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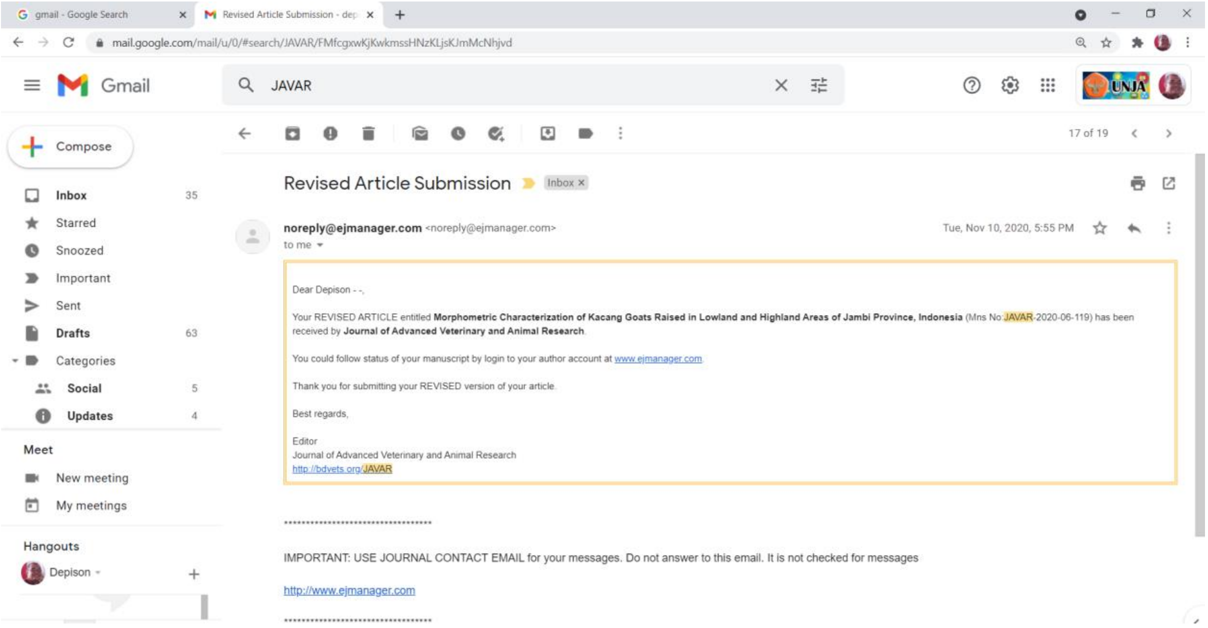

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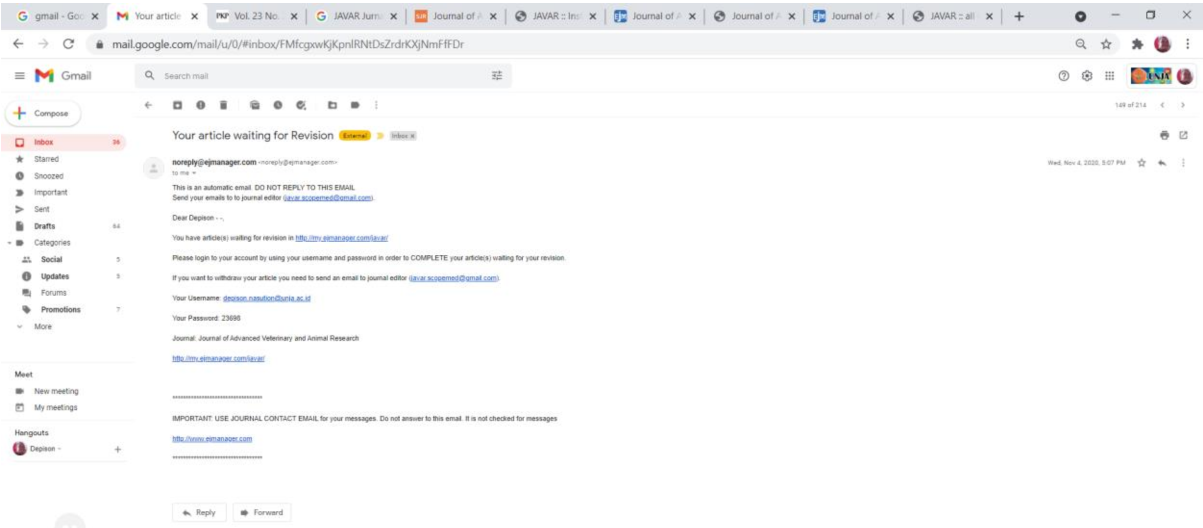

