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REGRESSION TREE ANALYSIS TO PREDICT BODY WEIGHT OF SOUTH AFRICAN NON-DESCRIPT GOATS RAISED AT SYFERKUIL FARM, CAPRICORN DISTRICT OF SOUTH AFRICA

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Abstract: Regression tree is the data mining algorithm method which contains a series of calculations that creates a model from collected data. Present study aimed to develop model to estimate body weight (BW) from biometric traits viz. withers height (WH), sternum height (SH), body length (BL), heart girth (HG) and rump height (RH). A total of eighty-three (n = 83) South African non-descript indigenous goats (54 females and 29 males) aged three months and above were used in the study. Pearson's correlations and classification and regression tree (CART) as statistical techniques were used for data analysis. Correlation results indicated that there was a positive highly statistical significant ($P < 0.01$) correlation between BW and all biometric traits in both males and females, the positive highly statistical significant correlation was observed between BW and WH ($r = 0.82$) in female goats while in males the highest positive statistical significant correlation was detected between BW and BL ($r = 0.83$). CART model indicated that the BW mean was 29.868 kilograms (kg) as dependent variable and BL had the highest remarkable role in BW followed by SH, RH while the age had the least remarkable role in BW. This study suggests that BL, SH and RH might be used by South African non-descript goats' farmers as a selection criterion during breeding to improve BW of animal. More completive studies and experiments need to be done using CART to predict BW in more sample size of South African non-descript goats or other goat breeds.

Keywords: Biometric traits, body length**,** heart girth, rump height, sternum height.

Introduction

Classification and regression tree is one of the data mining algorithm that can predict categorical dependent variables referred as classification and continuous dependent variables referred as regression by constructing trees *(Breiman et al., 1984)*. This data mining algorithm has been practiced world widely in animal breeding to predict body weight (BW) and it is also used in livestock; Potchefstroom Koekoek chickens *(Tyasi et al., 2020a)*, in Beetal goats of Pakistan *(Eyduran et al., 2017)*, in Turkish Tazi dogs *(Celik and Yilmaz, 2018)* and also in Balochi sheep *(Huma and Iqbal, 2019)*. South African non-descript goat is commonly kept in rural areas of South Africa, mainly with traditional methods *(Webb et al., 2003*; *Norris et al., 2015)*. According to *Tyasi et al. (2020b)* non-descript indigenous goats are more resistance to diseases and parasites in comparison with other breeds. This breed is one of the non-selective browsers and survive well in harsh environment *(Mara et al., 2013)*. Goat production contribute to economy by producing meat and milk which serve as part of human diet, moreover they play a role when performing religious and cultural ceremonies *(Hassen and Tesfay, 2014)*. Challenges experienced in rural areas are that farmers are disadvantaged when it comes to selling, feeding, and providing medication to their goats due to lack of weighing scales, as they are expensive *(Eyduran et al., 2017)*. There is limited information of prediction of BW from morphological traits and characterizes using classification and regression tree in non-descript goats of South Africa. Hence, the objective of the study was to establish a model to predict the BW using withers height, sternum height, body length, hearth girth and rump height of South African non-descript indigenous goats. The study will provide information which will help the farmer to select the best biometric traits that might be used to predict BW.

Materials and Methods

Study area

The study was conducted in Limpopo province, Syferkruil Experimental farm (Figure 1) which is situated 9 kilometres northwest from University of Limpopo. Temperatures in winter range between 5 ^{O}C and 28 ^{O}C and in summer ranges from 10 ^{O}C to 36 ^{O}C and the mean annual rainfall is less than 400mm.

Research animals, design, and management

South African non-descript indigenous goats of 3 months and above one year of age were used in the current study. Cross-sectional design was used with one replicate per goat. The farm was visited, and data was collected once from 83

goats (54 female and 29 male). Goats were kept under extensive production whereby the animals lived in a constricted area called a kraal. They grazed during the day and the animals were placed in the kraal during the evenings. Fresh, clean water was provided to the animals daily.

