A live weight-heart girth relationship in Nguni-type and Brahman-type cattle as a tool for small-scale farmers

Anne Conan[1,2#], Anne Meyer[2,3], Bjorn Reininghaus[4], Jacques van Rooyen[2] & Darryn L. Knobel[1,2]

[1]Center for Conservation Medicine and Ecosystem Health, Ross University School of Veterinary Medicine, St Kitts and Nevis; [2]Department of Veterinary Tropical Diseases, University of Pretoria, Pretoria, South Africa; [3] AusVet Pty Ltd, Canberra, Australia; [4]Mpumalanga Veterinary Services, Department of Agriculture, Rural Development, Land and Environmental Affairs, Thulamahashe, South Africa

Abstract

Estimation of animal weight is critical in cattle production to assist in herd management and to estimate the value chain prices of the animals. There is a lack of tools for small-scale farmers and stakeholders to readily estimate cattle weight in communal livestock farming systems in South Africa. Models found in the literature cannot be easily adapted, as they may not be validated for the relevant breeds or may be too complex. The aim of this study was to build simple models based on heart girth and height to estimate the weight of Brahman and Nguni type cattle, the most common cattle raised by small-scale farmers in the lowveld of South Africa. Two models based on the heart girth performed well: $weight^{0.263} = 0.022 \times heart\ girth + 1.101$ for Brahman type cattle and$weight^{0.465} = 0.115 \times heart\ girth - 3.578$ for Nguni type cattle. When using these equations for herd management, correction to intercept by age should be added to estimate the sales value of an animal. Models based on height were less accurate, and models with two predictors had only a marginal improvement in accuracy while increasing the time for measurement collection.

Keywords: Cattle live weight, communal cattle, heart girth, Brahman-type, Nguni-type

[#]Corresponding author: aconan@rossvet.edu.kn

Introduction

Livestock in low- and middle-income countries is a main source of household livelihoods (FAO, 2017). In these countries, animals are typically raised in an agro-pastoral system (Davies *et al.*, 2016). Cattle herds are characteristically small with dominance of indigenous breeds that range freely on extensive rangeland. General efforts are given to enhance production in these systems, to improve cattle health, and subsequently to improve farmer wealth (FAO, 2006).

Estimation of animal weight is critical in agro-pastoral systems for two reasons. Firstly, the sale price of an animal in a beef-value-chain is based on its weight, age and breed. Incorrect weight estimations can result in a direct monetary loss for the farmer. Secondly, the live weight of cattle can be used as an indicator of the correct application of management interventions. The weight of the animal is used to calculate the amount of adult food supplementation, calf milk quantity and treatment. Incorrect estimation results in indirect monetary losses, inefficient treatments or inappropriate supplementation. With the common absence of weighing infrastructure (e.g. races, clamps, scales) in communal areas, researchers have developed regression models based on various body measurements to estimate the live weight of cattle. Buvanendran *et al*. (1980) showed that the live weight of different cattle breeds, i.e. White Fulani, Sokoto Gudali and N'Dama could be estimated by using heart girth circumference as well as an estimation of age and possibly animals health condition. Subsequently, numerous breed-specific models were developed for different breeds, i.e. Nicholson & Sayers (1987) for Boran breed, Nesamvuni *et al. (*2000) for Nguni-type cattle, and Abdelhadi & Babiker (2012) for the Sudanese indigenous Baggara breed. Unfortunately, these models involve several measurements, for which collection is time consuming. To circumvent this issue, Lesosky *et al.* (2012) developed a simple model based on heart girth only. This model was fit for East African Shorthorn zebu cattle.

In South Africa, the national seed stock beef herd comprises three types of cattle, i.e. approximately 47% Sanga and Sanga derived cattle, 30% Zebu and Zebu derived cattle and 23% European and Brittish breeds (Scholtz *et al.*, 2008). The Mpumalanga Province represents almost a quarter of the beef production of the country from mostly commercial farms (Strous, 2010). However, in the lowveld area of Mpumalanga, cattle farming is characterised by subsistence or small-scale production systems on communal rangelands.