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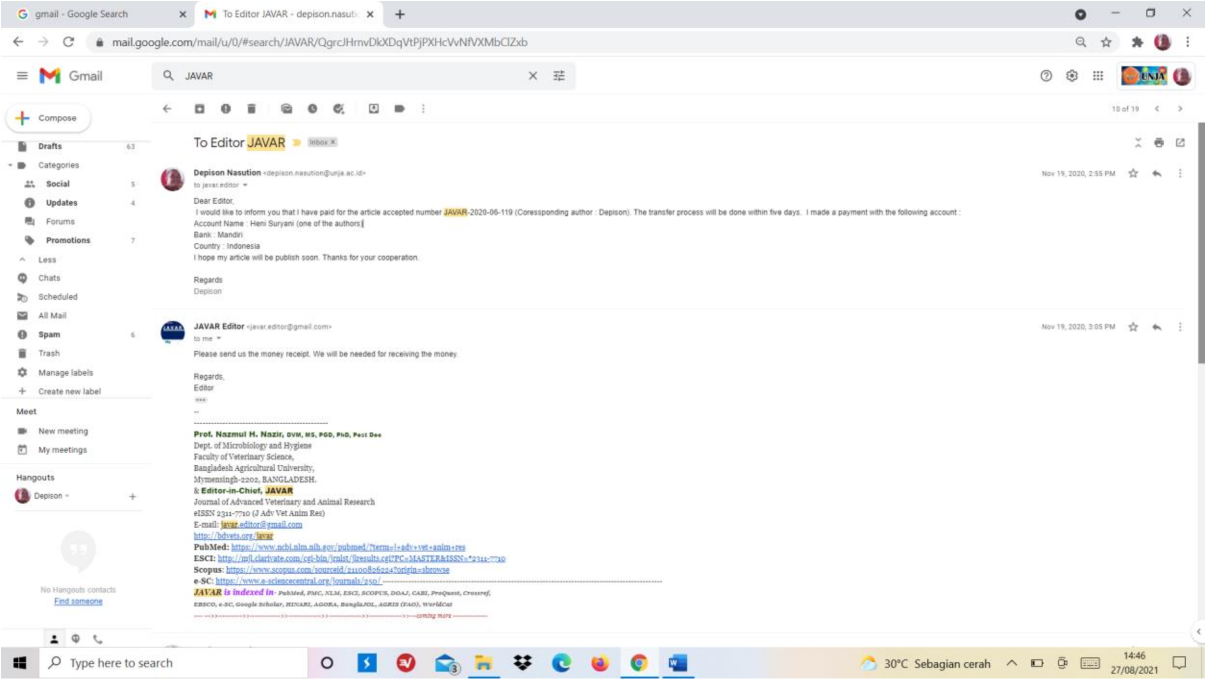

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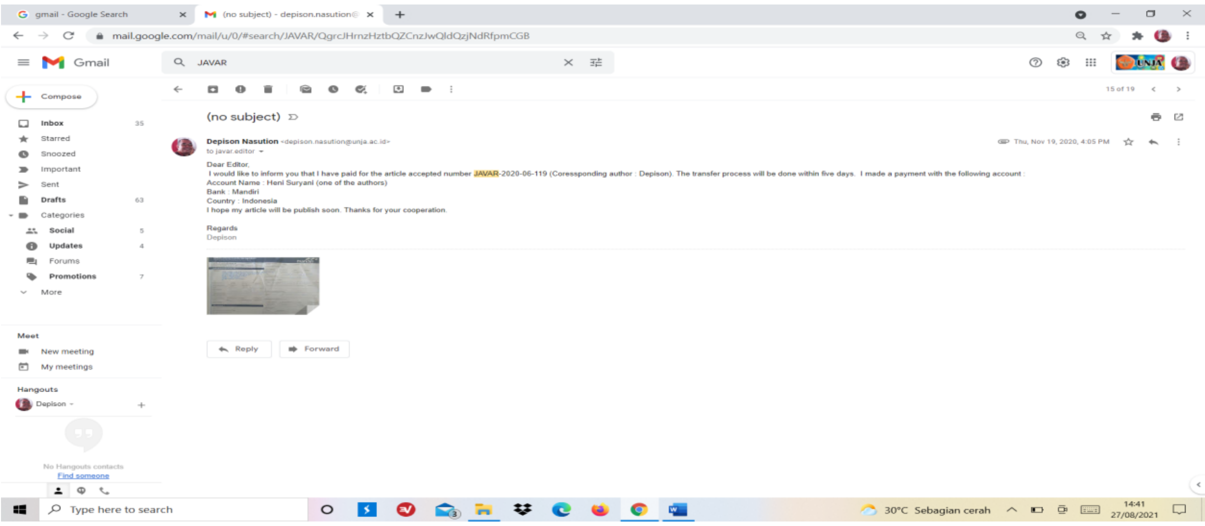