Data collection

BW and five biometric traits were measured on each goat in the morning before they are released for grazing or feeding. Biometric traits measured were: withers height (WH), sternum height (SH), heart girth (HG), rump height (RH) and body length (BL). BW was measured in kilograms (kg) using a balance scale while biometric traits were measured using a measuring tape in centimetres (cm). All measurements were taken according to the suggestion of *Norris et al. (2015)*. Briefly, WH: distance from the highest point of the shoulder (wither) to the ground surface in relation to level of the fore legs, BL: distance between anterior shoulder point to the posterior extremity of the pin bone, SH: vertical distance from lower tip of the sternum to the ground as the animal standing, RH: distance from the top of the pelvic girdle to the ground surface in relation to the level of hind legs and HG: vertical distance from the ground to the top of the pelvic. All the measurements were taken by one person to avoid errors.

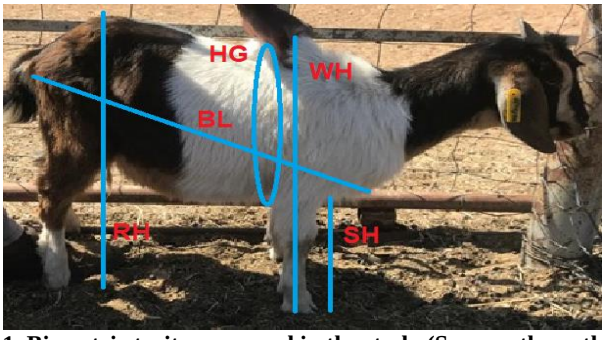

Figure 1. Biometric traits measured in the study (Source: the author)

Classification and regression tree (CART) algorithm

CART algorithm is a tree decision technique which was developed by *Breiman et al. (1984)* and it is mostly used in the animal industry because it is very simple, easy, and applied to visualize. CART was performed as described by *Eyduran et al. (2019)* and *Tyasi et al. (2021)*. Briefly, CART was applied to estimate BW as the dependent variable from five biometric traits viz. WH, SH, HG, RH and BL. Age and sex of the animal was also included in the model as the independent variables. Ten (10) fold cross-validation was used as an error estimation method documented to be the most acceptable method of prediction to

offer estimate of the future error of prediction for each node and explained the variation observed in the dependent-variable was predicted as follows:
$S^2_x = (1 – S^2_e) \times 100$
S^2_e = risk value/S^2_y
Where in details:
S^2_x = explained variation, S^2_e = unexplained variation and S^2_y = variance of the root node (standard deviation of the root node)^2.

Data analysis

The current experimental data were analysed using Statistical Package for Social Sciences (IBM SPSS, 2019) version 26 software. Probability of 5% for significant was used and probability of 1% for highly significant between traits was also used. Descriptive statistics such as average, standard deviation, standard error, and coefficient of variation were calculated. Pearson's correlation coefficient was used to estimate the relationships between all the measured traits while classification and regression tree (CART) was computed to develop a model.

Results

Descriptive statistics

The summary of all examined traits on South African non-descript indigenous goats (male and female) which are less than one-year-old and above is presented in Table 1. In goats younger than a year, BW mean numerical value of female kids were higher than those of male kids. Descriptive statistics of biometric traits recognised that female kids had higher mean numerical values in all traits, HG, RH, BL, WH and SH respectively. While in goats older than a year, BW mean numerical value of male goats were higher than those of female goats. The summary of biometric traits showed that male goats had higher mean numerical values in all traits, HG, RH, BL, WH and SH. Coefficient of variation of goats that are lower than one year of age ranged from 9.03% to 60.51% while animals above or equals to one year of age had coefficient of variation ranging from 7.22% to 20.35%.