Cattle are mainly Nguni (56%), Brahman (43%) and the remainder being Brahman cross cattle (Meyer, 2012). This area is in the foot-and-mouth disease protection zone with vaccination, which means that cattle movement is restricted. Due to legal restrictions, marketing of cattle (dead or alive) is local. Purchase and selling occurs directly in the field or at the abattoir. As a consequence, for subsistence farmers very little formal trade exists and the majority of animals are sold locally through various informal trade channels, such as informal butchers and local live sales (Van Rooyen, 2017). However, more recently, attempts have been made, through pilot programmes, to increase formal market access. For this, the valuation of cattle is based on weight (Heyl, 2017). Farmers therefore need tools to help with market readiness so they can access and benefit from improved market channels. Due to differences in cattle breeds and farming systems, using published available models in this system could lead to inaccurate live weight estimations (Lesosky *et al.*, 2012). The aim of this study was to develop simple models to estimate the live weight of Brahman and Nguni type animals typical of the communal farming systems in the Mpumalanga lowveld.

Materials and Methods

The study took place in the area of the Mnisi Traditional Authority, Bushbuckridge Municipality, Mpumalanga Province, South Africa. To improve disease surveillance and understand the cattle population dynamics in this area, a Health and Demographic Surveillance System in Livestock (HDSS-Live) was implemented in three wards (~15,000 cattle) in 2012 and 2013. The HDSS-Live comprised weekly herd surveillance and unique identification of all individuals by ear-tagging and tattooing. Its main objective was to understand the demographic parameters of the cattle population in the area. Ethical clearance for the HDSS-Live was granted by Animal Use and Care Committee (University of Pretoria, reference: V032-11). Informed consent was obtained from all cattle owners included in the study. During the first part of the HDSS-Live project, all cattle from the selected wards were individually enrolled by the study team. The cattle were restrained in a mobile crush with neck clamp (Tal-Tec Mobile Cattle Crush, Brits, South Africa) and identified with an ear-tag and a tattoo using an individually-unique number. Individual demographic data (age, sex, type) were collected for each animal. The age of the cattle was asked of the owner and validated by inspection of dentition. The weight of the animal was measured using a scale placed in the crush (Module LS4, Tal-Tec, Brits, South Africa). Other measures taken while the animal was restrained in the crush are defined as follows:

Height at withers**:** distance between the ground and the withers, measured with a home-made measuring stick.

Heart girth**:** Circumference of the chest immediately behind the elbow, measured with a tape ruler.

Body condition Score (BCS)*:* On a 9-point scale of 1 to 5 with half point intervals, BCS is based on the observations of the ribs, the lumbar spine and the pararectal fossa (Grobler, 2013).

All data were entered using the Open Data Kit Collect application on smartphone (Hartung *et al.*, 2010). Analyses of the data and estimation of the model were performed using R software (R Core Team, 2017). For analyses, animals were separated by cattle types: 1) Nguni (typical) and 2) Brahman (typical and cross). Other types (number of animals=3) were excluded. Outliers of weight, heart girth and height were defined as those values outside 1.5 the interquartile range above the upper quartile and below the lower quartile; they were detected by boxplot and excluded from the analyses. For each cattle type, three models were built to estimate the weight of the animals: a univariate model with heart girth as predictor, a univariate model with height as predictor and a multivariate model with both predictors. The protocol for model building and validation was identical for the six models. For each model, transformation power coefficient were calculated using the Box-Cox method (Box & Cox, 1964) and a linear regression model was fitted to the transformed weight.