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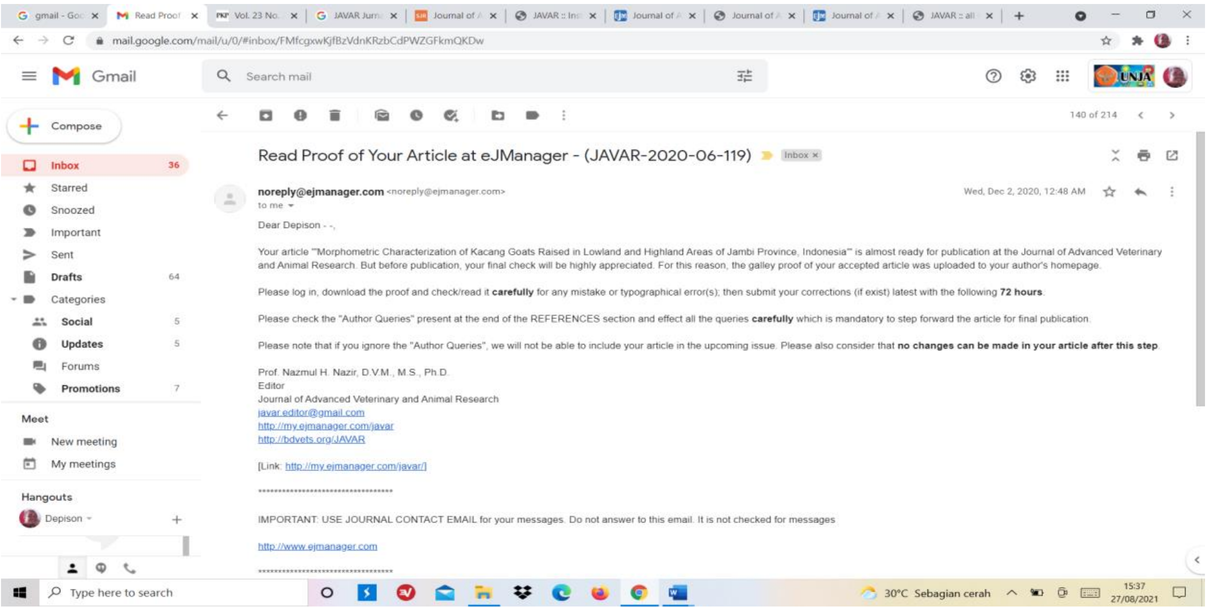

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The text correction below :

1. In the introduction there was small mistakes in the text which are :
   a. Hence, the morphometric characteristics can be used to characterize goat and sheep from different populations **[8, 13].**
      Correction text : Hence, the morphometric characteristics can be used to characterize goat and sheep from different populations **[8-13] or (8,9,10,11,12,13) .**
   b. Therefore, morphometric characterization can be performed using two statistical analyses of principal component analysis (PCA), canonical discriminant analysis (CDA) and hierarchical cluster analysis (HCA) are three statistical analyses that widely used to characterize a goat and sheep breeds from different populations **[15, 19].**
      Correcion text : Therefore, morphometric characterization can be performed using two statistical analyses of principal component analysis (PCA), canonical discriminant analysis (CDA) and hierarchical cluster analysis (HCA) are three statistical analyses that widely used to characterize a goat and sheep breeds from different populations **[15-19] or (15,16,17,18,19).**
2. Table 8 should be explained in the text below. The text should be written in the first sentences on second paragraph in the page 741th
   The value of the genetic distance matrix between goats from different populations based on body weight and body size is presented in Table 8. The value of this genetic distance matrix is used to construct a phenogram tree as shown in Figure 5. The phenogram tree describes the genetic distance of the goat population in Muaro Jambi, Batanghari, Sungai Penuh, and Kerinci. Accortding to Figure 5, Kacang goats at Muaro Jambi and Batanghari were classified in the similar cluster with a Euclidean distance value of 2.81 (Table 8). Both regencies are located in the similar geographic area (lowlands) with similar environmental factors that affecting to the morphometrics traits of goat raised at both regencies. Meanwhile, Kacang goats at Kerinci regency alone was classified in different cluster. It can be suggested that Kacang goats at this location have the different of morphometric traits rather than the other regencies.
3. The figure 4 on the page 741th should be written the figure 5 and the position should be after table 8.
4. On the page 741th, there was small correction in the text below :
   However, the D2 value between Kacang goats in the lowland and the highland regions based on body measurements was **0.32**. It was similar to the D2 value observed between Arbi goats in the Jerid and Nefzawa populations (0.33) of Tunisia [10].
   Correction text : However, the D2 value between Kacang goats in the lowland and the highland regions based on body measurements was **0.36 (Table 6)**. It was similar to the D2 value observed between Arbi goats in the Jerid and Nefzawa populations (0.33) of Tunisia [10].

