A Comparative Study of the Nonlinear Methods for Estimate Body Weight by Body Measurements on Different Sample Sizes in Morkaraman Sheeps

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Research Article

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Abstract

The objective of this study was to estimate body weight of Morkaraman sheeps from body measurements with nonlinear models. Selected 110 sheeps 3-5 years were scored for body weight, body length, height at wither, chest width and pump width. For determine relationships with body weight between body measurements, correlation analysis was performed. The results of the correlation analysis indicated that the highest relationship according to the all sample sizes were body weight between body length (0.95, 0.90, 0.83, 0.81). Considering all parameters included in the model, the parameter showing the highest correlation with body weight was determined as body length according to all sample sizes. the highest correlation was found in 50 sample sizes (r:0.95). According to the small sample sizes (10-20), Logistic and Saturation growth models can be used to determine the body weight by using body length, on the other hand, Incomplete gamma model is more succesful to estimate body weight when sample size is nearly 30 and 50.

Introduction

The increase in the number and size of cells in certain time intervals in accordance with the type of animal, shaped by the interaction of the genetic structure of living things and the environmental conditions in which they are found, is expressed as growth (Şahin et al., 2014). Body measurements taken from animals give information about their morphological structures and it is known that there is a close relationship between these measurements and the live weights of animals (Çankaya et al., 2009). It is stated that if the degree of relationship between some body measurements and live weight is known, simple measurements on animals with a measuring tape or measuring stick can give the breeder an idea about the live weight of the animal (Akman, 1998). The most common estimation model used to interpret the relationship between body weight and body measurements is the multiple regression model. With multiple regression analysis, characteristics such as live weight and live weight gain can be estimated by using body measurements (Çankaya et al., 2009).

It is concluded that as an alternative to linear models, incomplete gamma and exponential models can be used to predict body weight of sheep using some body measurements (Barragan et al., 2021). Values of live weight can be estimated by taking body measurements at any stage of the fattening period (beginning, middle, end). However, the correlation coefficients to be obtained in this case depend on the fattening period can be different. For example, a correlation that is significant at the beginning of fattening may be insignificant at the end of fattening. For this reason, it can be said that it would be more appropriate to calculate the live weight values in the fattening period from the average values of body measurements. At the same time, since there is a high and statistically significant relationship between body weight at the end of fattening and chest circumference, body weight can be estimated using only chest circumference from body measurements (Şahin et al., 2018). South Karaman breed has generally black or blackish ash and dark brown colours, males were horned and females were hornless, has a fatty tail with an “S” shaped extension at the end, there were statistically significant correlations between different body measurements and body weight scales and the highest correlation coefficient was determined between body weight and chest circumference, live weight can be estimated safely by measuring the chest circumference in the establishment where it is not possible to weigh the sheep (Bebek and Keskin, 2020).

Selection of the appropriate model requires a statistical decision process, since the live weight varies according to the species, environmental conditions and the trait studied. It has been reported in the literature that although a constant rate of weight gain occurs in certain periods for some characteristics of some living things, the weight increase in living things is not constant throughout their lifetime (Kshirsagar and Smith, 1995; Efe, 1990; Akbaş,1995; Kocabaş et al., 1997).

For this reason, linear models are often insufficient to model the growth of living things over the lifespan (Perotto et al., 1992; Efe, 1990). In the case of periods of different growth rates, it is useful or even necessary to use non-linear models, which are slightly more complex than linear models.

The determination and estimation of non-linear models are more difficult than linear models, and the results are determined iteratively using different methods (Draper and Smith, 1981). If a model cannot be linearized as a result of reparameterization, parameter estimates will not have desirable properties such as unbiasedness, normality, and minimum variance; For this reason, complex estimation methods such as the Marquardt (1963) method may be needed (Ratkowsky, 1983 and 1990). These numerical approaches, which are used instead of analytical solutions, generally produce approximate results. Therefore, the aim of this study is to determine the best model for body weight - body measurements according to the different sample sizes using Allometric, Logistic, Saturation growth, Exponential, and Incomplete gamma non-linear models.

Material And Methods

Animals

Tha data from 110 Morkaraman sheep (3-5 years) were taken from Atatürk University application and research farm in Erzurum. Morkaraman sheeps were included in the study as 10, 20, 30 and 50 separately according to sample size.

Statistical Analysis

Correlation coefficients were used to determine the relationship between parameters. In addition, it is aimed to determine the best model according to the sample size in determining the live weight by using the nonlinear models which are described below.

The models were tested for goodness of fit by the (MSE) Mean Square Error and (R^2), adjusted coefficient of determination (R^2adj), Akaike information criterion (AIC), Bayes information criterion (BIC) and mean squared prediction error (MEP). The statements of these evaluators are also presented in detail in Silveira et al., 2011.