The adjusted R^2 and regression coefficients were recorded. Residual plots, normal probability plots and leverage plots were also checked to assess goodness of fit of each model. As measurement outliers were dealt with previously, regression outliers and influential points were investigated by running the model without them but they were kept in the final model. To estimate the prediction error, 95 % confidence intervals were computed by bootstrap using the function *boot* (with 1,000 iterations) of the package *boot* (Canty & Ripley, 2017). Residuals of the selected model were compared between age group, sex and BCS using ANOVA and

Student's t-test. To evaluate the accuracy of predictions, predicted values were compared with a 20 % safe zone for use of therapeutic drugs (Machila *et al.*, 2008).

Results

From April through September 2013, 2018 animals (20.3 %) were weighed. Demographic parameters of the weighed animals are described in Table 1. Live weights ranged from 24 to 726 kg. The frequency distribution of Brahman live weights was relatively uniform between 50 kg to 450 kg, while the frequency distribution for Nguni was bimodal with a first peak around 100 kg and a higher one between 350 and 400 kg (Figure 1). Summaries of measurements by type are presented in Table 2.

Table 1 Demographic description of the weighed cattle and entire studied population in the Mnisi area in Mpumalanga (2013)

		Number of individuals	% of sample	Population	% of population
Type	Nguni (typical)	857	42.5	4,233	42.5
	Brahman (typical)	163	8.1	368	3.7
	Brahman (cross)	995	49.3	5,340	53.7
	Other breed (typical)	3	0.1	11	0.1
Sex	Female	1461	72.4	7,070	71.0
	Male	557	27.6	2,882	29.0
Age	< 1 year	514	25.5	2,659	26.7
	1-4 years	935	46.3	4,407	44.3
	>5 years	569	28.2	2,886	29.0

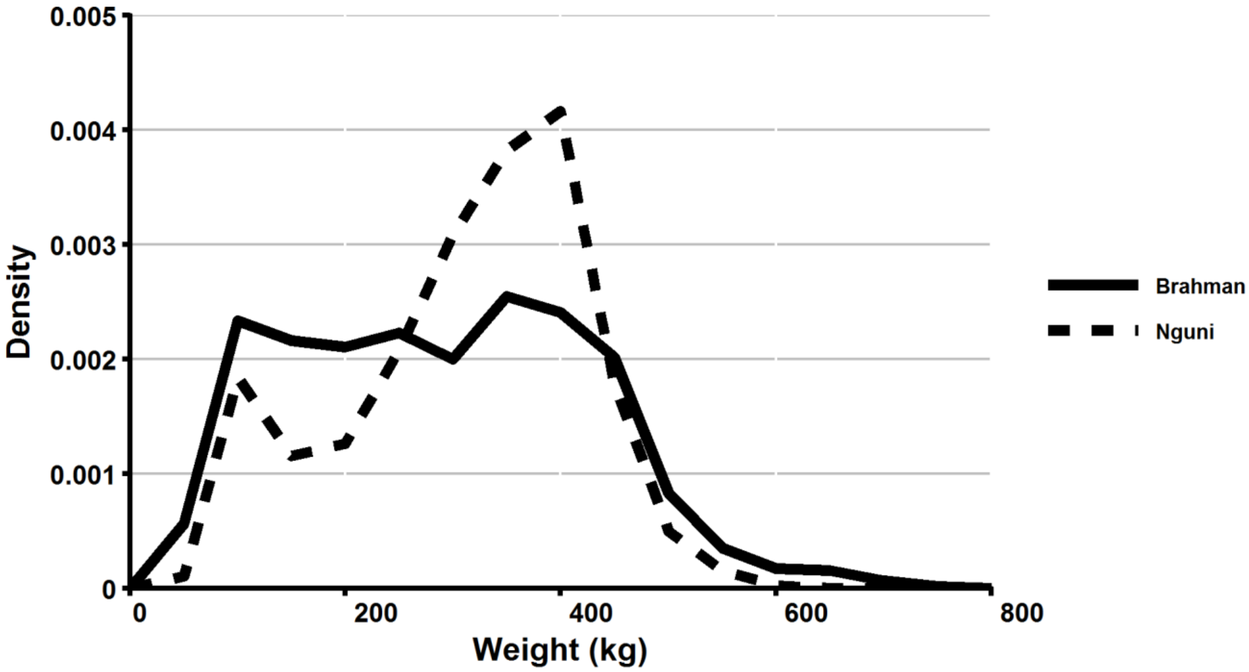

Figure 1 Brahman and Nguni frequency distribution (density) according to the animal weight