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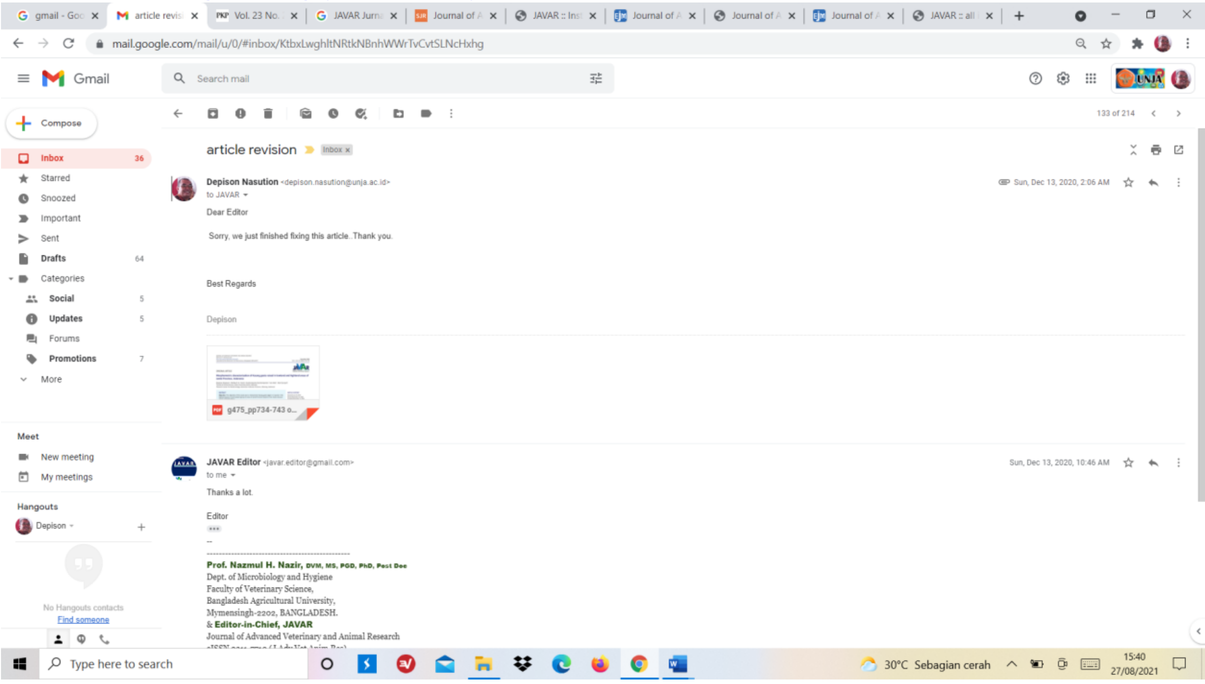