Resuls And Discussion

Considering all parameters included in the model, the parameter showing the highest correlation with body weight was determined as body length according to all sample sizes. As indicated in Table 2, the highest correlation was found in 50 sample sizes (r:0.95). This was followed by sample sizes of 30, 20 and 10, respectively. The highest correlations for the BW parameters between BL were found 0.95, 0.90, 0.83 and 0.81 respectively. In addition, the lowest correlation values are BW between HW (r:0.46), BW between HG (r:0.51) and BW between PW (r:0.48). Considering all sample sizes, body length was included as an independent variable in nonlinear models.

As shown in Table 3, the results of nonlinear models, in which five different models for estimate best-fitted model for relationship between body length and body weight of Morkaraman sheeps at different sample sizes.

R^2 and MSE values for models estimated by five different models and sample sizes have been used to determine the best fit models.

Considering the sample sizes; the lowest R^2 and the highest Mean Square Error values occurred in the group with sample size 10. According to this group, the highest R^2 value (0.64) was determined in Logistic and the lowest MSE value (14.76) was determined in Saturation growth models. Topal and Macit (2004) were reported that in their study on 66 Morkaraman sheep, as a result of multiple regression analysis, the R^2 value of body length affecting body weight was 0.282 and MSE value was 31.702 respectively. When we take into the group with a sample size of 20, the highest R^2 value (0.71) and the lowest MSE value (13.44) was detected in Saturation growth models. Rather et al. (2021) were emphasized that the coefficient of determination (R^2) is succesful to estimate body weight from body measurements in Kashmir Merino sheeps. Considering the sample sizes of 30 and 50, the highest R^2 values (0,82-0,92) and the lowest MSE values (11,88-11-94) were found in the Incomplete gamma model, respectively. In Dağlıç and Kıvircik male lambs, Akbaş et al. (1999) and in Morkaraman and Awassi, Bilgin et al. (2004), reported that Brody is the best model for describing as unfit between body weight and age in sheeps.

Considering the different sample sizes, the results of the linear regression model are given in Table 4. According to these results, the R^2 value was 0.66 and the MSE value was 17.16 in the model with a sample size of 10, and the R^2 value was 0.69 and the MSE value was 15.44 in the model with a sample size of 20. In addition, the R^2 value was 0.81 and the MSE value was 13.11 in the model with a sample size of 30, and the R^2 value was 0.90 and the MSE value was 11.08 in the model with a sample size of 50. According to these obtained values, it was found that as the sample size increased, the R^2 value increased and the MSE value decreased. According to different sample sizes, these coefficients showed that, there are more similarity between the (linear and nonlinear) methods. Barragan et.al 2020 reported that according to all nonlinear models R^2 value is calculated higher than 0.75 for estimate body weight from body measurements.

In Table 5, the results of the evaluators of goodness of fit (R^2_{aj}, AIC, BIC, MEP) for each model. Considering the R^2_{aj} value, the highest value was obtained as Incomplete gamma (0.8464), Logistic (0.7921), Allometric (0.7744) and Exponential (0.7744) with sample size 50. The low MEP values, the lowest values were obtained as Incomplete gamma (10.9096), Exponential (11.0864) and Logistic (11.3212), respectively. The lowest R^2_a value was obtained as Allometric (0.3481), Exponential (0.3600), Saturation growth (0.3721) and Incomplete gamma (0.3969) with sample size 10. Considering the high MEP values, the highest values were obtained as Incomplete gamma (24.8530), Exponential (24.2070) and Allometric (20.6392), respectively. Considering the AIC value, the lowest value was obtained as Incomplete gamma (175.3682), Logistic (187.7116), Allometric (188.9002) and Exponential (189.4751) with sample size 50. The lowest BIC value were obtained as Incomplete gamma (182.4006), Exponential (198.6672) and Logistic (202.1524), respectively.

Conclusion

As a result of the different nonlinear models used to estimate the body weight of Morkaraman sheeps, according to the all sample sizes Incomplete gamma model is the most appropriate model when R^2, MSE, R^2_{aj}, AIC and BIC values were taken into account. Considering small sample sizes as 10-20, Logistic and Saturation growth models are more suitable than Allometric, Exponential and Incomplete gamma models for predicting body weight from body length measures. According to the lineer model the highest R^2 and the lowest MSE is obtained from the group of 50 sample size. Considering 30-50 sample sizes group, according the R^2_{aj}, AIC, BIC and MEP values Incomplete model is more appropriate model than the others.

It is concluded that according to the small sample sizes (10-20), Logistic and Saturation growth models can be used to determine the body weight by using body length, on the other hand, Incomplete gamma model is more succesful to estimate body weight when sample size is bigger than 20.

