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Correlation Analysis of Morphometric Traits and Principal Component Analysis (PCA) for Selection of Female Bali Cattle in East Kalimantan

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ABSTRACT: Bali cattle is one of Indonesia's native germplasm sources for meat supply. This study aimed to characterize basic morphometric traits, analyze the relationships among morphometric traits, and identify potential regions as superior breeding stock for female Bali cattle. The research was conducted from December 2024 to March 2025 across six regions in East Kalimantan Province, involving a total of 251 female Bali cattle aged 12 and 24 months. Data were analyzed using descriptive statistics, ANOVA, Duncan's test, Pearson correlation, and Principal Component Analysis (PCA). Correlation analysis indicated strong to very strong relationships among body measurements and morphometric indices. A high correlation was found between Chest Girth (CG) and Chest Index (CI) (r = 0.86) as well as Body Length (BL) (r = 0.74). Body Length (BL) showed a strong correlation with Length Index (LI) (r = 0.82) and with Proportion Index (PI) (r = 0.50). PCA analysis revealed two principal components for 12-month-old cattle: PC1 (BL; CG; LI) at 53.6% and PC2 (PI; LI) at 28.5%. The principal components at 24 months showed PC1 (CG; BL; CI]) at 50.5% and PC2 (PI; LI) at 32.2%. The PCA analysis explained more than 82% of the variation, with chest girth (CG) and body length (BL) consistently emerging as dominant variables. All cattle met the Indonesian National Standard (SNI) criteria for female Bali cattle breeding stock.

KEYWORDS: Bali cattle, breeding stock, correlation, morphometric traits, PCA.

INTRODUCTION

Bali cattle are one of Indonesia's native livestock breeds with significant potential for development as a source of meat supply. The beef cattle industry contributes significantly to the income of farmers and economic growth. Beef cattle also play an important role in meeting the animal protein needs of society, especially because animal protein contains essential amino acids that cannot be replaced by plant-based protein. According to Kusuma et al. (2017), beef cattle are one of the livestock commodities that play an important role in supporting the fulfillment of animal-based protein food needs.

The demand for beef in East Kalimantan is estimated to reach 10,457 tons per year; however, local production can only meet about 28 to 36 percent of the total need (Central Bureau of Statistics, 2024). East Kalimantan has geographical and climatic characteristics that support the growth of the beef cattle industry. Along with the increasing demand for beef in the domestic market and the selection of East Kalimantan as the capital of the Indonesian Archipelago (IKN) for administrative and government purposes, the East Kalimantan provincial government is striving to increase cattle population through various programs, such as providing cattle seed assistance, a bull fattening program, and supporting facilities for livestock farmer groups. The cattle population in East Kalimantan was around 108,613 heads in 2022 and about 109,700 heads in 2023 (Animal Husbandry Department, 2024).

According to Astiti (2018), Bali cattle have advantages in reproduction and production, with high fertility rates (80-85%), short calving intervals (12-14 months), high carcass percentage (56%), estrous cycles in young females ranging from 16-23 days, estrus duration (36-48 hours), and fertile periods (18-27 hours). The success of Bali cattle maintenance can be measured by their productivity, seen in the physical growth aspects of the livestock. Efforts to increase the Bali cattle population have been made by the East Kalimantan provincial government through the distribution of Bali cattle seeds to six cities/regencies (Bontang City, East Kutai Regency, Barau Regency, Kutai Kartanegara Regency, Penajam Paser Utara Regency, and Paser Regency).

According to Mahmudi et al. (2019), livestock body size is often used to evaluate growth, as body size is an important indicator of growth. Morphological traits such as body length, withers height, and chest circumference are body size measurements that are useful for providing basic data for improving livestock genetic quality (Warman et al., 2023; Baliarti et al., 2023). Measurements such as withers height, chest circumference, and body length can be used as phenotypic indicators reflecting the genetic ability of livestock. In addition, the relationships between morphometric parameters also provide a picture of functional

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correlations that are important in performance-based selection. Previous studies have shown that certain morphometric traits, such as body length and chest circumference, have moderate to high heritability, making them suitable as the basis for breeding programs and improving the genetic quality of Bali cattle (Chaerunissa and Nurgiartiningsih, 2022; Warmadewi et al., 2017; Garantjang et al., 2020). Therefore, morphometric analysis is not only useful for physical evaluation but also as a tool to determine genetic improvement and sustainable conservation strategies for Bali cattle germplasm.

