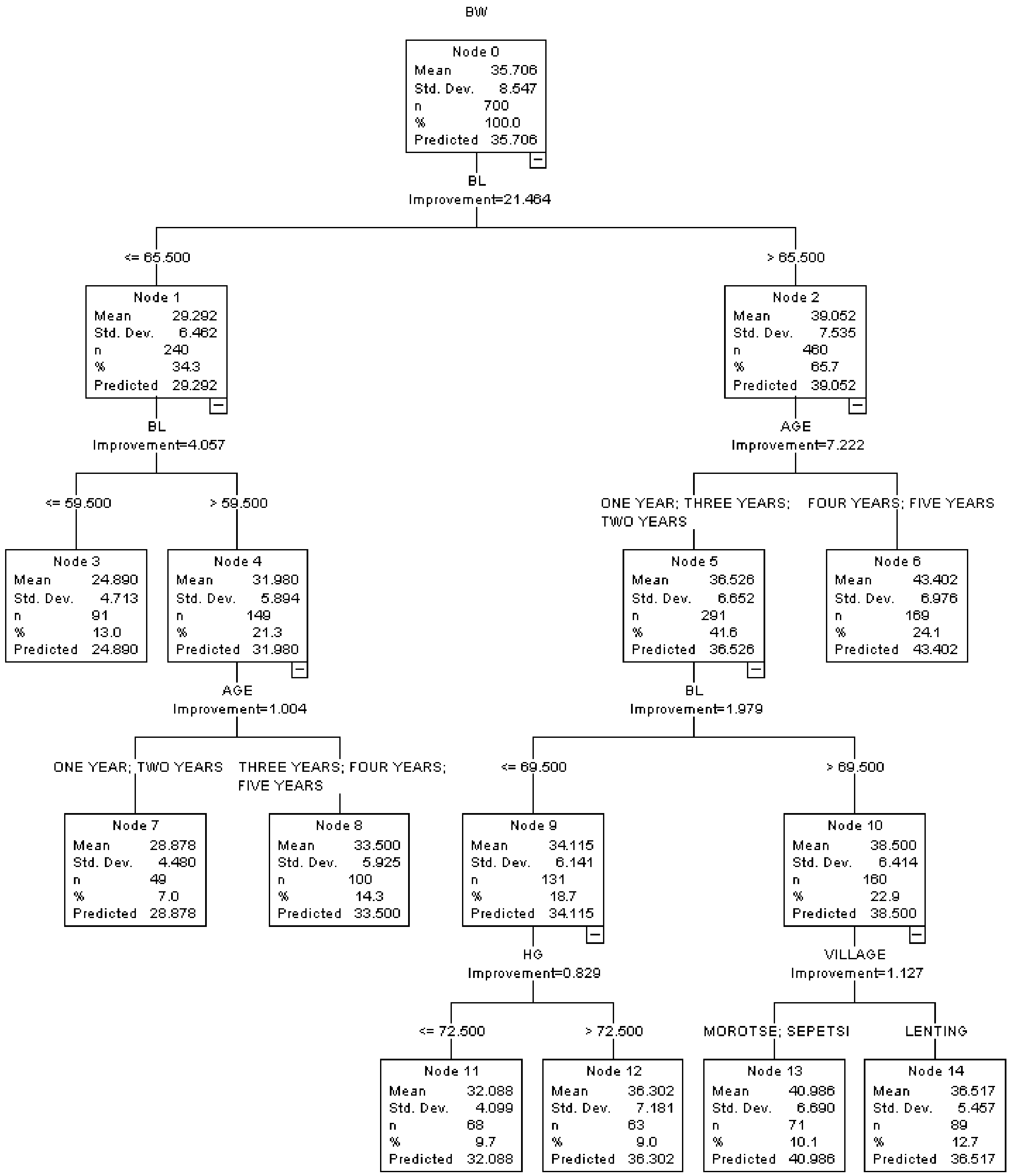

Figure 4.01: Classification and regression tree model

4.4 CHAID modelling

Figure 4.02, showing regression tree diagram constructed with Chi-squared Automatic Interaction Detector. The model displayed morphological traits and considered factors that affect body weight of South African non-descript indigenous goats from three villages of Lepelle-Nkumbi Municipality. Node 0 displayed average body weight of goats to be 35.706±8.547kg with n = 700. Node 0 a root node was split according to body length into six subgroups as Node 1 less than or equals to 58.00cm (24.35±4.61kg; n = 69), Node 2 between 58.00 - 62.00cm (29.94±5.91kg; n = 79), Node 3 between 62.00 – 64.00cm (79, 31.88±5.23kg; n = 64), Node 4 between 64.00 – 69.00cm (35.69±7.24kg; n = 205), Node 5 between 69.00 – 77.00cm (39.95±6.84kg; n = 206) and Node 6 greater than 77.00cm (43.68±7.08kg; n = 77). According to age, Node 4 had a binary branch, which is Node 7 and Node 8. Node 7 represented goats that are one, two and three years old while Node 8 represented goats that are four and five years old with average body weight 33.99±6.39kg with n = 154 and 40.82±7.28kg with n = 51, respectively. Node 5 was divided into Node 9 and 10 based on age. Node 9 represented goats that are three and two years old while Node 10 indicated goats that are four and five years old with average body weight 38.00±6.54kg (n = 125) and 42.96±6.21kg (n = 81), respectively. Node 7 was split into Node 11 and Node 12 based on heart girth. Node 11 showed goats with heart girth less or equals to 70.00cm while Node 12 represented goats with heart girth greater than 70.00cm with average body weight 31.79±4.17kg (n = 70) and 35.82±7.30kg (n = 84), respectively. Node 9 was split into Node 13 and Node 14 based on villages where goats were raised and bred. Node 13 represented goats from Morotse and Sepetsi while Node 14 represented goats from Linting with average body weight 40.70±6.85kg (n = 68) and 35.74±5.34kg (n = 68), respectively. Node 6 with body length greater than 77.00cm recorded the heaviest average body weight 43.67kg in the model as compared to other nodes.