Table 1. Descriptive statistics for body weight and biometric traits of male and female South African non-descript goats

Age group	Traits	Sex	Mean±SE	SD	CV (%)	Min	Max
< 1 year	BW (kg)	M	24.82±3.20	15.02	60.51	7.00	60.00
		F	40.36±2.49	10.28	25.47	25.30	58.00
	HG (cm)	M	64.02±3.02	14.17	22.13	37.50	82.60
		F	87.49±2.68	11.06	12.64	75.00	104.90
	RH (cm)	M	49.59±1.99	9.31	18.77	32.50	64.00
		F	58.87±1.68	6.94	11.79	43.00	66.00
	BL (cm)	M	59.00±2.56	12.01	20.35	38.00	76.40
		F	77.95±1.93	7.95	10.20	66.40	90.00
	WH (cm)	M	50.70±2.02	9.49	18.72	35.00	69.00
		F	67.31±2.20	9.06	13.46	50.00	79.00
	SH (cm)	M	35.33±1.13	5.32	15.06	27.00	42.50
		F	40.31±0.88	3.64	9.03	32.00	45.00
≥ 1 year	BW (kg)	M	42.51±3.27	8.65	20.35	30.60	55.00
		F	25.66±1.49	9.04	35.23	9.00	43.00
	HG (cm)	M	83.93±3.10	8.20	9.77	78.00	96.50
		F	70.37±1.85	11.25	15.99	45.00	83.00
	RH (cm)	M	61.14±2.79	7.38	12.07	51.00	68.00
		F	52.42±1.42	8.62	16.44	39.00	68.00
	BL (cm)	M	77.41±3.84	10.17	13.14	66.40	89.50
		F	62.16±1.43	8.68	13.96	41.00	76.40
	WH (cm)	M	72.14±1.97	5.21	7.22	65.00	78.00
		F	55.42±1.62	9.84	17.76	40.00	75.00
	SH (cm)	M	41.07±1.51	4.00	9.74	36.00	45.00
		F	35.62±0.78	4.74	13.31	26.00	43.00

SE: Standard Error, CV: Coefficient of Variation, SD: Standard Deviation, BW: Body Weight, HG: Heart Girth, RH: Rump Height, BL: Body Length, WH: Withers Height, SH: Sternum Height, < 1 year: Younger than one year, ≥ 1 year: Older than a year.

Phenotypic correlations among measured traits

Pearson's correlation was used to examine the relationship between BW and biometric traits of South African non-descript goats for both sexes (Table 2). The results above diagonal line show correlation results of female goats. The results indicated that BW had a positive highly statistical significant ($P < 0.01$) correlation with HG, RH, BL, WH and SH. However, phenotypic correlation findings of male below the diagonal line showed that BW had a positive highly significant correlation ($P < 0.01$) with HG, RH, BL, WH and SH .

Table 2. Phenotypic correlation between body weight and biometric traits of female above diagonal and male below diagonal

Traits	BW	HG	RH	BL	WH	SH
BW (kg)		0.79**	0.80**	0.83**	0.76**	0.66**
HG (cm)	0.68**		0.82**	0.88**	0.78**	0.60**
RH (cm)	0.62**	0.58**		0.88**	0.84**	0.72**
BL (cm)	0.77**	0.87**	0.62**		0.88**	0.73**
WH (cm)	0.82**	0.66**	0.86**	0.73**		0.73**
SH (cm)	0.63**	0.50**	0.81**	0.63**	0.83**	