Optimizing local genetic resources through morphometric-based selection offers a promising path toward greater self-sufficiency (Ministry of Agriculture, 2015; Astiti, 2018). Morphometric traits such as chest circumference and body length are well-established proxies for productivity and adaptability in cattle (Jakaria et al., 2019; Adinata et al., 2023). With modern multivariate analysis techniques like PCA, regional selection for superior breeding stock can be made objective and robust (Patel and Rank, 2023). Based on the issues mentioned above, a study on the characterization and correlation of morphometric traits in Bali cattle in East Kalimantan was conducted to develop information regarding the potential of Bali cattle in six Bali cattle seed source regions in East Kalimantan. The research findings provide a foundation for evaluating genetic potential, which is useful as input for policy development in improving the quality of Bali cattle in East Kalimantan.

MATERIALS AND METHODS

Research Materials

The research was conducted in six regions (cities/regencies) in East Kalimantan, namely: Bontang City, East Kutai Regency (Kutim), Berau Regency, Kutai Kartanegara Regency (Kukar), Penajam Paser Utara Regency (PPU), and Paser Regency. The research materials consisted of 251 female Bali cattle spread across the six regions. The number of samples in each region were: 15 female cattle in Bontang City, 82 female cattle in East Kutai Regency, 12 female cattle in Berau Regency, 42 female cattle in Kutai Kartanegara Regency, 26 female cattle in Penajam Paser Utara Regency, and 74 female cattle in Paser Regency. The age groups of 12 months and 24 months were chosen based on biological, physiological, and technical considerations related to growth phases and the evaluation of seedstock feasibility.

According to the Indonesian National Standardization Agency (SNI) 2023, female Bali cattle aged between 12-24 months represent the ideal age group for initial seed selection because, at this age, the cattle have already shown stable morphometric traits and are ready to enter the productive phase. This study aims to compare these two age groups to understand the dynamics of morphometric growth from the young to the adult phase, as well as evaluate the genetic potential that emerges at each age stage. The cattle used as research subjects were grouped based on physiological age groups, namely 12 months and 24 months, which were determined based on the pattern of permanent incisor teeth growth.

Research Methods

The method used in this study was descriptive research, involving the collection of data related to the observed variables, which were then organized and analyzed. The collected data included the following measured morphometric traits: Withers Height (WH); Chest Girth (CG); Body Length (BL), and morphometric indices: Chest Index (CI) = (CG/WH) × 100; Length Index (LI) = (BL/WH) × 100; Proportion Index (PI) = (BL/CG) × 100. Classification and measurement standards followed the Indonesian National Standard SNI 7651:2023 (BSN, 2023).

The morphometric data obtained from the study were statistically analyzed using Analysis of Variance (ANOVA) to determine differences in physical characteristics among the observed regions. The strength of relationships between variables was analyzed using Pearson's correlation, and Principal Component Analysis (PCA) was conducted. According to Jolliffe and Cadima (2016), PCA is used to identify patterns in data and reduce complexity without significant loss of information. ANOVA, Duncan's test, correlation, and PCA were performed using RStudio software version 4.5.0 (R Core Team, 2024).

The correlation coefficient (r) measures the degree of association between two traits or variables. The value of r ranges between -1.0 and +1.0, representing a unitless abstract measure of relationship strength. The correlation coefficient (r) was calculated using the formula from Nurgiartiningsih (2017):

$$\mathbf{r} = \frac{cov_{XY}}{\sqrt{(\sigma_X^2 + \sigma_Y^2)}} = \frac{cov_{XY}}{\sigma_X \sigma_Y}$$

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Description:
r : correlation coefficient
cov_{XY} : covariance of traits X and Y
σ_X^2 : variance of trait X
σ_Y^2 : variance of trait Y
σ_X : standard deviation of trait X
σ_Y : standard deviation of trait Y

RESULTS AND DISCUSSION

Morphometric Correlation of Female Bali Cattle

Correlation is used to determine the extent to which changes in one trait are related to changes in another trait. The results of the correlation between variables (withers height, chest girth, body length, chest index, length index, and proportion index) in female Bali cattle in this study can be used to determine selection strategies and improve livestock quality. According to Nurgiartiningsih (2017), quantitative traits in livestock can be interrelated, and the relationship between these traits can be measured using the correlation coefficient, which can have either a positive or negative value.

