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Canonical Discriminant Analysis of Morphometric Variables of Swamp Buffalo (*Bubalus bubalis*) in Kalimantan Island

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ABSTRACT

Swamp buffalo (*Bubalus bubalis*) is important livestock by farmers at Kalimantan Island for meat production and drought purposes. This research was carried out to classify buffalo (about 3.5 years of age) based on their morphometrical measurements. The animals in this study were collected from North Kalimantan (NK), East Kalimantan (EK), and South Kalimantan (SK) regions. A Total of 50 animals (25 males and 25 females) were collected from each region. Thus, eight morphometrics of withers height (WH), body length (BL), chest girth (CG), shoulder width (SW), chest depth (CD), rump height (RH), rump width (RW), and rump length (RL) were measured in this study. Research findings showed that four morphometrics of WH, RL, CG, and BL were described as the discriminating variables. According to the Euclidean distance, the buffalo from EK and SK were grouped into a similar cluster. Meanwhile, the buffalo from NK was grouped into a different cluster. Therefore, the observed morphometrics in this study was capable to classify buffalo at NK (100%), EK (66%), and SK (70%) into their original population group. In conclusion, the buffalo at EK and SK regions have a imminent genetic relationship. Moreover, a studies to classify buffalo using cranial measurements is important to support this finding due to mtDNA analysis.

Key words: Buffalo, Canonical analysis, Euclidean distance, Kalimantan, Morphometrics.

INTRODUCTION

Buffalo is important livestock and mainly kept for meat production and social status for the Indonesian farmers at Kalimantan (Borneo) island. In Kalimantan island, the biggest breeding site of buffalo (2019) is located in South Kalimantan provinces (Indonesia) with a total population of 16,556 heads (Ministery of Agriculture of the Republic of Indonesia 2020). Hence, Kalimantan island is one of the centers of the buffalo population in the Southeast Asia region (Zhang et al. 2020). Recently, special attention to the buffalo characteristics and artificial insemination (AI) program for Indonesian buffalo at Kalimantan island was performed since 2011 (Suhardi 2020). Therefore, a selection program in the buffalo at Kalimantan island is important to obtain superior buffalo bulls for frozen sperm (straw) production. Further, it is a good basis to perform selection and breeding development through pedigree recording, reproductive efficiency, crossbreeding, and genetic modification to produce high-quality breeding stock of domestic buffaloes for the buffalo farming industry (Yusnizar et al. 2015; Singh and Balhara 2016; Coates et al. 2018; El Debaky et al. 2019; Nguyen et al. 2020).

Multivariate analysis or canonical discriminant analysis (CDA) is one of the statistical analyses that has been used to characterize livestock (Mahmood and Naeem 2011; Dauda et al. 2016). Thus, the morphometric

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characterization is important to obtain the breed's standard for the breeding program. In the livestock, morphometric measurements were relatively easy and cheap to be applied to the smallholders (Putra et al. 2020). The discriminant analysis is one of statistical method has been proved to be assessing the variation within population or breed and can characterize of different population or breed based on morphometrical measurements (Boujenane et al. 2016). However, the CDA of morphometric traits is not clear to explain the origin or ancestry since these traits were affected by environment, management system, and adaptability factors. Hence, CDA of morphometric traits was used to classify animals into their original population. In addition, previous studies have been worked with CDA to classify buffalo based on milk quality (Mahmood and Naeem 2011) and morphometrical measurements (Johari et al. 2009; Salamena and Papilaja 2010; Anggraeni et al. 2011; Rezende et al. 2017; Murni et al. 2020).

Unfortunately, studies to characterize buffaloes at Kalimantan with CDA of morphometric have not been reported. Hence, this study was conducted to classify Indonesian buffalo kept at three different regions (North, East, and South) of Kalimantan island, Indonesia. In the future, the results of this study can be used as the basic information for developing the breeding program in Kalimantan.