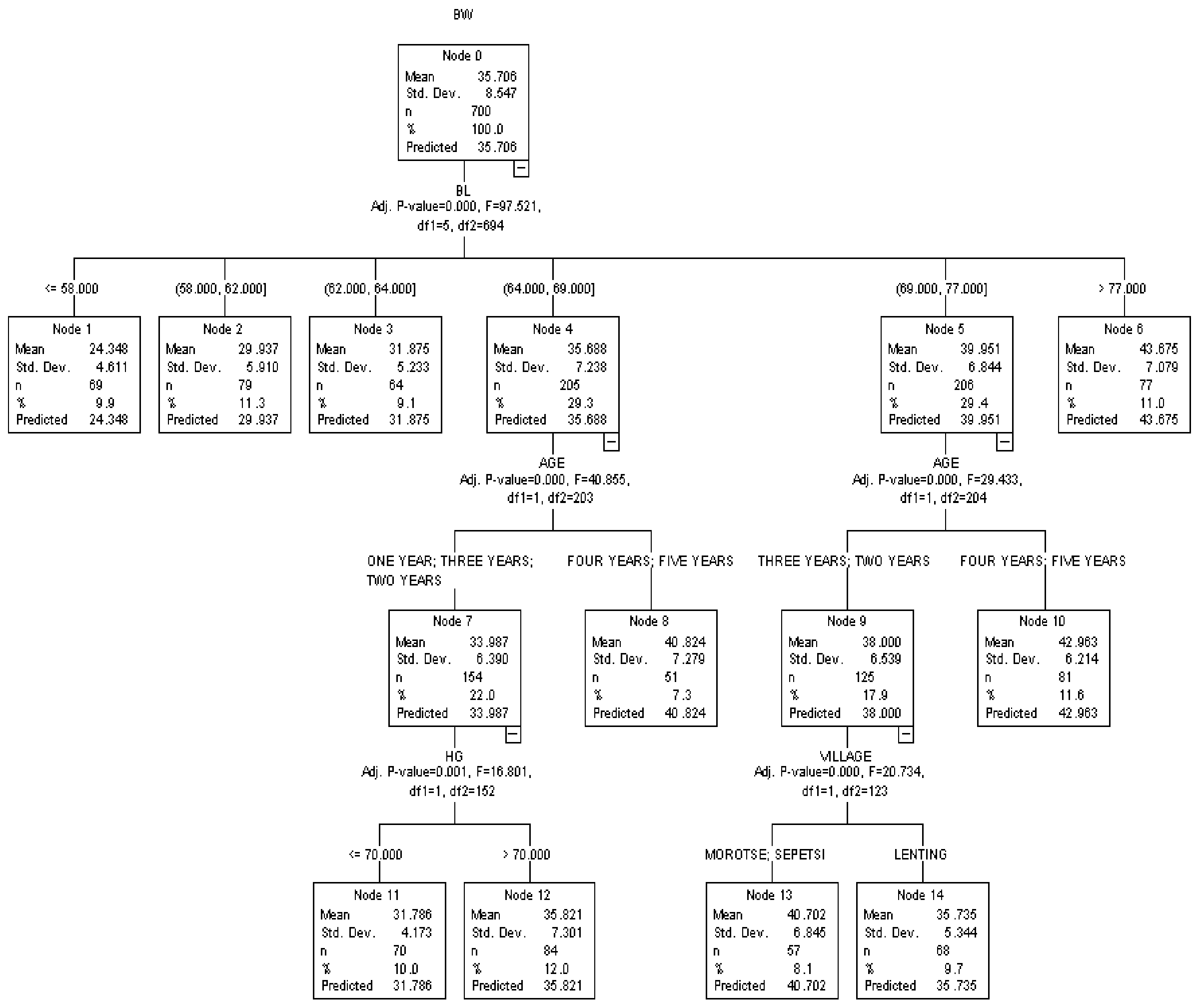

Figure 4.02: Chi-square automatic interaction detector model (CHAID)

4.5 Predictive performance of CHART and CHAID models

The predictive performance of CART and CHAID algorithm was performed using R-studio software and it is presented in Table 4.04. The R^2 between actual and predicted body weight values for CHAID and CART were found to be 58.1% and 51.4%, respectively. Adjusted coefficient of determination were 57.5% and 45.7%, respectively. Standard deviation ratio was 0.65 and 0.70, respectively. In addition, Relative approximate error estimates were 0.02 and 0.02, respectively while the Root mean square error estimates were 5.53 and 5.95, respectively. The coefficient of variance was 14.71 and 15.49, respectively.

Table 4.04: Predictive performance of CHAID and CART

	R^2	Adj. R^2	SD. ratio	RAE	RMSE	CV
CHAID	0.58	0.58	0.65	0.02	5.53	14.49
CART	0.51	0.46	0.70	0.20	5.95	15.49

R^2: Coefficient of determination; Adj. R^2: Adjusted coefficient of determination; SD. ratio: Standard deviation ratio; RAE: Relative approximate error; RMSE: Root mean square error; CV: Coefficient of variation

4.6 Effect of age on measured traits

Table 4.05 presents the effects of age on body weight and morphological traits of South African non-descript indigenous goats of Lepelle-Nkumbi Local Municipality. Age groups 1PPI, 2PPI, 3PPI, 4PPI and 5PPI had highly significant differences ($P < 0.01$) on BW, BL, HG, WH and RH. The results showed that age group 5PPI had highest BW, BL, HG, and WH than other age groups. Age group 1PPI indicated the lowest BW, BL, HG and WH as compared to other age groups. The results showed non-significant differences ($P > 0.05$) between 1PPI, 2PPI, 3PPI, 4PPI and 5PPI in RL.