Table 1. Correlation of Female Bali Cattle at 12 Months and 24 Months of Age

12 Bulan / 24 Bulan	Withers Height (WH)	Chest Girth (CG)	Body Length (BL)	Chest Index (CI)	Length Index (LI)	Proportion Index (PI)
Withers Height (WH)	1	0,67	0,54	0,07	-0,02	-0,08
Chest Girth (CG)	0,62	1	0,74	0,79	0,43	-0,22
Body Length (BL)	0,51	0,64	1	0,55	0,83	0,50
Chest Index (CI)	0,13	0,86	0,47	1	0,60	-0,22
Length Index (LI)	-0,07	0,33	0,82	0,46	1	0,65
Proportion Index (PI)	-0,21	-0,52	0,32	-0,53	0,51	1

Description:
r = 1 indicates a perfect positive correlation;
r = -1 indicates a perfect negative correlation;
r = 0 indicates no correlation;
r > 0 – 0.25 indicates a very weak correlation;
r > 0.25 – 0.5 indicates a moderate correlation;
r > 0.5 – 0.75 indicates a strong correlation;
r > 0.75 – 0.99 indicates a very strong correlation.

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Female Bali cattle at 12 and 24 months of age show a strong to very strong correlation between CG (chest girth) with BL (body length) and WH (withers height) at both 12 and 24 months, indicating consistent linear growth between the main body parameters. A high correlation was found between Chest Girth (CG) and Chest Index (CI) (r = 0.86) and Body Length (BL) (r = 0.74). Body Length (BL) has a strong correlation with Length Index (LI) (r = 0.82) and a moderate correlation with Proportion Index (PI) (r = 0.50). Chest Girth at 12 and 24 months of age showed a strong correlation with Body Length (0.74 and 0.64), a very strong correlation with Chest Index (0.79 and 0.86), and a moderate correlation with Length Index (0.43 and 0.33).

The consistently highest correlation value for chest girth (CG) strengthens the finding that CG can be used as a quick selection indicator in breeding programs to obtain individuals with optimal carcass growth potential. This finding aligns with the statement by Warmadewi et al. (2017), who reported that the highest selection response is observed in chest girth, making selection to improve the genetic quality of Bali cattle most effective when focused on chest girth rather than body length and withers height.

Body Length shows a very strong correlation with Length Index (r = 0.82) and a moderate correlation with Chest Index (r = 0.47) and Proportion Index (r = 0.32), indicating that body length in 24-month-old female Bali cattle greatly influences the development of an elongated body type. The correlation results between body length and chest girth with morphometric indices show a very strong relationship (r > 0.80). This finding is in line with research by Chaerunissa and Nurgiartiningsih (2022), which reported that body length has a genetic correlation of 0.98 with body weight and a heritability value of 0.44, while chest girth showed a genetic correlation of 0.35. Therefore, both of these variables are suitable indicators for Bali cattle seed selection.

PCA (Principal Component Analysis) Results for 12-Month and 24-Month Old Female Bali Cattle

Principal Component Analysis (PCA) was conducted to reduce the number of morphometric variables of female Bali cattle into several principal components that explain the largest variance in the data. The PCA statistical approach is useful for simplifying the data structure and identifying the morphometric dimensions that have the greatest impact on body shape at different ages.

Scree Plot of 12-Month and 24-Month Old Female Bali Cattle

The results of the scree plot and eigenvalue values show that the first two components are able to explain more than 80% of the data variance in both age groups. The consistency of the variance proportions between 12 and 24 months indicates that the morphometric structure of female Bali cattle in the study areas tends to remain stable as they age.