MATERIALS AND METHODS

Animal and Research Site

A total of 150 swamp buffaloes (*Bubalus bubalis*) were used in this study and collected from NK, EK, and SK provinces of Indonesia. The location of the research site in this study was illustrated in Fig. 1. Each province is presented by 50 buffaloes with 25 males and 25 females. The average age in the animal study was about 3.5 years (3 pairs of permanent incisors). Thus, the average body weight in animal study was about 406±15.09kg male and 398±20.41kg female.

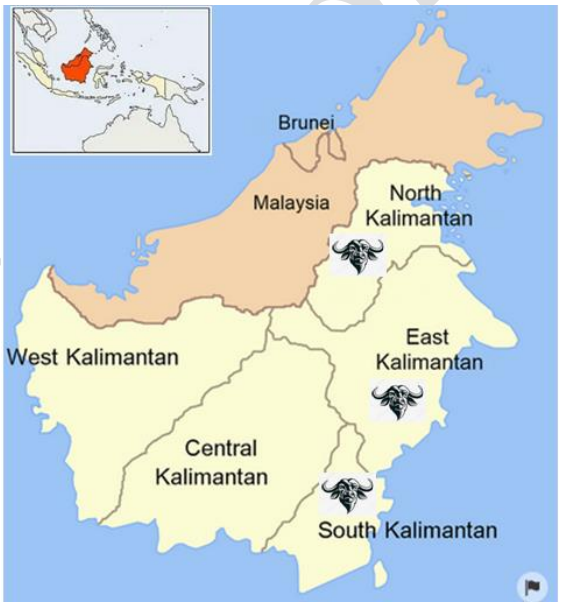

Fig. 1: The research location (buffalo head symbol) at three regions of Borneo Island

Animal Management

During the drought season, the buffaloes were grazed in pasture areas (swamp and marshes) where the labor cost is less than an intensive system, nonetheless, the social conflicts can be raised and escalated due to uncontrol grazing between the buffalo owners and the other citizens. Conversely in the rainy season or the grazing area submerged by water due to flooding, the buffaloes were fed on the paddock where the system is semi-intensive or it is well known as the cut and carry system combining with the grazing system. On the flip side, in two other provinces (EK and NK) the feeding system on buffalo is exstensive, where the adult and calf were grazed extensively, the distance of grazing area around 1-2 km from the paddock, and it took a time around six months. The pregnant and nursery buffaloes usually are farmed and fed intensively during the rainy season or flooding. The main forages are used for feeding buffalo mostly is kumpai grass, there are two types of Kumpai grass where it commonly uses as a feed source by the farmers in three provinces in Kalimantan island consisted of Kumpai batu (*Ishaemum polystachyum*) and Kumpai minyak (*Hymnenachne amplexiacalis*). The feed was consumed by buffaloes only forages (kumpai grass) without concentrate or the other feed supplements added.

Morphometrical Measurements

Eight morphometrical measurements of withers height (WH), body length (BL), chest girth (CG), shoulder width (SW), chest depth (CD), rump height (RH), rump width (RW), and rump length (RL) were taken in this study. WH was measured from the surface of the platform on which the animal stood to the withers of the animal. BL was measured from the point of the shoulder to the pin bone. CG was measured as the body circumference just behind the forelegs. SW was measured as the distance from the left to right shoulder blade. RH was measured from the surface of a platform to the rump. RW was measured as the distance between two *tuber coxae.* RL was measured with a caliper from hips to pins. All the measurements were recorded once in an upright animal standing on level ground (Fig. 2).

Statistical Analysis

Descriptive statistics of the morphometrical measurements were calculated using SPSS 16.0 software to describe mean and standard deviation values. A canonical discriminant analysis (CDA) was performed in this study using similar software to obtain the discriminant variables from eight morphometrical measurements. In the CDA, Mahalanobis distance (D^2), tolerance (T), and canonical correlation (r_c) values were computed to obtain the discriminating variable for the buffaloes from three different populations. Here, the CDA was applied with the backward-stepping automatic elimination method for the variables, with F-value entry = 3.84 and F-value removal = 2.71. The T-value (0–1) was computed to detect the correlation among the discriminant function variables. Suppose a variable is positively correlated with one or more of the others. In that case, the negative value is minimal, and the resulting estimates of the discriminant function coefficient may be unstable. Moreover, the Euclidean distance was performed to obtain the dendrogram distance among buffaloes from the three different populations (groups).

