Predicting Madura cattle growth curve using non-linear model

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Abstract. Madura cattle is Indonesian native. It is a composite breed that has undergone hundreds of years of selection and domestication to reach nowadays remarkable uniformity. Crossbreeding has reached the isle of Madura and the Madrasin, a cross between Madura cows and Limousine semen emerged. This paper aimed to compare the growth curve between Madrasin and one type of pure Madura cows, the common Madura cattle (Madura) using non-linear models. Madura cattles are kept traditionally thus reliable records are hardly available. Data were collected from small holder farmers in Madura. Cows from different age classes (<6 months, 6 -12 months, 1 -2years, 2 -3years, 3 -5years and >5years) were observed, and body measurements (chest girth, body length and wither height) were taken. In total 63 Madura and 120 Madrasin records obtained. Linear model was built with cattle sub-populations and age as explanatory variables. Body weights were estimated based on the chest girth. Growth curves were built using logistic regression. Results showed that within the same age, Madrasin has significantly larger body compared to Madura (p<0.05). The logistic models fit better for Madura and Madrasin cattle data; with the estimated MSE for these models were 39.09 and 759.28 with prediction accuracy of 99 and 92% for Madura and Madrasin, respectively. Prediction of growth curve using logistic regression model performed well in both types of Madura cattle. However, attempts to administer accurate data on Madura cattle are necessary to better characterize and study these cattle.

1. Introduction
Madura isle, located at the northeast of Java coast is the home of a native and unique cattle breed called the Madura cattle. This breed is a product of cross mating between Zebu (Bos indicus) and Banteng (Bos javanicus) which happened around 1,500 years ago [1]–[3]. The fame of Madura cattle in cultural events, however, started around the 13th century during the Dutch colony, when the karapan or bull racing started to take place. The cattle culture in Madura is very intense, until recently, local people refuse the inclusion of other cattle breeds into their region. Around the year of 2000, Indonesian government introduced Limousine breed through artificial insemination (AI) program to the Maduran farmers and it was surprisingly well received in some areas [2], [4], and thus, the Madrasin cattle started to exist. It was revealed that nowadays Madura cattle are divided into four distinct sub populations named common Madura cattle (Madura), Karapan, Sonok and Madrasin (Rudi Haryanto, Personal communication, August 20, 2017). The production system of every sub population differs; while Karapan is the sub population specialized for bull races and Sonok is the body
conformation contest cow’s population, Madura cattle and Madrasin belong to the commercial meat producer class.

Having the advantages of a tropical breed, Madura cattle excel in heat stress, adaptability, tick resistance and high tolerance towards low quality feed [4]–[6]. However, the genetic and physical characteristic of Madura sub population showed remarkable decrease due to unplanned traditional breeding including the selection and mating system [2]. The introduction of Limousine breed as a new genetic resource was objected in improving this once decreasing quality of Madura cattle.

All sub populations of Madura cattle were kept by smallholder farmers with low number of cattle per family [2]. Nowadays farmers still manage their cattle traditionally with semi intensive farming system and no documented records; thus, reliable information are very limited. As both sub populations objectives were for meat production, growth trait is important in determining their potentials. This paper aimed to observe and compare the growth trajectories of Madura and Madrasin cattle using body measurements variables. This information shall serve as guidelines for farmers in order to keep in tract of the cattle growth as well as to give warning in case of anomalies occurred hence early precaution could be made.

2. Methods

Data were collected from female common Madura cattle and Madrasin sub populations from various ages. We conducted direct observations on farms with cattle classified as common Madura and Madrasin. We measure their body variables including chest girth (CG), wither height (WH) and body length (BL). The ages were then classified in to six classes inclusive: 1 (< 6 months old), 2 (6-12 months), 3 (1-2 years old), 4 (2-3 years old), 5 (3-5 years old) and 6 (>5 years old). Number of observations per age classes were presented in Table 1. In total 63 Madura and 120 Madrasin records were obtained.

| Age       | Sub-population | Madura | Madrasin |
|-----------|----------------|--------|----------|
| 1 (< 6 mo)|                | 3      | 0        |
| 2 (6-12 mo)|              | 4      | 4        |
| 3 (1-2 yo)|                | 2      | 8        |
| 4 (2-3 yo)|                | 16     | 44       |
| 5 (3.5 yo)|                | 23     | 46       |
| 6 (>5 yo)|                | 15     | 18       |

*no new born calves were available for measurements

Table 1. Number of observations per age classes.