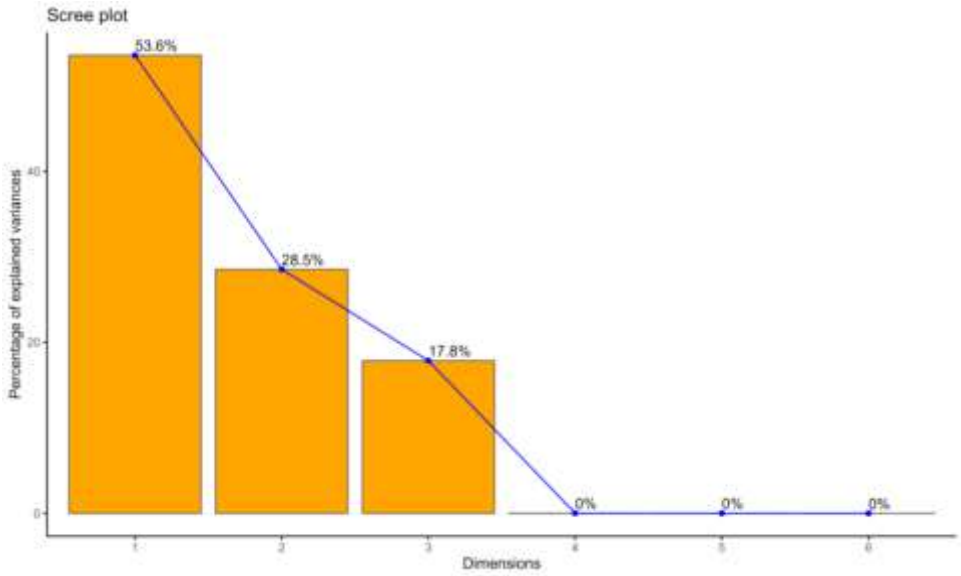

Figure 1. Scree Plot of Eigenvalue of 12-Month-Old Female Bali Cattle

The scree plot of the PCA results for 12-month-old female Bali cattle (Figure 1) shows that the first principal component (PC1) explains 53.6% of the variance, while the second principal component (PC2) explains an additional 28.5%. Cumulatively, the first two components account for 82.1% of the total variation in the data, indicating that these two dimensions represent the main morphometric characteristics at 12 months of age.

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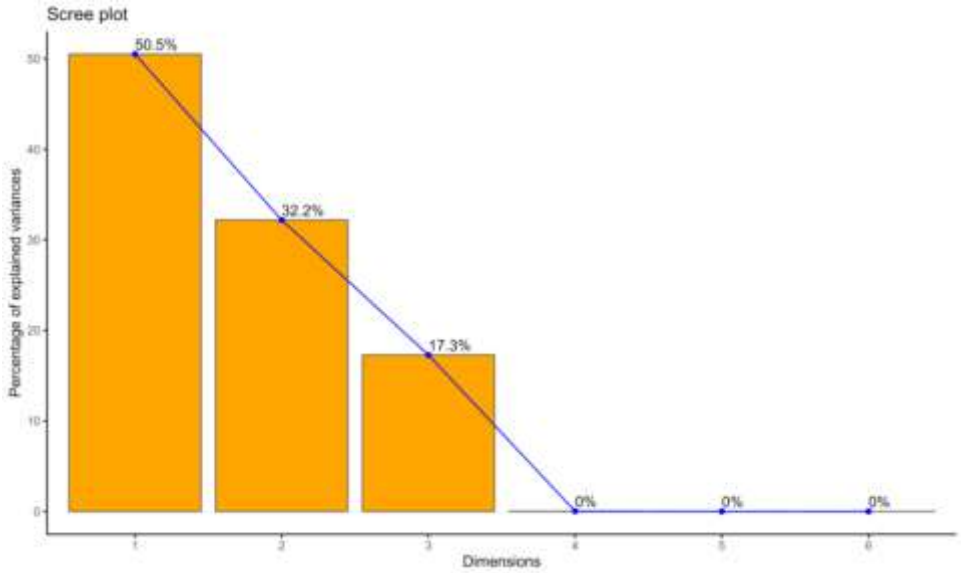

Figure 2. Scree Plot of Eigenvalue of 24-Month-Old Female Bali Cattle

The scree plot of the PCA results for 24-month-old female Bali cattle (Figure 2) shows that the first principal component (PC1) explains 50.5% of the variance, while the second principal component (PC2) explains 32.2%. Cumulatively, the first two components account for 82.7% of the total variation in the data, indicating that these two dimensions represent the main morphometric characteristics at 24 months of age, which is very similar to the results at 12 months.