Table 2 Description of the measurements weight, height, girth and BCS by type

	Type	N	Median	Inter-Quartile Range (IQR)	Range	Number of outliers*
Weight	Nguni	856	327	183	24-590	1
	Brahman	1154	294	221	33-726	4
Height	Nguni	763	116	11	85-127	60
	Brahman	1134	115	20	72-146	4
Girth	Nguni	829	160	29	92-198	27
	Brahman	1133	155	44	74-218	0
Body Condition Score	Nguni	857	3	0.5	1.5-4	0
	Brahman	1158	2.9	0.3	1.5-4	0

*Values outside 1.5 the interquartile range above the upper quartile and below the lower quartile

The results of the fitted models are described in Table 3. For both cattle types, univariate models based on heart girth performed better than those based on height (based on R^2). For Brahman type, the fitted model based on heart girth followed the equation $weight^{0.263} = 0.022 * heart\ girth + 1.101$. Residuals were not different between BCS scores (p=0.2) and sexes (p=0.5). However, residuals were different between young animals (< 1 year) and adults (p<0.001). A correction to the intercept of -0.037 equal to the median of the residuals can be added to the previous equation for young animals (< 1 year old), $+0.003$ for young adults (1-4 years old) and 0.040 for old animals (5 years and more). For Nguni type, the fitted model based on heart girth followed the equation $weight^{0.465} = 0.115 * heart\ girth - 3.578$. Residuals were not different between BCS scores (p=1) and sexes (p=0.09). Residuals by age group were different (p<0.001). Correction of intercept should be -0.242 for young animals (< 1year old), -0.111 for young adults and $+0.235$ for old animals (5 years and more). Agreement between measured weight and predicted weight is plotted in Figure 2. For both girth models three outliers were detected but were not influential. Eighty-six Nguni observations (10.0 %) and 177 Brahman observations (15.3%) were out of a 20 % safe zone for use of therapeutic drugs (Machila *et al.*, 2008) (Figure 3).

Table 3 Models of weight using heart girth and height as predictors for Brahman and Nguni cattle breeds.

	Measurement		Transformation Power coefficient	Intercept	Coefficient Estimator	Coefficient 95 % Confidence Interval	R^2
Brahman	**Heart girth**		0.263	1.101	0.022	0.021-0.022	0.89
	Height		0.222	0.367	0.028	0.027-0.028	0.82
	Multivariate	**Heart girth**	0.263	0.524	0.015	0.013-0.018	0.90
		Height			0.014	0.009-0.018	
Nguni	**Heart girth**		0.465	-3.578	0.115	0.116-0.118	0.88
	Height		0.424	-8.093	0.171	0.156-0.175	0.82
	Multivariate	**Heart girth**	0.505	-12.209	0.101	0.080-0.121	0.89
		Height			0.128	0.087-0.169	