Table 4.05: Effect of age on body weight and morphological traits

	Age				
	1PPI (N = 24)	2PPI (N = 168)	3PPI (N = 312)	4PPI (N = 187)	5PPI (N = 9)
Traits	Mean±SE	Mean±SE	Mean±SE	Mean±SE	Mean±SE
BW	$25.0±1.3^e$	$29.0±0.5^d$	$35.9±0.4^c$	$41.9±0.5^b$	$50.5±2.8^a$
BL	$58.1±1.0^d$	$63.5±0.5^c$	$68.8±0.4^b$	$71.9±0.4^b$	$75.3±2.5^a$
HG	$63.7±1.3^b$	$71.9±0.5^a$	$73.1±0.4^a$	$74.5±0.5^a$	$74.7±2.0^a$
WH	$57.8±0.8^b$	$61.5±0.4^a$	$63.5±0.3^a$	$63.7±0.5^a$	$64.4±2.1^a$
RH	$59.5±1.0^b$	$64.0±0.5^a$	$64.1±0.3^a$	$64.9±0.4^a$	$64.4±1.9^a$
RL	16.1±0.6	16.2±0.2	16.6±0.1	16.6±0.2	16.5±0.7

1PPI: One Pair of Permanent Incisor; 2PPI: Two Pair of Permanent Incisor; 3PPI: Three Pair of Permanent Incisor; 4PPI: Four Pair of Permanent Incisor; 5PPI: Five Pair of Permanent Incisor; BW: Body weight; BL: Body length; HG: Heart girth; WH: Wither's height; RH: Rump height; RL: Rump length; [a, b, c]: superscripts that shows difference between means; SE: Standard Error; N: Number of animals.

4.7 Effect of sex on measured traits

Table 4.06 presents the effect of sex on body weight and morphological traits of South African non-descript indigenous goats of Lepelle-Nkumbi Local Municipality. Sex indicated a non-significant difference (P > 0.05) on BW, BL, HG, WH and RH but highly significant differences (P < 0.01) with RL.

Table 4.06: Effect of sex on body weight and morphological traits

	Sex	
	Female (N = 417)	**Male (N = 283)**
Traits	**Mean±SE**	**Mean±SE**
BW	36.0±0.4	35.1±0.4
BL	67.9±0.3	68.4±0.4
HG	73.3±0.3	72.2±0.4
WH	63.4±0.2	63.8±0.3
RH	64.1±0.2	64.1±0.3
RL	16.7±0.1[a]	16.1±0.1[b]

BW: Body weight; BL: Body length; HG: Heart girth; WH: Wither's height; RH: Rump height; RL: Rump length; SE: Standard Error; N: Number of animals.

CHAPTER 5

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Discussion

In a situation where there is absence of weighing scales, resource-constrained farmers in rural areas can adopt the use of morphological traits to predict livestock body weight (Adhianto et al., 2020). The first part of this study looked at the association between live body weight and some morphological characteristics of non-descript indigenous South African goats in the Lepelle-Nkumbi Local Municipality. The study used phenotypic correlation to determine the association between body weight and some morphological traits, and there was association found between body weight and body length and heart girth. Females had a positive highly statistical significant correlation with body length and a positive statistical significant correlation with heart girth but a non-significant correlation with withers height, rump height, and rump length. The study also found a non-significant correlation among the morphological traits. Body weight had a positive highly statistical significant correlation with body length but a non-significant correlation with heart girth, withers height, rump height, and rump length in bucks. However, there was no significant correlation among the morphological traits.

The findings of the current study were consistent with those of Khargharia et al. (2015), Karna et al. (2020), and Mathapo and Tyasi (2021), who found a positive highly statistical significant correlation between body weight and body length in Assam Hill goats, Ganjam goats of Odisha, and yearling female Boer goats, respectively. However, Tsegaye et al. (2013) reported a different result from the current study with a lower correlation coefficient found between body weight and body length in Harrarghe Highland goats in Ethiopia. This could be due to variation in environmental conditions. Furthermore, the findings of Novoselec et al. (2020) in their study of Travnik Pramenka sheep contradicted the findings of the current study, who reported a high correlation between chest width and body weight. This could be due to differences in species and environmental factors. Tekin et al. (2019) found a significant correlation between body weight and heart girth in hair goats, which agreed with the findings of the current study. Vanvanhossou et al. (2018), on the other hand, reported in their study that chest girth had the highest correlation coefficient in West African Savannah Shorthorn cattle. This could be due to the different animal species, the environmental conditions, or the production system used. Due to the highest correlation coefficient observed for body length in the current study, it would be a reliable trait for predicting body weight of South African non-descript indigenous goats.