Principal Components, Eigenvalue, and Variance of Morphometric Characteristics of 12- and 24-Month-Old Female Bali Cattle Based on PCA Analysis

Principal Component Analysis (PCA) was performed to reduce dimensions and identify the main variation patterns of morphometric characteristics of 12-month-old and 24-month-old female Bali cattle.

Table 2. Principal Components, Eigenvalue, and Variance of Morphometric Characteristics of 12-Month-Old and 24-Month-Old Female Bali Cattle

Variable	Age 12 Months		Age 24 Months	
	PC1	PC2	PC1	PC2
Withers Height	-0,28	0,36	0,32	0,18
Chest Girth	-0,48	0,38	0,54	0,23
Body Length	-0,54	-0,15	0,48	-0,36
Chest Index	-0,42	0,21	0,48	0,18
Length Index	-0,45	-0,41	0,35	-0,53
Proportion Index	-0,15	-0,70	-0,13	-0,69
Eigenvalue	3,22	1,71	3,03	1,93
Percentage of Variance	0,536	0,285	0,505	0,322
Cumulative Variance	0,536	0,821	0,505	0,827

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The 12-month-old female Bali cattle in the first principal component (PC1) show 53.6% of the total data, while the second principal component (PC2) shows 28.5%, making the cumulative total of PC1 and PC2 reach 82.1%. The morphometric variables with the greatest contribution to PC1 are body length (-0.54), chest girth (-0.48), and length index (-0.45), while the most dominant variable for PC2 is proportion index (-0.70), followed by length index (-0.41). These results are in line with Warman et al. (2023), which showed that body length, chest girth, and index values were highest on PC1 in Bali cattle, explaining most of the variance.

For the 24-month-old female Bali cattle, the first principal component (PC1) accounts for 50.5%, while the second principal component (PC2) accounts for 32.2%, making the cumulative total of PC1 and PC2 reach 82.7%. The morphometric variables with the greatest contribution to PC1 are chest girth (0.54), body length (0.48), and chest index (0.48), while the most dominant variable for PC2 is proportion index (-0.69), followed by length index (-0.53). According to Jolliffe and Cadima (2016), the negative values indicate that as the character value increases, it decreases in the component, but this does not mean the character is not important; it simply shows the correlation direction in the PCA space.

The cumulative results of PC1 and PC2 at 12 months (82.1%) and 24 months (82.7%) are consistent with the research of Kuswati et al. (2022), which states that the cumulative value explained by the first four principal components reached 80.8%. The use of PC1 and PC2 is capable of illustrating the diversity of morphometric characteristics in Galekan cattle due to their highest cumulative values. Further explanation by Heryani et al. (2018) states that the first principal component (PC1) can be accepted as a size vector and the second principal component (PC2) as a shape vector, so PC1 can show size differences that explain various levels of body size variation in a group of animals, while PC2 explains shapes not captured in PC1.

PCA Biplot of 12-Month-Old and 24-Month-Old Female Bali Cattle

The PCA biplot visualization of the first component (Dim1) represents body size horizontally, or the growth in length and body volume, while the second component (Dim2) represents body shape vertically, or height and chest depth. The PCA results show that body length and chest girth are the dominant variables in the first principal component, making the selection process in the field easier, as farmers can use these two parameters as indicators of superior breeding stock.