Declarations

Author contribution

The design of the study, data collection, statistical analysis, writing of the manuscript, conversion to the journal format, and submission to the journal were done by the author. The author has approved the submitted version.

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Data availability

Not applicable.

Code availability

Not applicable.

Ethics approval

In the study, there is no need for an ethical approval due to the lack of blood sampling from the animals and the absence of any surgical procedures. All data were collected with the approval of the breeder.

Conflict of interest

The author declare no competing interests.

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Tables

Table 1. Nonlinear regression models

Model	Equation
Allometric	$Y= aX^{h}$
Logistic	$Y= a/1+exp^{(b-cX)}$
Saturation growth	$Y= aX/(b+X)$
Exponential	$Y= aexp^{(bX)}$
Incomplete gamma	$Y= aX^{(b)}exp^{(cX)}$

Table 2. Correlations between body weight and body measurements with different sample sizes

	Sample size	BL	HD	HW	CW	HG	PW
BW	10	**0.81****	0.57*	0.46	0.73**	0.51	0.48
BW	20	**0.83****	0.72*	0.58*	0.75**	0.66*	0.53
BW	30	**0.90****	0,78**	0.60*	0.74**	0.76*	0.61*
BW	50	**0.95****	0,81*	0.69*	0.74**	0.76*	0.66*

**: p<0.01, *: p<0.05; *BW*: Body weight, *BL*: Body length, *HW*: Height at wither, *CW*: Chest width, *PW*: Pump width

Table 3. Estimation nonlinear models for predicting body weight of Morkaraman lambs from body length

n	Model	*Equation*	p		MSE
10	Allometric	$0.004BL^{2.09}$	0.035	0.59	15.18
	Logistic	$196.85/(1+exp^{(3.446-0.0512BL)}$	0.020	0.64	14.98
	Saturation growth	$-19.785BL/(-196.71+BL)$	0.016	0.61	14.76
	Exponential	$5.0142exp^{(0.0375BL)}$	0.020	0.60	14.91
	Incomplete gamma	$0.1014BL^{1.214}exp^{(0.021BL)}$	0.028	0.63	14.89
20	Allometric	$0.003BL^{2.11}$	0.016	0.66	14.01
	Logistic	$202.45/(1+exp^{(3.4141-0.0548BL)}$	0.013	0.65	14.01
	Saturation growth	$-18.471BL/(-1188.16+BL)$	0.008	0.71	13.44
	Exponential	$4.7811exp^{(0.0108BL)}$	0.002	0.60	13.75
	Incomplete gamma	$0.1008BL^{1.303}exp^{(0.025BL)}$	0.008	0.68	13.67
30	Allometric	$0.003BL^{2.14}$	0.012	0.74	12.11
	Logistic	$201.48/(1+exp^{(3.358-0.0442BL)}$	0.008	0.79	12.02
	Saturation growth	$-20.016BL/(-198.34+BL)$	0.010	0.78	12.16
	Exponential	$4.842exp^{(0.0392BL)}$	0.002	0.79	12.08
	Incomplete gamma	$0.1021BL^{1.136}exp^{(0.019BL)}$	0.001	0.82	11.88
50	Allometric	$0.003BL^{2.15}$	0.003	0.88	12.02
	Logistic	$199.61/(1+exp^{(3.303-0.0398BL)}$	0.001	0.89	12.00
	Saturation growth	$-20.038BL/(-199.16+BL)$	0.001	0.86	12.01
	Exponential	$4.8805exp^{(0.0384BL)}$	0.001	0.88	12.02
	Incomplete gamma	$0.1019BL^{1.149}exp^{(0.020BL)}$	0.001	0.92	11.94

Table 4. Estimation linear equations for predicting body weight of Morkaraman lambs from body measurements

n	Model	*Equation*	p		MSE
10	Linear	BW= -12.516 + 0.811BL	0.040	0.66	17.16
20	Linear	BW= -11.986 + 0.793BL	0.035	0.69	15.44
30	Linear	BW= -9.542 + 0.707BL	0.012	0.81	13.11
50	Linear	BW= -9.233 + 0.765BL	0.003	0.90	11.08