A linear model was built to identify the possibility of having significant systematic effects of age classes and sub populations with \( \alpha = 0.05 \).

\[
y_{ijk} = \mu + Age_i + P_j + e_{ijk}
\]

where,

- \( y \) : response variable of body measurements
- \( \mu \) : general mean
- \( Age \) : Age effect
- \( P \) : Sub population effect
- \( e \) : random residuals

We estimated the body weight (kg) in our data based on the chest girth (cm) using the measuring tape developed by FHK Ogawa Seki Co. Ltd, Tokyo, Japan. We built the growth curve by fitting the means of body weight from each age classes into a plot. A logistic regression model was then used to predict the body weights for both sub populations.
where,
\[ y(t) = \frac{\alpha}{1 + (\beta \exp(-kt))} \]

where,
- \( y(t) \): growth at time \( t \)
- \( t \): time point
- \( \alpha \): upper asymptote
- \( \beta \): growth range
- \( k \): growth rate

The estimated and predicted body weight data were then compared to estimate the accuracy of the non-linear prediction model.

3. Results and Discussion

The arithmetic means and standard deviations of the body measurements variables are presented in Table 2. It is clearly visible that Madrasin have significantly larger build in all body dimensions compared to Madura cattle (\( p<0.05 \)). This finding is in agreement with Kustiyah (2005) [7] which mentioned that crossbred individuals between Limousin and Madura cattle yielded heavier body weight compared to pure Madura cattle in all three time frame (birth, weaning and post-weaning). The body measurements growth trends in different age classes can also be seen in Table 2.

| Table 2. Mean and standard deviation of cattle’s body measurements. |
|---------------------------------------------------------------|
| Variables | Body measurements (cm) |
| Sub-populations | Chest girth | Wither height | Body length |
| Madura\(^a\) | 147.95±16.58 | 113.95±8.32 | 107.95±13.72 |
| Madrasin\(^b\) | 153.87±22.23 | 120.24±9.90 | 115.32±11.01 |
| Age Group | | | |
| 1 | 102.00±3.46 | 89.83±3.75 | 74.30±6.46 |
| 2 | 124.25±14.87 | 102.93±7.59 | 90.44±12.78 |
| 3 | 126.90±16.57 | 114.80±5.29 | 97.20±6.02 |
| 4 | 152.20±21.16 | 119.59±7.99 | 114.58±8.94 |
| 5 | 157.07±15.79 | 119.23±8.94 | 115.86±9.34 |
| 6 | 159.00±14.24 | 120.14±9.67 | 116.73±10.96 |

\(^a,b\) different superscripts showed significant difference with \( p\)-value < 0.05

Cattle’s body weight were estimated based on the chest girth following the measuring tape developed by FHK Ogawa Seki Co. Ltd, Tokyo, Japan. This approach was taken due to the circumstances in the field where weighing the cattle using standard scale is not feasible.

![Figure 1](image1.png)

**Figure 1.** Growth curve based on the estimated body weight A) Madura cattle, B) Madrasin cattle.

The estimated body weights were then plotted as in Figure 1 where in X axis was the age classes and in Y was the estimated body weight. A logistic regression model was built to predict the body weights across sub-populations and age classes and plotted as the lines in Figure 1. It is shown that the model
fit the Madura cattle data better than the Madrasin. The mean square error (MSE) for Madura cattle was 39.09 whereas for Madrasin cattle was a lot larger at 759.28. Correlation value between estimated and predicted body weights was used to describe the accuracy of the logistic model prediction. We estimated the accuracy of prediction for Madura cattle was 99% and Madrasin cattle was 92%.

4. Conclusions
We concluded that body dimensions wise, Madrasin cattle are larger compared to common Madura cattle. Non-linear model can be used to visualize the growth trend in both cattle sub-populations with considerably high accuracy.

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