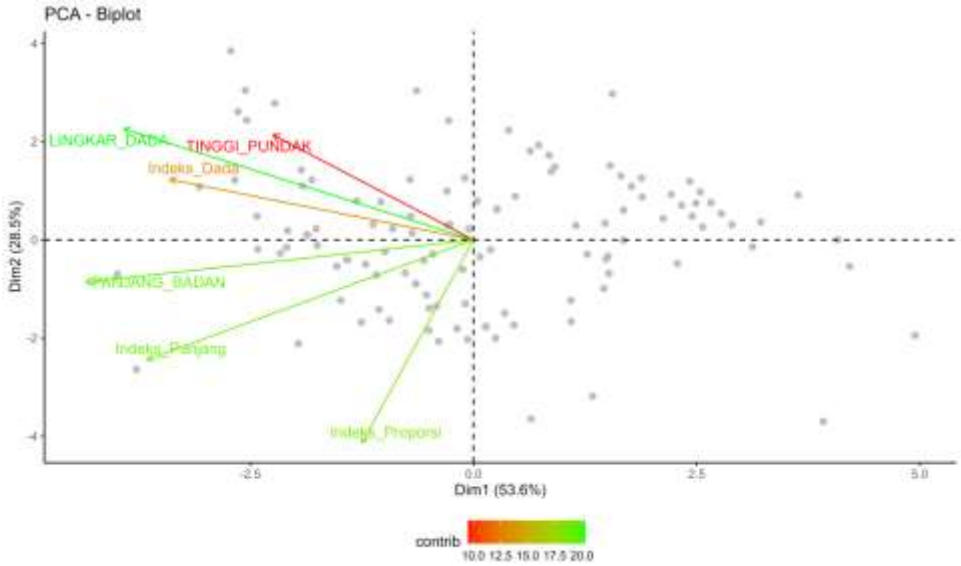

Figure 3. PCA Biplot of 12-Month-Old Female Bali Cattle

Based on the PCA biplot visualization for 12-month-old female Bali cattle (Figure 3), the suggested initial selection criteria are as follows: at 12 months of age, body length should be greater than 100 cm and chest girth should be greater than 120 cm, while at 24 months of age, body length should be greater than 110 cm and chest girth should be greater than 130 cm.

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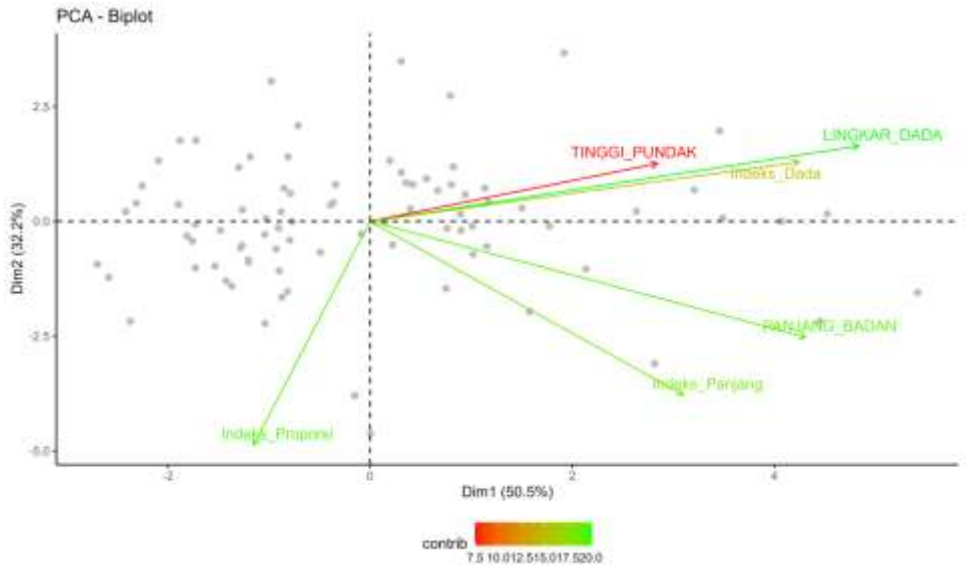

Figure 4. PCA Biplot of 24-Month-Old Female Bali Cattle

Based on the PCA biplot visualization for 24-month-old female Bali cattle (Figure 4), it can be observed that the variables of chest girth, body length, and chest index provide the dominant contribution to the first component (Dim1), which represents increasing body size and length. The proportion index is more dominant in the second component (Dim2), which represents the balance or proportionality of the body.

PCA Individual Plot of 12-Month-Old and 24-Month-Old Female Bali Cattle

The distribution pattern, which tends to be concentrated, also indicates a high level of homogeneity within the population. This condition reflects the morphometric similarity between individuals, which may indicate uniform livestock management or relatively stable genetic factors. This consistency becomes an important aspect in the breeding selection process, as it shows the potential for superior and phenotypically uniform offspring.