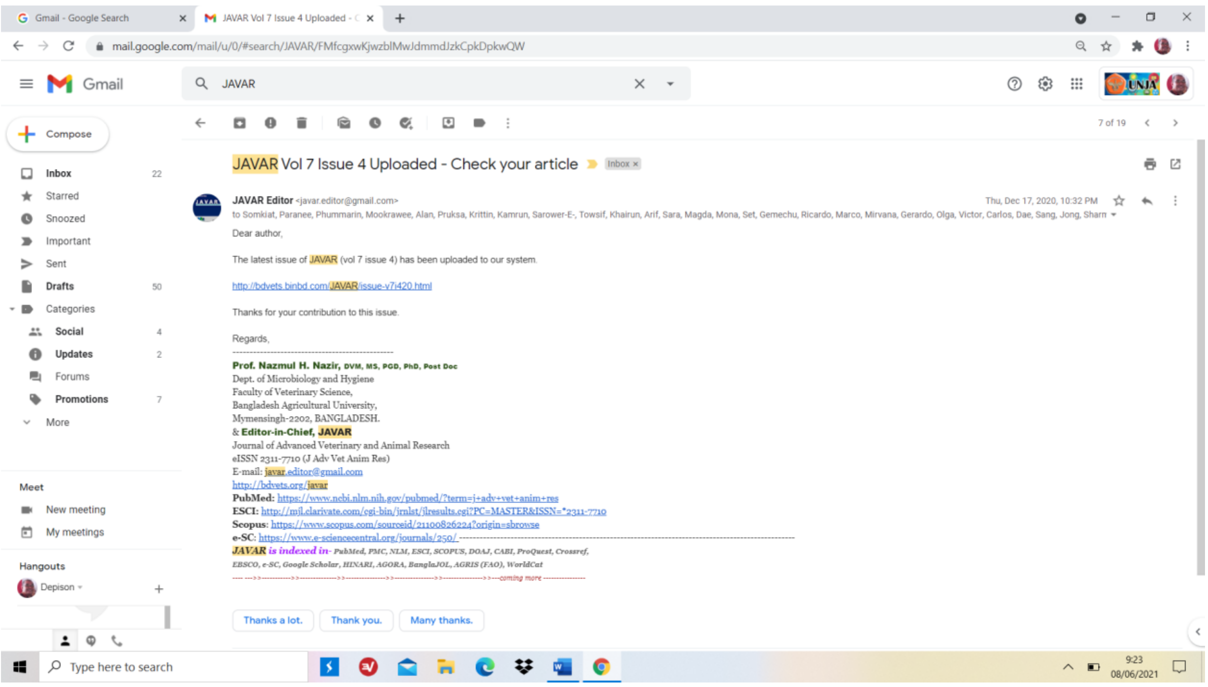

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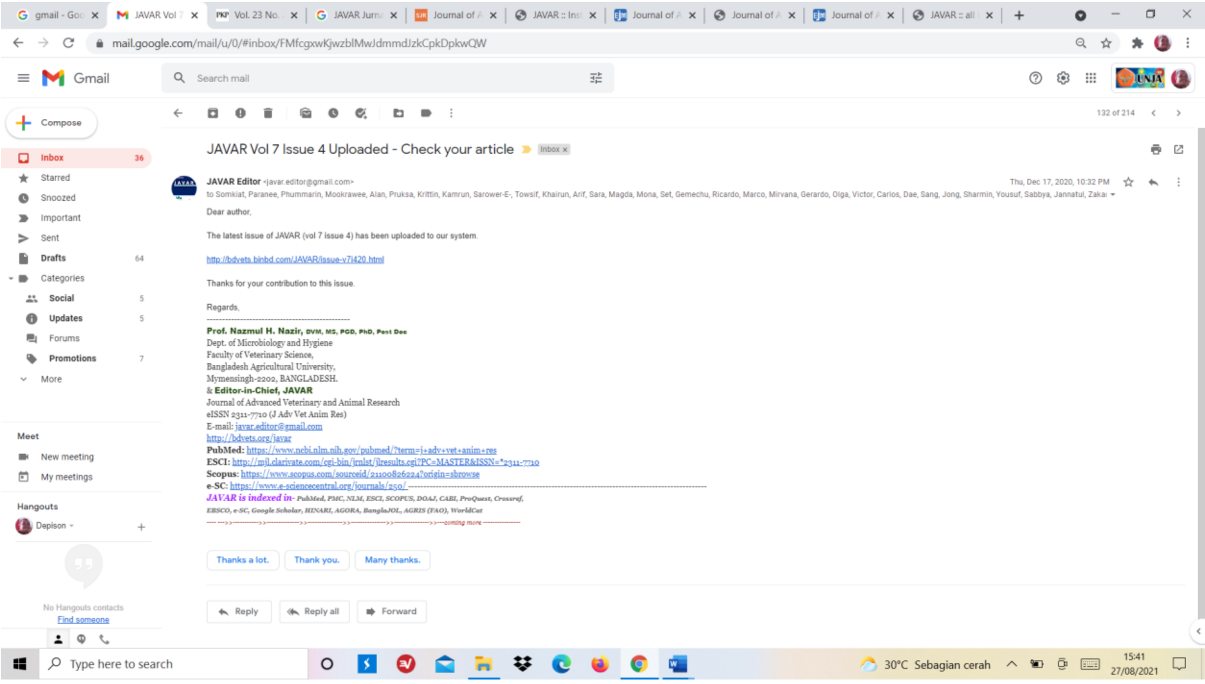
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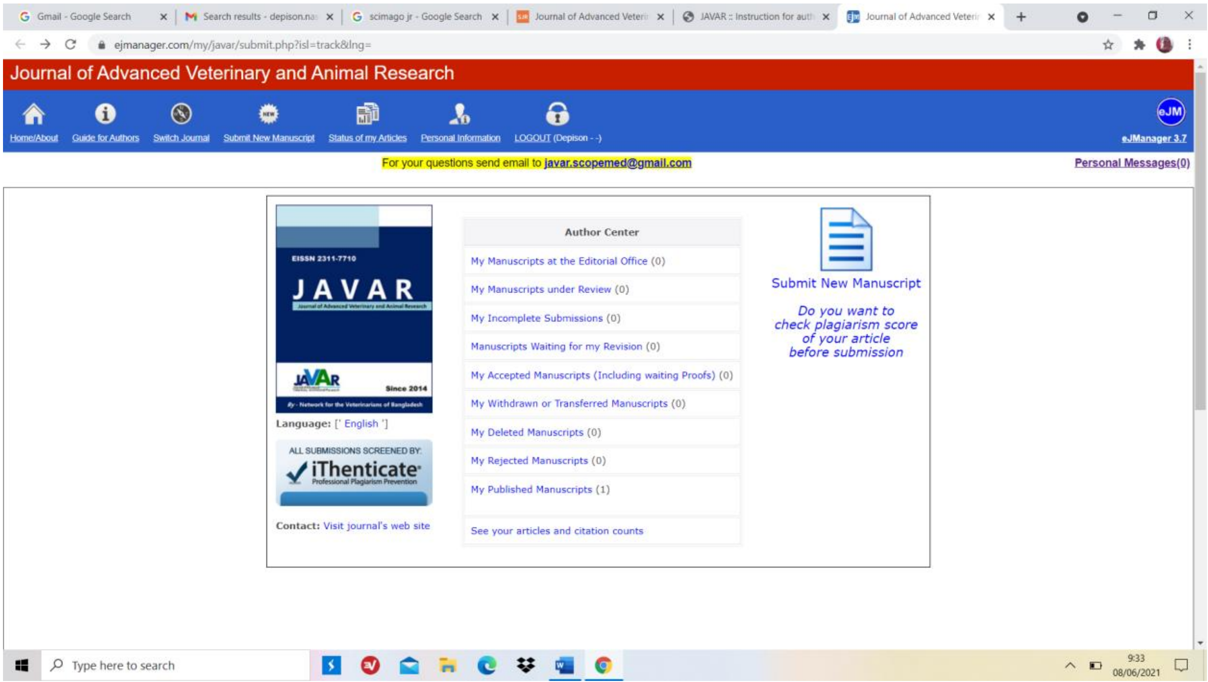
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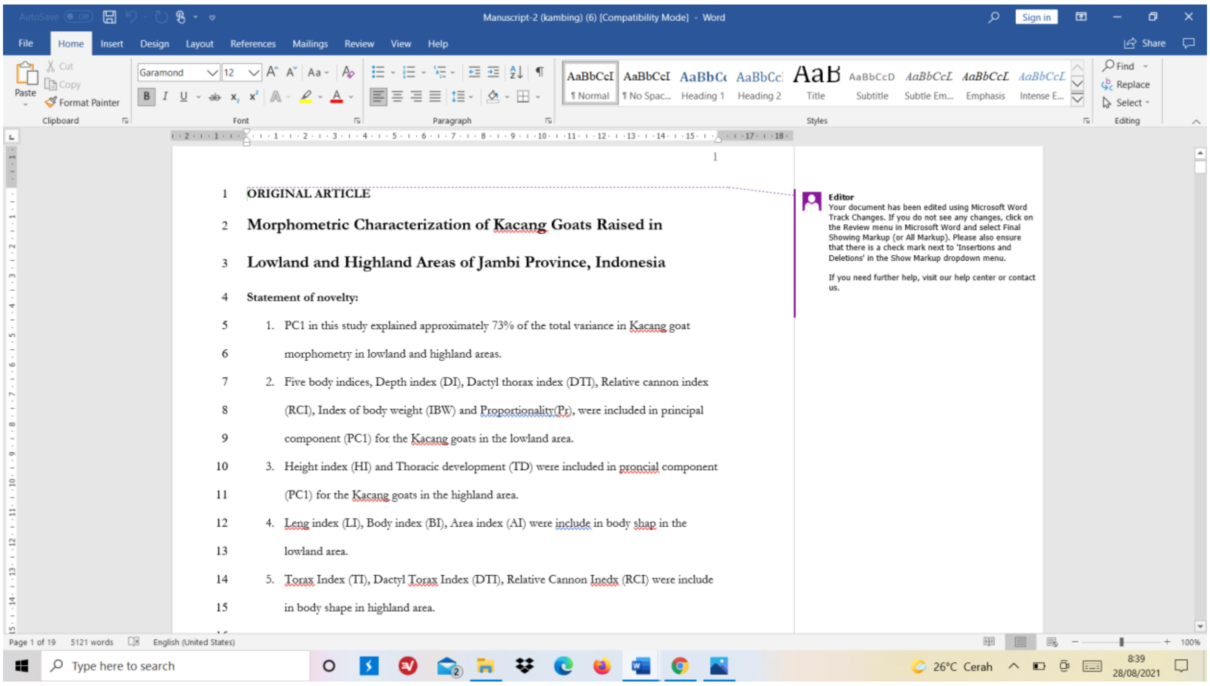
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2. Five body indices, Depth index (DI), Dactyl thorax index (DTI), Relative cannon index (RCI), Index of body weight (IBW) and Proportionality(Pr), were included in principal component (PC1) for the Kacang goats in the lowland area.
3. Height index (HI) and Thoracic development (TD) were included in proncial component (PC1) for the Kacang goats in the highland area.
4. Leng index (LI), Body index (BI), Area index (AI) were include in body shap in the lowland area.
5. Torax Index (TI), Dactyl Torax Index (DTI), Relative Cannon Inedx (RCI) were include in body shape in highland area.
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Morphometrics Characterization of Thin-tailed Sheeps in Lowland and Highland Areas