Table 5. Results of the quality of fit evaluators for the Morkaraman sheeps

n	Model	R^2_{aj}	AIC	BIC	MEP
10	Allometric	0.3481	204.9446	219.7146	20.6392
	Logistic	0.4096	198.4871	213.9151	19.7252
	Saturation growth	0.3721	198.4871	213.7989	15.6051
	Exponential	0.3600	210.0728	226.2827	24.2070
	Incomplete gamma	0.3969	204.9446	220.2445	24.8530
20	Allometric	0.4356	198.2946	215.0813	21.6386
	Logistic	0.4225	210.8582	226.7405	20.2056
	Saturation growth	0.5041	205.5648	222.9836	21.3546
	Exponential	0.3600	204.9446	222.7792	17.3273
	Incomplete gamma	0.4624	208.5478	224.3540	15.1510
30	Allometric	0.5476	206.7871	223.7148	16.7722
	Logistic	0.6241	202.1458	218.5526	14.6922
	Saturation growth	0.6084	199.2580	216.1218	15.4842
	Exponential	0.6241	197.6542	218.8890	14.6692
	Incomplete gamma	0.6724	192.8586	214.4148	12.5628
50	Allometric	0.7744	188.9002	202.3128	12.2018
	Logistic	0.7921	187.7116	202.1524	11.3212
	Saturation growth	0.7396	192.1541	216.7005	13.4086
	Exponential	0.7744	189.4751	198.6672	11.0864
	Incomplete gamma	0.8464	175.3682	182.4006	10.9096

Figures

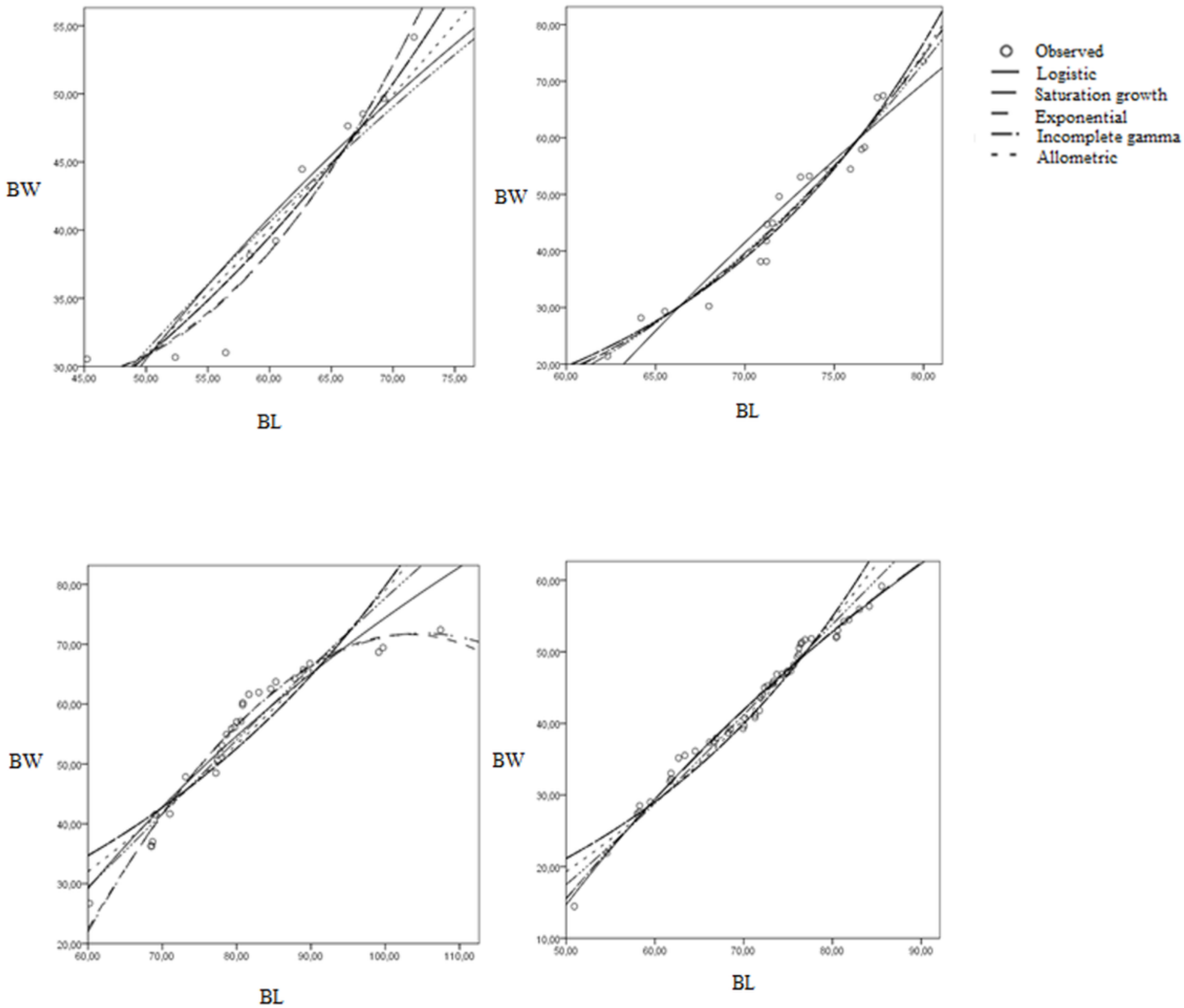

Figure 1

Relationships between BW and BL of Morkaraman sheeps according to nonlinear models