**P<0.01; BW: Body weight; HG: Heart girth; RH: Rump height; BL: Body length; WH: Withers height; SH: Sternum height

CART algorithm

CART model in South African non-descript goats (Figure 2) with BW as a dependent variable and biometric traits, sex and age as the independent variables. This model contained a total of fourteen (14) nodes on which eight of them were terminal nodes (node 3, 6, 8, 10, 11, 12, 13, 14), respectively. Node 0 is the root node containing the descriptive statistics of BW (mean = 29.868kg, standard deviation = 13.080 and n = 83). Node 0 based on BL was divided into node 1 (<= 63.050cm) and node 2 (> 63.050cm), respectively. Node 1 was divided based on HG into node 3 (<=56.500cm) and node 4 (> 56.500 cm). Node 4 was divided based on HG into node 7 (<=70.500cm) and node 8 (>70.500 cm). Node 7 was divided on the basis of RH into node 11 (<= 50.500 cm) and node 12 (> 50.500cm), respectively. Node 2 on the other hand was divided based on SH into node 5 (<= 43.250cm) and node 6 (>43.250cm). Node 5 was divided based on BL into node 9 (<=72.050cm) and node10 (>72.050cm). The last node to be divided in this model was node 9 which was divided on the basis of age into node 13 (goats that are two years and four years old) and node 14 (goats that are one year and eleven years old), respectively. In all the terminal nodes, node 6 appeared to be the best node as it was recorded the highest predicted mean (54.00kg) than node 3 (10.939kg), node 8 (25.500kg), node 10 (39.467kg), node 11 (18.444kg), node 12 (20.600kg), node 13 (38.333kg) and node 14 (30.750kg), respectively. The model showed that node 12 had the lowest variance $(0.894)^2 = 0.799$ and the variance of the root node or dependent variable (BW) was $S^2_y = (13.080)^2 = 171.086$. The unexplained variation in the BW was S^2_e = risk value ÷ S^2_y = 25.316 ÷ 171.086 = 0.148 and the variation in the model was explained as $S^2y = (1 - S^2_e) \times 100 = (1-0.148) \times 100 = 0.85 \times 100 = 85\%$,

respectively.