Depison[1]*, W.P.B. Putra[2], Gushairiyanto[1], Yun Alwi[1] and Heni Suryani[1]

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ABSTRACT

Breed characterization in the livestock is important for the breeding program in the future. The objective of this research was to characterize Thin-tailed sheeps in the highland and lowland areas of Jambi Province based on 7 body measurements and body indices using multivariate analysis. Data was collected from 160 sheeps consisted of 80 rams and 80 ewes (320 sheep in total with 1-2 years old). The research showed that the principal component analysis (PCA) in this study was explained 65.84-72.30% (body measurements) and 78.23-84.99% (body indices) of total phenotypic variance of animals. Body measurement of cannon circumference (CC) and body indices of area index (AI), relative cannon index (RCI), dactyl thorax index (DTI), conformation index (CI) and index of body weight (IBW) were selected as the discrimanating variable for Thin-tailed sheeps in different area. However, the canonical correlation (r_c) values in this study were 0.44 (body measurements) and 0.47 (body indices). Therefore, about 67.5% (lowland) and 57.5% (highland) of Thin-tailed sheeps can be characterized with body measurements. Hence, about 61.2% (lowland) and 65.6% (highland) of Thin-tailed sheeps can be characterized with body indices. Temperature, humidity, rainfall and length of radiation in the highlands are lower than in the lowlands. The cluster analysis in four Thin-tailed populations revealed two cluster of cluster 1 (Kerinci and Sungai Penuh) and cluster 2 (Muaro Jambi and Batanghari). It was concluded that about 60% of Thin-tailed sheep can be characterized through their body indices.

Key words: Thin-tailed sheep, characterization, principal component, canonical correlation, cluster

INTRODUCTION

Thin-tailed sheeps are local Indonesian sheeps kept by smallholders for meat production. Sheep are livestock that are beneficial for human interests, namely as a food source for animal protein. The average weaning weight of Thin-tailed lambs in Sedan village was 8.53±1.57 (Najmuddin and Nasich, 2019). The average body weight for 1 year old male was 27.834±6.914 and female 22.798±2.823 (Ashari et al., 2015). In addition, the average litter size and lambing interval in Thin-tailed ewes were 1.82±0.42 lamb/ewe/year and 9.66±0.69 months respectively (Najmuddin and Nasich, 2019). One of the breeding tract for Thin-tailed sheeps in Indonesia is located in Jambi Province. The total number of sheeps in this province in 2017 reached 76,370 heads or 0.46% fof the total sheep population (16,462,274 heads) in Indonesia (KEMENTAN RI, 2017).

One of the breeding tract of Thin-tailed sheeps located in lowland and highland areas of Jambi Province. The morphometric characterization of livestock is important for planning improvement, sustainable utilization, concervation strategies and breeding programs of a breed (FAO, 2012). In small ruminant animals, morphometric characterization can be performed with body measurements and body indices (Esquivelzeta *et al.* 2011; Ouchene-Khelifi *et al.* 2018; Putra and Ilham, 2019; Markovic *et al.* 2019). Moreover, previous studies have been classified the small ruminant animals from different populations based on their morphometrics (Zaitoun *et al.* 2005; Traore *et al. 2*008; Nafti *et al.* 2014; Dekhili *et al.* 2014; Gatew *et al.* 2015; Hosseini *et al.*, 2016 : Birhaniea *et al.*, 2019 : Jarquin *et al.* 2019).