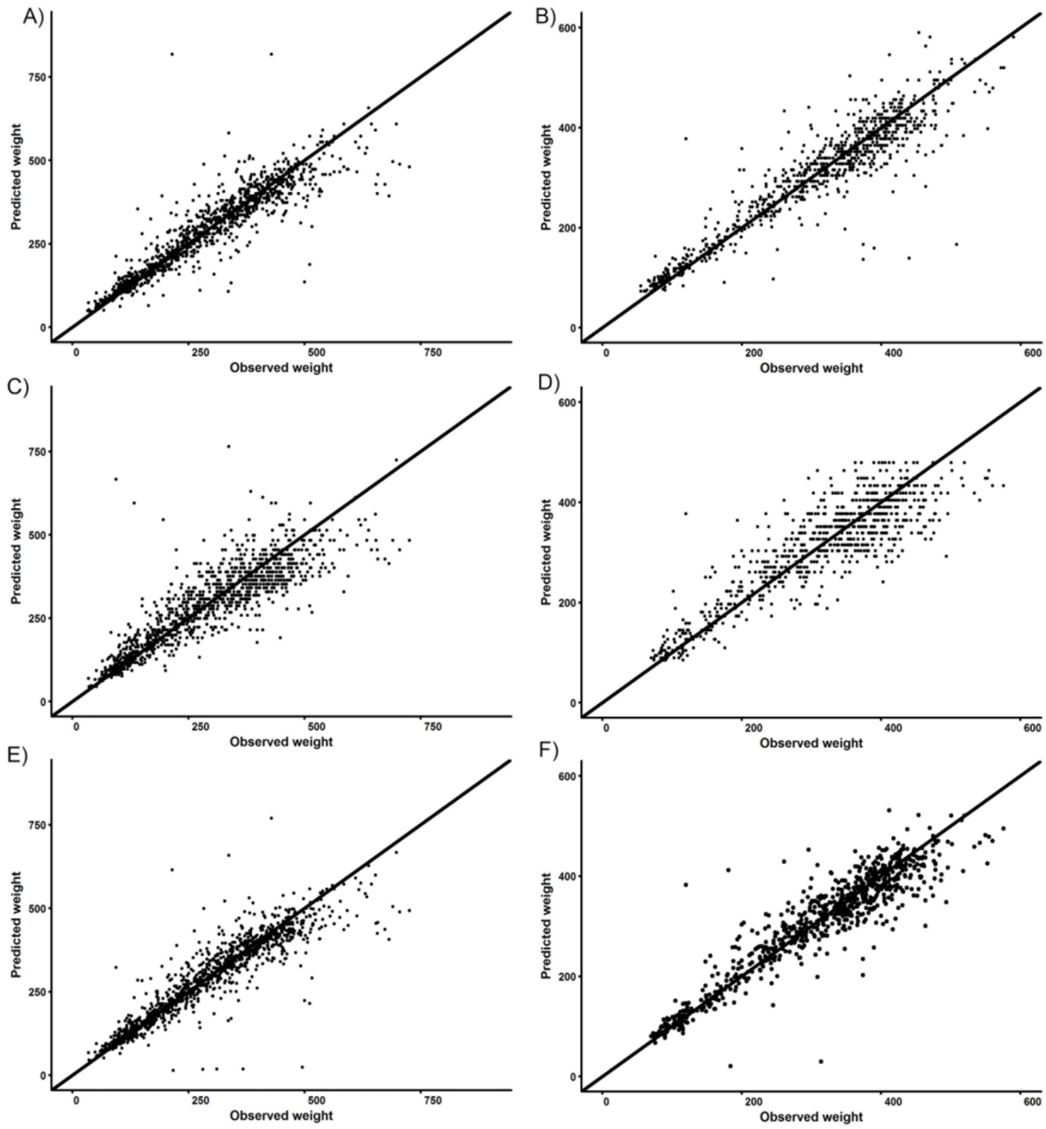

Figure 2 Observations versus predicted values of weight for the models based on heartgirth (A: Brahman, B: Nguni), on height (C: Brahman, D: Nguni) and with 2 predictors (E: Brahman, F: Nguni)