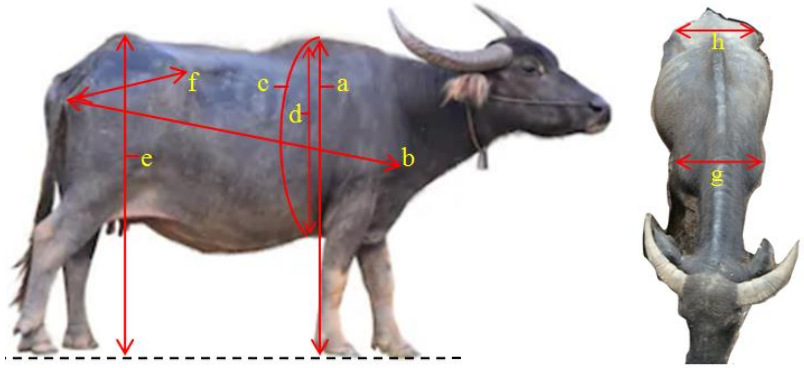

Fig. 2: The scheme of morphometric measurements in withers height (a), body length (b), chest girth (c), chest depth (d), rump height (e), rump length (f), shoulder width (g), and rump width (h) on a buffalo

Table 1: The morphometric measurements of swamp buffalo in Kalimantan (Borneo) Island.

Sex	Region	WH	BL	CG	SW	CD	RH	RW	RL
Male	NK	122.94±4.50^{a}	119.44±3.07^{a}	169.16±4.53^{a}	38.60±5.98^{a}	69.18±6.64^{a}	120.01±4.54^{a}	39.86±6.21^{a}	29.40±6.06^{a}
	EK	130.90±3.48^{b}	130.60±3.93^{b}	182.24±3.72^{b}	42.26±3.92^{b}	70.68±3.92^{a}	128.52±3.77^{b}	44.18±3.97^{b}	33.76±6.51^{b}
	SK	135.16±2.53^{c}	134.20±3.04^{c}	186.56±3.79^{c}	45.22±4.10^{c}	76.80±4.05^{b}	131.04±3.04^{c}	47.56±3.98^{c}	36.16±3.77^{b}
Female	NK	121.58±2.69^{a}	117.20±4.29^{a}	172.34±5.29^{a}	39.32±12.31	69.08±8.51	118.18±3.84^{a}	40.82±12.59	28.18±4.77^{a}
	EK	129.04±2.91^{b}	131.78±5.95^{b}	179.48±5.77^{b}	42.28±4.50	71.60±3.30	126.18±3.35^{b}	44.06±4.53	32.06±5.35^{b}
	SK	130.22±2.31^{b}	130.20±3.45^{b}	182.14±6.70^{b}	42.12±5.46	72.22±3.60	128.22±2.31^{c}	44.12±5.17	33.96±3.49^{b}

NK: North Kalimantan; EK: East Kalimantan; SK: South Kalimantan; WH: withers height; BL: body length; CG: chest girth; SW: shoulder width; CD: chest depth; RH: rump height; RL: rump length; RW: rump width. Superscript in the similar column of sex differ significantly (P<0.05).