These findings imply that increased body length and heart girth in does and body length only in bucks will increase body weight, and that may be used as a selection criterion during breeding to improve body weight. The relationship discovered between some morphological traits (BL and HG) and body weight suggests that these traits are controlled by a single gene (Maiwashe et al., 2002). Furthermore, the current study suggests that body length can be used to estimate the body weight in both sexes of South African non-descript indigenous goats from Lepelle-Nkumbi Local Municipality.

Two different data mining algorithms (CART and CHAID) that were used to create a model to estimate body weight of non-descript indigenous goats of Lepelle-Nmbi Local Municipality of South Africa which was based on several morphological traits and factors, the two models, (CHAID and CART) indicated that body length, heart girth, age, and the villages (where South African non-descript indigenous goats were bred and raised) can be used as influential predictors of body weight of goats. Based on body length and age parameters, the heaviest average body weight was recorded in node six for both CHAID and CART. In the current study, the CART model produced four levels of branching, whereas CHAID produced three levels of branching. This means that the CHAID model may be much easier to interpret than the CART model (Ali et al., 2015). The current study's findings from the CHAID and CART models both explained that body length played the most significant role in goat body weight and can be used as a body weight predictor in South African non-descript indigenous goats.

In contrast to the current findings, Koc et al. (2017) discovered that birth weight was the most effective trait on body weight of Mengali lambs from both CART and CHAID algorithms. The findings of Mohammad et al. (2012), who reported that chest girth significantly affected body weight of indigenous sheep breeds in Balochistan, Pakistan, using CHAID, contradicted the findings of the current study. This could be because of the different species used in the studies. From the study of Faraz et al. (2021) who used the CART model for analysis, it was reported that body length was the most effective variable on body weight of sheep under tropical conditions in Pakistan. In the current study, sex variable was excluded from both CART and CHAID models. This finding was also consistent with the findings of Olfaz et al. (2019) in the breeding of Karayaka sheep, where it was discovered that sex was not included in the model, but it was considered in the study as a factor that affects body weight. However, Eyduran et al. (2017) reported findings that differed from the current findings in that they included the sex factor in both the CART and CHAID models in their study, and the sex factor was found to significantly influence the body weight of indigenous Beetal goats in Pakistan.

The performance of the algorithms (CART and CHAID) in the current study were nearly identical. According to Chitra et al. (2012), a coefficient of determination of 0.70 or higher is considered good, while a coefficient of determination of less than 0.70 is considered poor. The CHAID and CART models in the current study had a coefficient of determination of less than 0.70 which made it to fall into the category of poor predictive models. The findings of the current study is in line with that of Celik (2019), who reported that the CHAID and CART models performed poorly when predicting body weight of Pakistan goats. Yakubu (2012) also found similar results to the current study, who reported that CART had a lower coefficient of determination in Nigerian Uda sheep. In comparison to the current findings, Celik et al. (2017) found that CART and CHAID had the best predictive performance when predicting body weight of Mangali rams in Pakistan, and CART was the best model to use to predict body weight. The reason for these findings may not be clearly understood, however, it could be as a result of the varied species that was used in the study, or may be as a result of environmental conditions, the age of the animals, and the number of animals used in their study. Furthermore, it was found that the CART model was the only algorithm tool that had a lower coefficient of determination when predicting dog body weight (Celik and Yilmaz, 2017). Meanwhile, the findings of Tyasi et al. (2020c) is in line with the current study who reported a lower coefficient of determination in the CART model when predicting body weight of Potchefstroom Laying hens. In comparison to the current findings, Karadas et al. (2017) found CHAID to have a high coefficient of determination, despite being outperformed by the MARS model.

The effect of age and sex on body weight and some morphological traits of South African non-descript indigenous goats was studied using analysis of variance. Age had a strong influence on body weight and some morphological traits of non-descript indigenous goats that were used based on the current results. It was revealed in the current study that body weight, body length, heart girth, withers height, and rump height showed a highly significant difference across all age groups, whereas rump length showed a non-significant difference across all age groups.