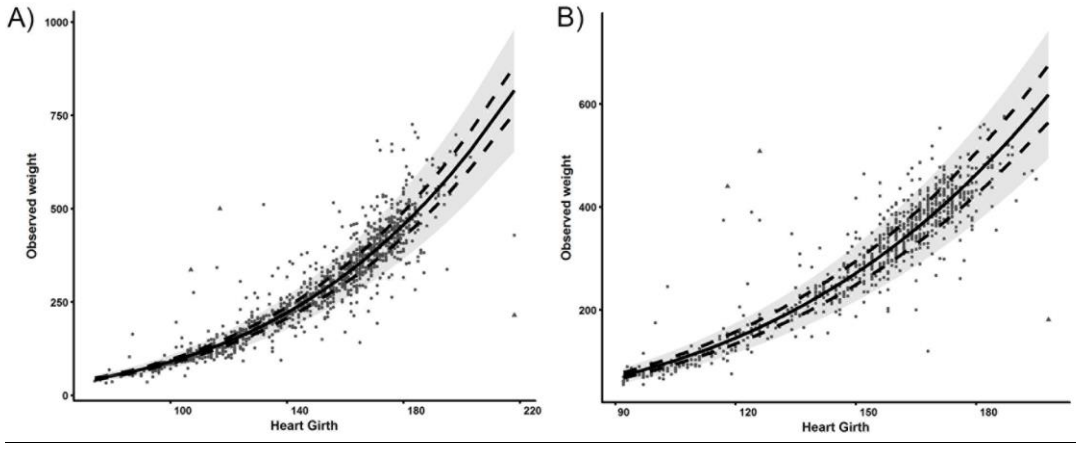

Figure 3 Relation heart girth with observed weight, with the best fit regression model (thick line), the bootstrap 95 % confidence interval (dash line), the 20 % body weight safe zone for drug dosing (grey area) and the regression outlier observation (triangles) (A: Brahman, B: Nguni)

Discussion

This paper describes two Southern African type-specific models based on heart girth to estimate the live weight of cattle. In the study area, the population of cattle mainly comprises two types: Brahman and Nguni (Meyer, 2012). Nesamvuni et al. (2000) published models in Nguni breed using heart girth and height as predictor and with low performance (R^2<0.80). To our knowledge, this is the only previously published weight regression model in Southern African cattle type. In our models, heart girth was an acceptable predictor for the weight of the animal (R^2>0.85). Our models based on height performed less well than models based on girth. While models with two predictors were more accurate, their application in the field may be difficult due to time and difficulty to obtain both measurements. Moreover, the improvement in the accuracy of estimation compared with the heart girth model was minimal. The models with two predictors could be used in slaughterhouses or other facilities where safety of workers is higher than in the field and where a more accurate estimation of the weight is needed. Models based on heart girth are easy to use by farmers. The estimation would help farmers and veterinarians to calculate accurate feed requirements or treatment doses. Ultimately, a tape measure with a weight scale can be created for each cattle type and used by farmers, animal technicians or veterinarians to estimate the weight of animals. Using a tape measure could lead to a bias due to the absence of age corrections. While this bias may have consequences for the estimation of the animal value chain prices, we expect the weight estimation errors to have a minimal consequence on subsequent herd management (Figure 3).

Models for Nguni performed less well than the models for Brahman type. This may be due to the distribution of weights in the study population. Nguni population had a higher number of animals around 400 kg in the dataset, while the Brahman population had a more uniform weight distribution from about 50 to 450 kg (Figure 1). In consequence, the model for Nguni should be taken with more caution for lighter animals (<300 kg).

It is acknowledged that these models may include other biases due to data collection and the exclusion of outliers. While the validation of models can be done during future studies to refine the equations, present models can already be used. There is no existing system to estimate the weight of cattle for the farmers and stakeholders in the communal farming system in South Africa. Future studies should focus on the application of these models (in calculation of feed requirement, animal growth, field experiments) and their use by the farmers and stakeholders.

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Ethical clearance

All procedures performed in studies involving animals were in accordance with the ethical standards of the institution at which the studies were conducted. Ethical clearance for HDSS-live was granted by Animal Use and Care Committee (University of Pretoria, reference: V032-11).

Authors' contribution

Study conception and design: DLK, JVR, BR; Methodology: DLK, AM, AC; Data Collection AM; Data analyses: AC; Writing: AC, AM, DLK; Review & editing AC, AM, DLK, BR, JVR.

Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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