RESULTS

The morphometrical measurement on buffaloes from three different regions in Kalimantan Island is depicted in (Table 1). Based on the mensuration of morphometric on buffaloes, there were significantly differences (P<0.05) on WH, BL, CG, SW, RH and RW especially in a male group from three different cluster where the buffaloes' group from SK show had highest value statistically and numerically compared to the others group of buffaloes from NK and EK (Table 1). On the flip side, in a female buffaloes' cluster data revealed that, the differences were happened apparently (P<0.05) only in NK. Therefore, in connection with the measurement of WH, BL CG, RH, and RL exhibited the group of female buffaloes in NK had a lowest value compared to the other groups EK and SK (Table 1). Thus, the male and female buffaloes at NK was the lowest than other population. Therefore, four morphometrical measurements of WH, RL, CG, and BL were identified as the discriminant variables for differentiating buffaloes from three different populations (Table 2). Hence, a total of four steps were obtained in the variable entered that increasing the D^2 value from 0.62 to 0.94. In addition, four discriminant variables in this study able to characterize in buffaloes into their original population with r_c of 0.87 (function 1) and 0.26 (function 2) as presented in Table 3. Moreover, four discriminant variables in this study were successfully classify buffalo from NK (100%), EK (66%), and SK (70%) into their original population (Table 4). According to the Euclidean distance, the morphostructure of buffalo from SK and EK were imminent (1.84). Hence, the buffalo from NK showed more distance compared to EK (3.87) and SK (5.45) as presented in Table 5. Therefore, the canonical discriminant plot (Fig. 3) and dendrogram distance (Fig. 4) revealed that buffaloes from SK and EK were grouped into a similar cluster. Hence, the buffalo from NK was grouped into a different clusters.

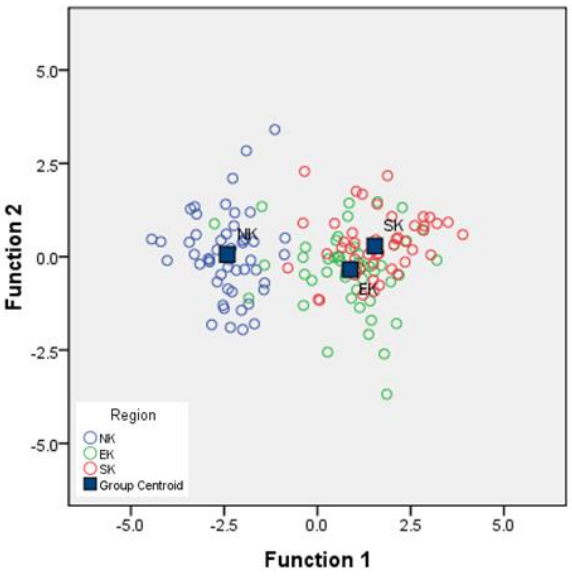

Fig. 3: The Canonical discriminant plot of the morphometric measurements for characterizing swamp buffalo raised in North Kalimantan (NK), East Kalimantan (EK) and South Kalimantan (SK).

Table 2: Factors selected by stepwise discriminant analysis to characterize swamp buffalo in Kalimantan (Borneo) Island.

Step	Variables entered	Tolerance	F Remove	D^2
1	Withers height	0.72	8.35	0.62
2	Rump length	0.98	5.06	0.72
3	Chest girth	0.77	3.41	0.84
4	Body length	0.84	27.06	0.94

D^2: Mahalonobis distance

Table 3: Summary of canonical discriminant analysis.

Function	Eigenvalue	Variance (%)	Cumulative (%)	Canonical correlation
1	3.22	97.7	97.7	0.87
2	0.08	2.3	100.0	0.26

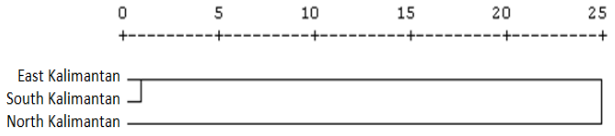

Fig. 4: Dendrogram of morphometric distance among the population of buffaloes in Kalimantan Island.

Table 4: Percentage of individual classification per region based on discriminant analysis.

Region	Predicted group membership (N)			Total (N)
	NK	EK	SK	
NK	100.0 (50)	0.0 (0)	0.0 (0)	100.0 (50)
EK	8.0 (4)	66.0 (33)	26.0 (13)	100.0 (50)
SK	0.0 (0)	30.0 (15)	70.0 (35)	100.0 (50)

N: number of animal; NK: North Kalimantan; EK: East Kalimantan; SK: South Kalimantan.

Table 5: Euclidean distance between swamp buffalo from different population based on morphometric measurements.

Region	NK	EK	SK
NK	0.00	3.87	5.45
EK		0.00	1.84
SK			0.00

NK: North Kalimantan; EK: East Kalimantan; SK: South Kalimantan.