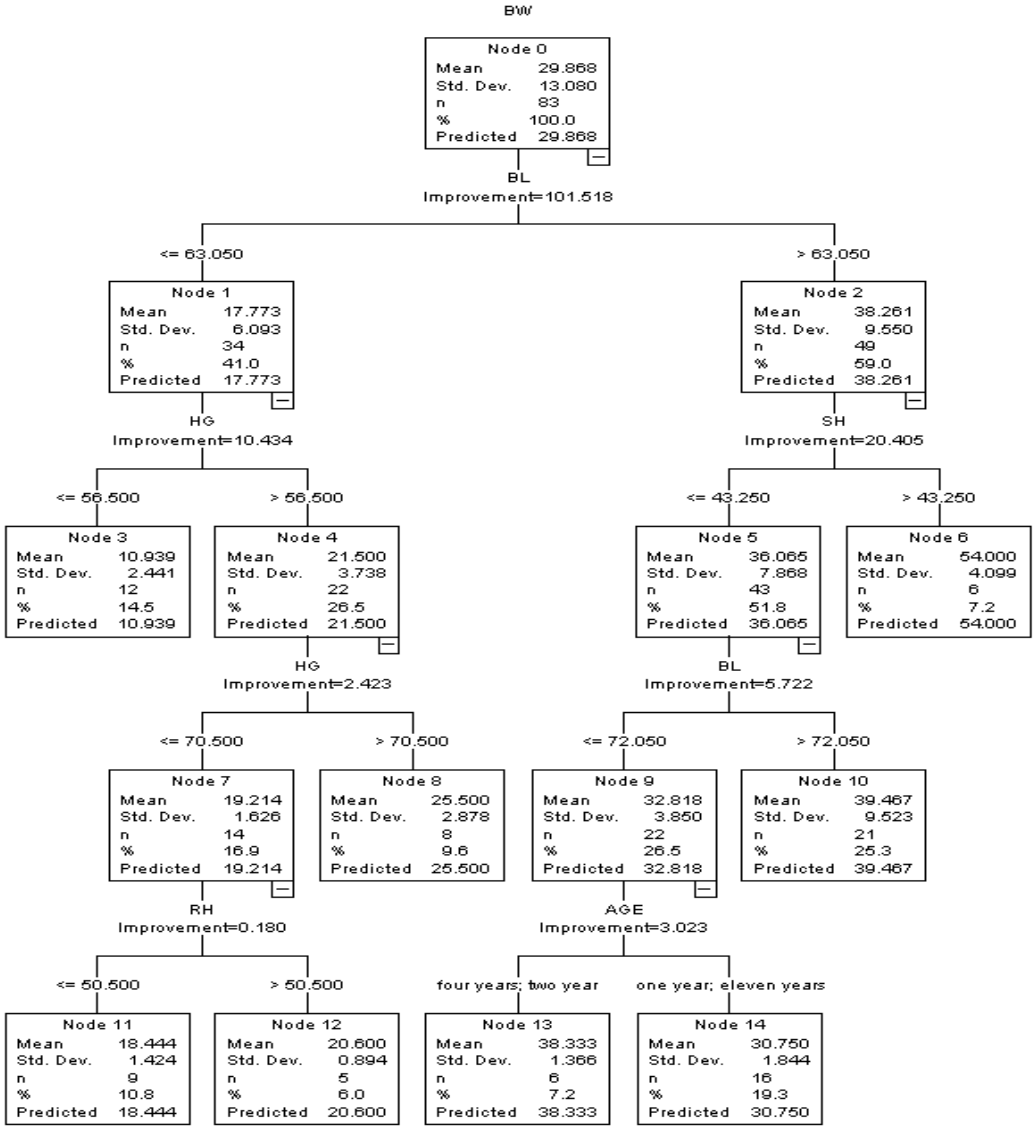

Figure 2. Classification and regression tree model (CART) (Source: the author)

Discussion

Biometric traits are alternatives which can be used to predict BW mostly at rural areas where the weighing scale is not available *(Norris et al., 2015*; *Eyduran et al., 2017, Tyasi et al., 2020b)*. Classification and regression tree is the best decision tree technique for recognizing biometric traits playing a critical role on live BW of animal *(Eyduran et al., 2017*; *Tyasi et al., 2021)*. The current study firstly determined the relationship between body weight, rump height, body length, withers height and sternum height of South African non-descript goats. Correlation findings in both sexes indicated that BW had positive highly significant correlation with body length, rump height, heart girth, withers height and sternum height. Increasing body length, rump height, heart girth, withers height and sternum height in both sexes might cause an increase in BW. Therefore, body length, rump height, heart girth, withers height and sternum height might be used for genetic improvement of BW during breeding. Contrary to the current study was reported by *Tyasi et al. (2020b)* where BW showed the lowest correlation with heart girth, no correlation with rump length and high correlation with withers height, rump height and body length in South African non-descript indigenous female goats. Study differences might be due to age group of goats used in the study. Similar studies concluded that body weight had positive high significant correlation with the biometric traits. *Yakubu and Mohammed (2012)*, agrees with the current study where there is positive highly significant correlation between body weight and body length, body weight and heart girth in red Sokoto goats. *Yakubu (2009)*, observations are in harmony with the current study where there is positive highly significant correlation between BW and withers height, rump height, body length, heart girth in West African dwarf goats. *Norris et al. (2015)*, had a positive highly significant correlation between BW and heart girth in female meanwhile, *Berhe (2017)* observed positive high significant correlation between body weight and heart girth, body weight and withers height.

CART algorithm was used in the current study to develop a model to predict the BW from withers height, sternum height, body weight, body length hearth girth and rump height of South African non-descript. Our findings indicated that body length, heart girth, sternum height, rump height and age explained 85% of variation in body weight of South African non-descript goats. Model developed from the current study suggests that body length had the highest remarkable role in body weight followed by heart girth, sternum height, rump height, respectively. It was also shown that age also played a significant role in body weight of South African non-descript indigenous goats *Celik and Yilmaz (2018)* conducted CART in Turkish Tazi dogs and had disagreement with the current study, where 68.90% of the variability of the BW was explained with withers height, rump height and abdominal width and chest depth, while withers height played the highest role and chest depth played the lowest role on BW. The reason for variation may be due to

type of species differences. Contrary to the current study was also reported by *Celik et al. (2017)* in Beetal goats of Pakistan where age played a significant role on body weight followed by scrotal length, the traits found on CART explained 91.97% of variation in the body weight. The difference may be due to different breed and sample size. *Tyasi et al. (2020a)* performed a study on Potchefstroom Koekkoek laying hens and discovered that wing length played a higher role on body weight than other traits using. Classification and regression tree followed by beak length, and the traits found on CART explained 57% of the variation in body weight. The variation may be due to the type of species used, based on current study results.