The findings of the current study were consistent with those of Abegaz et al. (2013) and Ahmed et al. (2016), who found higher body weight at the oldest age group in Abergelle and Western lowland goats of Ethiopia and Western highland goats in Horro Guduru Wollega zone, respectively. The findings of Bekalu et al. (2016), who reported that all morphological traits increased as age group increased, contrasted with the findings of the current study that showed that rump length did not change as age increases in goats. Sex had a significant effect on rump length but had no effect on body weight, body length, heart girth, withers height, or rump length in South African non-descript indigenous goats. The current findings of our study were in contrast to those of Gelana and Belete (2016), Hulunim et al. (2017), and Yemane et al. (2020), who found that males were heavier than females in the majority of morphological traits for goats reared in different areas of Ethiopia. This difference in body weight and morphological traits between males and females could be attributed to hormone differences between the sexes (De Funentes-Fernandez et al., 2016). However, Alphonsus et al. (2017) indicated a significant relationship between sex and measured traits, with females being heavier than males in two Nigerian indigenous goat breeds.

Except for rump length, the current study found an increasing trend in body weight, body length, heart girth, withers height, and rump height across all age groups. When compared to other age groups, age group five had the highest values for body weight and all morphological traits except for rump length. The current findings imply that non-descript indigenous goats of South Africa gain more body weight later in life. Sowande et al. (2010) discovered that older animals had higher body weights than younger ones due to maturation. According to the findings of the current study, sex cannot be used as a determining factor of measured traits because had no significant effect on body weight, body length, heart girth, withers height, and rump height.

5.2 Conclusion

The current study used correlation coefficient to determine the association between body weight and some morphological traits of South African non-descript indigenous goats with the use of different data mining algorithms (CHAID and CART) to identify morphological traits that can be used to estimate body weight, and ANOVA to investigate the effect of age and sex on body weight and morphological traits of the goats. Body length was found to be highly correlated with body weight in the presence study, hence, it may be used as a selection criterion in both sexes when determining body weight of South African non-descript indigenous goats. The CHAID and CART models demonstrated that body length, heart girth, and age can be used to estimate goat body weights of goats. The models suggested that body length alone could be used to predict body weight in does and bucks of non-descript indigenous South African goats. The study found that the two models, CHAID and CART, performed poorly on the goodness of fit test; however, CHAID is suggested to be a better model than CART due to its high coefficient of determination, adjusted coefficient of determination and low relative approximate error, root mean square error, standard deviation ratio and coefficient of variation. Furthermore, age of goats had an effect on body weight, body length, heart girth, withers height, and rump height which implies that age can be used as a determining factor to predict body weight and mentioned morphological traits in South African indigenous goats. The current study found that sex had an effect on rump length but had no effect on body weight, body length, heart girth, withers height, or rump height. This suggests that sex can only be used to predict rump length and not any other measured traits of South African non-descript indigenous goats.

Furthermore, the findings of the current study could be used by South African non-descript indigenous goat farmers in the Lepelle-Nkumbi Local Municipality to improve and estimate body weight from morphological traits to make right management decisions in their herds such as selecting good bucks and does for breeding, giving required vaccination dosage to a specific goat, and setting price when selling. These findings may also aid extension officers and researchers in understanding the association between live body weight and biometric characteristics of non-descript indigenous goats of South Africa, as well as the sophisticated statistical techniques (data mining algorithms) that develop models that accurately estimate goat body weight.

5.3 Recommendations

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

- Researchers need to research more on the association between body weight and morphological traits using different data mining algorithm.
- Researchers must also consider using different goat breeds with high population size, in different areas around Limpopo province and different animal species.
- Researchers and extension officers must conduct workshops for communal and smallholder farmers in order to train them about alternative ways of predicting body weight of their animals without using weighing scales.
- Researchers must teach communal and smallholder goat farmers on how crucial body weight of their goats is to them and how it can help them to improve their herds, get better profit from their animals and to manage them.

CHAPTER 6
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