DISCUSSION

The average of CG in buffaloes at Kalimantan island showed the lowest compared to Jafarabadi (219.17±12.02cm), Murrah (204.36±10.61cm), and Mediterranean (207.48±12.47cm) buffaloes (Rezende et al. 2017; Yaemkong et al. 2019). Salamena and Papilaja (2010) reported that the average CG in buffaloes at Moa island of Indonesia (3-4 years age) was 170.91±14.33cm (male) and 167.35±8.62cm (female) and lower than buffaloes at EK and SK. Anggraeni et al. (2011) has been obtained the CG measurements in several Indonesian buffaloes (male/female) from Banten (169.20±10.12cm/ 165.50±13.18cm), Central Java (164.70±16.23cm/ 178.40±22.25cm), South Kalimantan (169.30±10.08cm/ 163.80±9.32cm), Aceh (172.80±5.36/161.80±5.11cm), West Nusa Tenggara (164.50±12.37cm/177.40±12.90cm), South Sulawesi (188.30±34.20cm/183.70±22.02cm) and North Sumatera (178.80±11.55cm/180.10±13.59cm). In this study, the average CG of buffaloes at SK was imminent to the buffalo at South Sulawesi according to Anggraeni et al. (2011). In a similar population group, the average CG in buffaloes from SK according to Anggraeni et al. (2011) was lower than in this study. In buffalo, the CG measurement has a high correlation with body weight (Dhillod et al. 2017; Husni et al. 2018; Eriani et al. 2019).

Murni et al. (2020) obtained nine discriminant variables (with five functions) from eleven morphometrical measurements in buffaloes from Banten (Indonesia) with r_c value of 0.81 (function 1). Nafiu et al. (2015) and Genedy et al. (2019) obtained three discriminant variables (with two functions) from seven measurements in buffaloes from Bombana Regency (Indonesia) with RC value of 0.85 (function 1). Hence, the r_c value of Banten buffaloes in the previous study was imminent to the present study. The CDA of morphometric measurements was successful indiscriminate 50.8 - 67.4% of buffaloes into their original subpopulation of Moa island (Salamena and Papilaja 2010). Thus, the CDA of morphometric measurements was successful to discriminate 38.02 - 95.00% of Indonesian buffaloes into their original population (Anggraeni et al. 2011). The Euclidean distance among three buffalo subpopulations in Moa island ranged from 1.84 to 3.87 (Salamena and Papilaja 2010) and imminent to the present study (1.84 to 5.45). Meanwhile, the Euclidean distance among six buffalo subpopulations in the Banten regency ranged from 0.20 to 0.69 (Murni et al. 2020; de Melo et al. 2018; Konda et al. 2019) and lower than the present study. The buffaloes at SK and EK were imminent and caused by an AI program with buffalo bulls from the SK region (called Kalang buffalo). Hence, the AI program was successfully spread in the imminent area from the SK region. So, the genetic flow of buffaloes from SK to EK has occurred decades ago. Therefore, mostly the morpho-structure of buffaloes in the EK region was imminent to buffaloes in SK regions. Recently, the Kalang buffalo was separated into two varieties based on the decision of the Ministry of the Republic of Indonesia No: 2844/Kpts/LB.430/8/2012 (SK variety) and No: 2843/Kpts/LB.430/8/2012 (EK variety).

Conclusion

The CDA of morphometric measurements can be used to classify the buffaloes at Kalimantan island. Thus, 100% buffalo of NK, 66% buffalo of EK, and 70% buffalo of SK were capable to be classified into their original population based on their morphometrics. In conclusion, the morphostructure of buffaloes from SK and EK regions were imminent and grouped into a similar clusters based on the dendrogram morphometric distance.

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Author's Contribution

SS and WPBP conceptualized the idea and finalization of edits, analyzed and interpreted the data. AW and AI performed the experiment and collected the data. R, MIH, and AS Provided support in the conceptualization of the research design, wrote and edited the manuscript. I and PS provided a material discussion on theory development and critical evaluation of research data and content.

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