Revisiting the application of classical formulas to estimate Bali cattle’s body weight based on body measurement variables

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Abstract. Predicting cattle’s body weight is a common practice considering various reasons. This paper revisits four classical formulas commonly found in papers published by Indonesian researchers in predicting cattle’s body weight based on their body measurements namely Schoorl, Winter, Smith and Lambourne models. Data on body weight (BW) and body measurements (Chest Girth=CG and Body Length=BL) of 118 male and 106 female Bali cattle (2-3 yo) were collected from Bali cattle Breeding Center. The estimates from the prediction formulas were compared to the actual body weight. We run 10-folds cross validation procedure to obtain the predictive ability parameters. The mean BW, CG and BL for male cattle were 199.19±51.51 Kg; 144.55±13.43 cm and 107.86±9.30 cm; whereas for females were 161.34±34.35 Kg; 134.25±10.26 cm and 101.48±3.60 cm respectively. All four formulas have the accuracy between 84.90 to maximum of 89.68% in both male and female cattle groups. RMSE were considerably high in both male group (17.64 – 45.31) and female group (11.52 – 26.61). Although the correlations between actual and predicted BW are high, further study need to be done to determine whether the utilization of these predicted values as a response variable will introduce enough bias to affect the results of a research.

1. Introduction
Bali cattle (Bos javanicus) is an Indonesian native cattle species. It is originated from wild Banteng (Bos javanicus) which was first domesticated in the isle of Bali [1-3]. This cattle are well known for their robustness towards tropical environment and low quality feedstuffs [4-7]. Most of Bali cattle were reared in semi-intensive farming system, where during morning and daytime cattle were stationed and allowed to graze freely in a grazing area while in the night time they were put inside the farmer’s paddocks [7]. Cattle were owned by smallholder farmers with low number of animals per farmers [8]. From behavioral point of view, Bali cattle are considered as having less favorable temperament for cattle handling and hence, placing them on the weighing scale require substantial labor. Considering these conditions, using body measurements as productivity indicator is preferable whether in the commercial practice and/or in researches when Bali cattle body weight is required as a variable [9,10]. It is thus the ability to predict cattle’s weight based on the body measurements become an important point.

Predicting cattle’s weight based on their body measurements is a common practice in livestock industry. The reason is mainly for the sake of ease of practice, especially when the cattle are reared in free range or when access to weighing scale is limited. Studies revealed that employing linear regression model to predict body weight based on their chest girth yielded good model fit, indicated by...
the coefficients of determination value of more than 60% in crossbred dairy cattle in Kenya [11], brown-swiss cattle in Turkey [12] and also in Ethiopian oxen [13]. In Indonesia, however, the most common practices to predict cattle’s body weight based on Body measurements are by using classical formulas such as from Schoorl, Winter, Smith and Lambourne [9,10,14–17]. When the inferences of a research were based on the predicted values as a response variable, the predictive ability of these formulas is the main factor determining the quality of the particular research. This paper concerned in estimating and studying the accuracy of Bali cattle’s body weight prediction using the aforementioned formulas.

2. Materials and methods

This research utilized records obtained from Balai Pembibitan Ternak Unggul dan Hijauan Pakan Ternak Pulukan (Bali cattle Breeding Centre), Indonesia. In total there were 224 mature Bali cattle (118 males and 106 females) above the age of 2 years were weighed and measured. The records including variables of Body Weight (BW), Chest Girth (CG) and Body Length (BL). We estimate the predicted body weight based on the following formulas [14]:

\[
\text{Schoorl} \quad BW = \frac{(CG+22)^2}{100}
\]

\[
\text{Winter} \quad BW = \frac{(WH \times BL)}{300}
\]

\[
\text{Smith} \quad BW = \frac{(CG+18)^2}{100}
\]

\[
\text{Lambourne} \quad BW = \frac{(BL \times CG)^2}{11050}
\]

The prediction with Schoorl formula was done in imperial/US units which were lbs for weight and inch for length; whereas body weight predictions with the other formulas were using standard International System of Units (SI) with Kg for weights and cm for lengths.

Caret package in R programming language were used to conduct 10-fold cross validation procedures. Further, predictive ability parameters of accuracy and Mean Squared Errors (MSE) were estimated. After the analyses were completed; we convert all units using SI system for the report’s consistency.

3. Results and discussion

Body weight and body measurement variables including CG and BL were observed. The summary statistics is presented in table 1

| Sex   | n^1 | Mean±sd^2 |
|-------|-----|------------|
|       |     | BW^3 (Kg) | CG^4 (cm) | BL^5 (cm) |
| Male  | 118 | 199.19±51.51 | 144.55±13.43 | 107.86±9.30 |
| Female| 106 | 161.34±34.35 | 134.25±10.26 | 101.48±6.30 |

Notes: ^1sample size; ^2mean and standard deviation; ^3Body Weight; ^4Wither Height; ^5Body Length

Bali cattle is considerably smaller breed when compared to the cattle from both Bos indicus and Bos taurus [18–21]. The mature weight of Bali cattle in this study were considerably lower compared to other studies. The mature weight of Bali cattle regardless sex and rearing environment were between 271.17 to 338.00 [18,19,22–27]. The difference in cattle body weight phenotype of the same
breed could be caused by the environmental difference [28,29]. Different environment contained differences in resources and micro-climate conditions which can contribute to the observed phenotypes.

Table 2. Parameter estimates of the predicted body weight

| Models       | $\hat{BW}^1$ | BW$^2$ | Accuracy (%) | RMSE$^3$ |
|--------------|--------------|--------|--------------|----------|
| **Male**     |              |        |              |          |
| Schoorl      | 279.18       | 199.19 | 85.97        | 18.13    |
| Winter       | 470.22       | 199.19 | 88.83        | 45.31    |
| Smith        | 266.02       | 199.19 | 85.46        | 17.64    |
| Lambourne    | 208.72       | 199.19 | 90.09        | 20.27    |
| **Female**   |              |        |              |          |
| Schoorl      | 245.20       | 161.34 | 84.54        | 11.94    |
| Winter       | 377.23       | 161.34 | 88.50        | 26.61    |
| Smith        | 232.86       | 161.34 | 88.38        | 11.52    |
| Lambourne    | 167.45       | 161.34 | 88.90        | 12.03    |

Notes: $^1$Predicted body weight; $^2$Observed body weight; $^3$Mean Squared Error

The average values of predicted body weight estimated with the classical formulas were presented in Table 2. We also estimated the predictive ability of the formulas with 10-fold cross validation method which included the parameters of accuracy of predictions and the RMSE. The accuracies of the prediction formulas were ranged between 84.90 to maximum of 89.68% in both male and female cattle groups. RMSE were considerably high in both male group (17.64 – 45.31) and female group (11.52 – 26.61). The predicting performance of Schoorl, Smith and Lambourne formulas were considerably similar. However, we don’t recommend to use Winter formula to predict Bali cattle BW based on their body measurement variables due to the strikingly high RMSE.

4. Conclusion
Although the correlations between actual and predicted BW are high, further study need to be done to determine whether the utilization of these predicted values as a response variable will introduce enough bias to affect the results of a research. Or, alternative methods to predict BW with higher accuracy need to be explored.

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