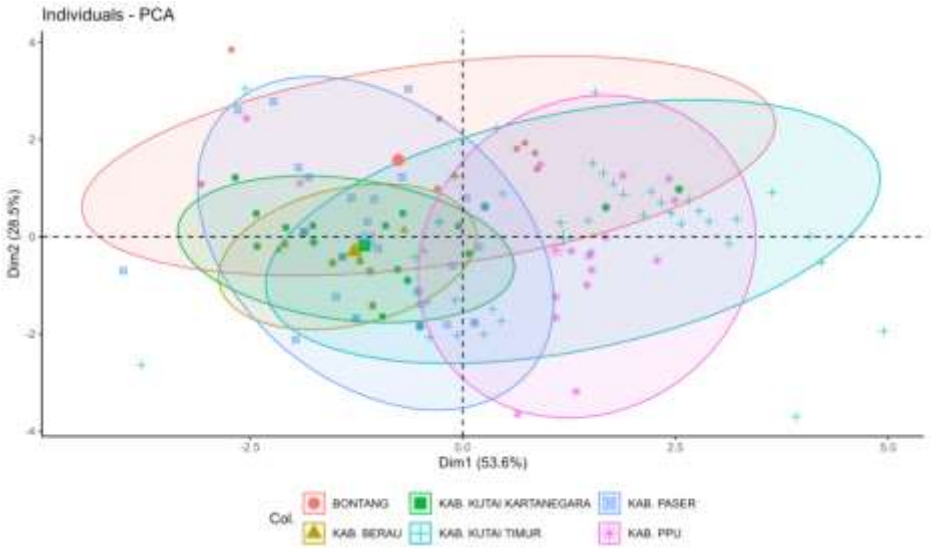

Figure 5. PCA Individual Plot of 12-Month-Old Female Bali Cattle

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The PCA individual plot for 12-month-old female Bali cattle (Figure 5) shows that individuals from Bontang City and North Penajam Paser Regency (PPU) tend to occupy the upper-right quadrant of the graph, indicating positive scores for both Dimension 1 and 2. The positive value in Dimension 1 is strongly correlated with key morphometric characteristics such as body length, shoulder height, and chest girth. Meanwhile, the positive value in Dimension 2 reflects the stability of body proportions. The distribution of individuals from Bontang and PPU in this quadrant indicates that cattle from these regions have larger and more proportional body sizes compared to those from other regions at 12 months of age.

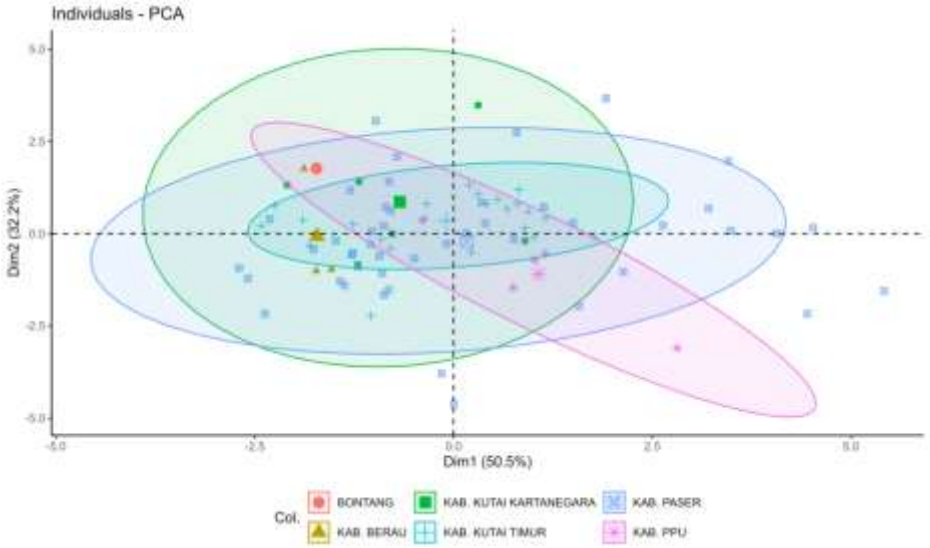

Figure 6. PCA Individual Plot of 24-Month-Old Female Bali Cattle

The PCA individual plot for 24-month-old female Bali cattle (Figure 6) shows that individuals from Kutai Kartanegara Regency have a wide distribution and dominate the positive quadrant in Dimension 1. This indicates that cattle from this region have experienced an improvement in morphometric performance at 24 months of age. Kutai Kartanegara shows the highest morphometric diversity at 24 months. However, other regions such as North Penajam Paser Regency (PPU), Paser, Bontang, Berau, and East Kutai also show significant morphometric improvements, with varying characteristics in each region.