Conclusion

It can be concluded that there is a positive highly significant relationship between body weight and biometric traits (rump height, body length, withers height, sternum height) of South African non-descript indigenous goats. The study suggests that all the biometric traits can be used as a selection criterion to improve body weight of South African non-descript indigenous goats, moreover they may assist in decision making when feeding, medicating, marketing and breeding their animals. Furthermore, the study emphasized that body length and withers height can be used as single traits to improve body weight in males and female goats, respectively. CART model can be used to predict body weight of South African non-descript indigenous goats precisely due to its high coefficient of determination. The model suggests that body length alone can be used to predict body weight of South African non-descript indigenous goats. The current study will help communal farmers in determining the feed amount, drug dose, and market price of an animal and in improving profitability of animal farms. It is recommended that prediction of body weight using biometric traits especially at rural areas might save farmers expenses for scales, help in decision making for breeding purposes for economic importance traits such as body weight. However, further studies need to be performed on the prediction of body weight using CART algorithm in different goat breeds or more sample size of the same breed.

Analiza regresijskog stabla za predviđanje telesne mase južnoafričkih autohtonih koza uzgajanih na farmi Syferkuil, u okrugu Kaprikorn u južnoj Africi

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Rezime

Regresijsko stablo je metoda algoritma za dobijanje podataka koja sadrži niz proračuna koji kreiraju model od prikupljenih podataka. Ova studija je imala za cilj da razvije model za procenu telesne mase (BW) na osnovu biometrijskih osobina, tj. visine grebena (WH), visine grudne kosti (SH), dužine tela (BL), obima srca (HG) i visine zadnjeg dela tela, kukova (RH). U istraživanju je korišćeno ukupno osamdeset tri (n = 83) južnoafričke autohtone koze (54 ženke i 29 mužjaka) starosti od tri meseca i više. Za analizu podataka korišćene su Pirsonove korelacije i stablo klasifikacije i regresije (CART - classification and regression tree) kao statističke tehnike. Rezultati korelacije su pokazali da postoji pozitivna visoko statistički značajna ($P < 0,01$) korelacija između BW i svih biometrijskih osobina, i kod muških i ženskih grla, pozitivna visoko statistički značajna korelacija je primećena između BW i WH ($r = 0,82$) kod ženskih grla koza dok kod muških grla, najveća pozitivna statistički značajna korelacija otkrivena je između BW i BL ($r = 0,83$). CART model je pokazao da je srednja vrednost BW bila 29,868 kilograma (kg) kao zavisna varijabla i BL je imao najveću značajnu ulogu u BW, praćen SH, RH, dok je starost imala najmanje značajnu ulogu kod BW. Ovo istraživanje sugeriše da bi BL, SH i RH mogli da koriste farmeri koji uzgajaju južnoafričke autohtone koze, kao kriterijum selekcije tokom uzgoja za poboljšanje telesne mase životinja. Sveobuhvatnija istraživanja i eksperimenti treba da se urade korišćenjem CART-a da se predvidi BW u većoj veličini uzorka južnoafričkih autohtonih koza ili drugih rasa koza.

Ključne reči: biometrijske osobine, dužina tela, obim srca, visina kukova, visina grudne kosti.

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Author's contributions

Thobela Louis Tyasi designed the experiment, analyzed the data, and wrote the manuscript. Amanda Tshegofatso Mkhonto, Madumetja Cyril Mathapo and Kagisho Madikadike Molabe performed the fieldwork and wrote the manuscript. Thobela Louis Tyasi read, edited, and approved the final manuscript.

Competing interests

The authors declare that they have no conflict of interest.

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