Implications for the Breeding and Development Strategy of Female Bali Cattle

The significant morphometric variation across regions indicates that local genetic adaptation and environmental conditions play an important role in the growth of female Bali cattle. The breeding strategy for female Bali cattle should also consider regional characteristics such as farmers' practices in livestock management, feed availability, and feed quality. According to Budiarto et al. (2021), animal breeding is the science of selecting and mating livestock to produce superior animals.

The application of selection strategies should use the dominant variables from the PCA results, namely body length and chest girth. Additionally, inbreeding should be avoided through crossbreeding between regions (outcrossing), such as mating bulls from PPU with cows from Berau. The PPU and Bontang regions can be established as centers for conservation and production of superior Bali cattle breeding stock due to their highest morphometric performance.

Comparison of Morphometric Values Against SNI Across Regions

Based on the research results, all 12- and 24-month-old female Bali cattle individuals sampled in this study have met the minimum morphometric standards according to the 2023 Indonesian National Standard (SNI) for classifying female Bali cattle breeding stock. This standard sets the minimum threshold values for several important parameters, such as shoulder height (TP), chest girth (LD), and body length (PB), which serve as the basis for determining the suitability of a cattle as a potential breeder.

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Table 3. Classification of Female Bali Cattle Breeding Stock Source Regions Based on Morphometric Values Against SNI

Class	Region	Age Group	Description
Class I (Superior)	PPU	24 months	• The highest values of TP, LD, and PB; • Exceeds the Class I SNI threshold.
	Bontang	12 months	• The highest LD and PB in the 12-month age group.
	Berau	12 months	• Consistently high in LD and PB.
Class II (Good Enough)	Kukar	12 and 24 months	• Meets SNI; • Stable performance but not dominant.
	Paser	12 and 24 months	• Meets SNI; • Good morphometric values, close to the national average.
Class III (Needs Management Improvement)	Kutim	Mainly 12 months	• The lowest values of TP, LD, and PB; • Still within SNI limits but need improvement.

At 12 months of age, female Bali cattle from Bontang City and Berau Regency occupy the top positions in terms of morphometric values, especially in the parameters of chest girth (LD) and body length (PB), which are consistently higher compared to other regions. On the other hand, female Bali cattle from East Kutai Regency at the same age show lower average values for shoulder height (TP), chest girth (LD), and body length (PB), although they are still within the SNI range. At 24 months of age, female Bali cattle from North Penajam Paser Regency (PPU) exhibit the highest morphometric performance, with average values of TP = 108.00 cm, LD = 138.40 cm, and PB = 110.60 cm. All of these values exceed the minimum threshold for Class I SNI, making PPU a potential priority region for the development of superior breeding stock.

According to Budiarto et al. (2021), in livestock farming, selection is the process of choosing superior animals to be used as breeding stock to produce the next generation, with the goal of ensuring that the average production performance of the offspring is better than that of the parent generation. A region-based selection approach is expected to be effective in designing strategies for improving local livestock populations and conserving the genetic resources of Bali cattle..

CONCLUSION AND RECOMMENDATIONS

Conclusion

The morphometric traits of female Bali cattle, including shoulder height, chest girth, and body length, have a strong positive correlation. Correlation analysis and PCA show that chest girth and body length are the main and dominant variables in shaping the morphometry of female Bali cattle. Twelve-month-old female Bali cattle from Bontang City and 24-month-old female Bali cattle from North Penajam Paser Regency (PPU) have the highest chest girth and body length traits and meet the SNI standards, making Bontang and PPU potential breeding stock source regions for Bali cattle.

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Recommendations

1) Female Bali cattle from North Penajam Paser Regency (PPU), which show the highest morphometric performance at 24 months, should be used as the breeding stock population in the Bali cattle breeding and development program in East Kalimantan.
2) Monitoring and recording the morphometric traits and growth of Bali cattle should be carried out periodically. Accurate recording is crucial for evaluating individual potential as the basis for selecting superior livestock to produce offspring. Accurate selection will improve the genetic quality and productivity of the Bali cattle population in East Kalimantan.
3) Further research is needed, including genetic and environmental analysis, to more specifically identify the factors influencing morphometric performance across regions, including evaluation of reproductive and production systems.

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