Recently, the morphometrics characterization in livestock can be performed using three statistical analyses of principal component analysis (PCA), canonical discriminant analysis (CDA) and hierarchical cluster analysis (HCA). Moreoverthese statistical analyses that widely used to characterize small ruminant breeds from different populations (Birteeb *et al.* 2012; Aziz and Al-Hur, 2013; Boujenane *et al.* 2016; Dauda *et al.* 2018;N'Goran*et al.* 2019 ; Nunes *et al.* 2020).

Morphometric characterization can be carried out on body measurements including; body length, chest girth, wither height, rump height, chest depth, canon bone length, canon bone circumference, pelvic width, rump length, and rump width (Getahun et al., 2020; Josiane et al., 2020). Morphometrics can also be used to estimate body weight (Sabbioni et al., 2020), livestock selection and preservation (Ashifudin et al., 2017). Morphometric data is needed for livestock identification, prediction of production potential, livestock productivity (Hilmawan et al., 2019; Mahmudi et al., 2019), continuity of breeding and livestock breeding (Saputra *et al*., 2019; Markovic *et al*., 2019) . Several morphometric studies have been carried out on sheep in order to improve genetic quality based on morphometric data (Vazic *et al*., 2017: Salvagno and Albarella, 2017: Sanni *et al*., 2018: Markovic *et al*., 2019). Using Linear Body Parameters and Craniometric Analysis in Etawah-Grade to prediction of prolificacy (Mulyono *et al.*, 2018) However, there is no information regarding the morphometric characteristics of two different areas, namely the lowlands and the highlands. It is thought that different lands conditions can affect the mofrometric characteristics of livestock. The aim of this study was to characterize the morphometric characteristics of thin tail sheep raised in the lowlands and highlands. The results of this study will be used as a basis for planning improvement, sustainable utilization, conservation strategies, conservation strategies and breeding programs for thin tail sheep in the highlands and lowlands in the future.

MATERIALS AND METHODS

Research Site and Animals

This research was conducted in the lowlands (0-100 masl) and highlands (>500 masl) areas of Jambi Province of Indonesia with located at latitude 0°45'- 2°45' S and longitude

101°10’ - 104°55’ E. (BAPPEDA, 2010). Hence, the research site of highlands area consisted of Sungai Penuh City (Kumun Debai and Tanah Kampung Sub-districts) and Kerinci Districts (Air Hangat and Depati Tujuh Sub-districts). Meanwhile, the research site of ; lowlands area consisted of Muaro Jambi (Sekernan and Kumpeh Sub-districts) and Batanghari Districts (Muaro Tembesi and Pemayung Sub-districts). The climatic condition in study area was presented in Table 1. Thus, the research site of this study was ilustrated in Figure 1 and Figure 2.

A total of 320 Thin-tailed sheeps were collected from two areas of lowland (160 sheeps) and highland (160 sheeps) with sex proportion of 80 rams and 80 ewes for each area. The sheep raising system in both locations is the same, namely the morning is released and the afternoon is put in captivity.

Management of Animal

The lowland and highland sheeps were reared by the farmers with semi-extensive farming system. The maintenance system is released in the morning and the evening without being given forage or concentrates in the cage. The mating system also occurs naturally.

Data Collection

The body measurements were taken from animals in a standing position with a raised head. Body measurements of animals were performed using measuring stick and flexible measuring tape and taken based on FAO (2012). Thus, the weighing scale was used to obtain body weight (BW) of animals. Eight body measurements of body length (BL), withers height (WH), chest girth (CG), chest depth (CD), shoulder width (SW), rump height (RH), rump width (RW) and cannon circumferance (CC). BL measured from the point of the shoulder to the pin bone. WH measured from the surface of a platform on which an animal stands, to the withers of the animal. CG measured as the body circumferance just behind the forelegs. CD measured from the most dorsal point of the withers to the ventral surface of the sternum. SW measured as a distance from left to right shoulder blade. RH measured from the surface of a platform to the rump. RW measured as a distance between two *tuber coxae*. The scheme of body measurements in Thin tail sheep was presented in Figure 3. Morever, calculation of body indices were obtained in this study according to Birteeb *et al.* (2014), Khargharia *et al.* (2015) and Boujenane *et al.* (2015) as follow:Length index (LI) = [BL/WH]×100, Thoracic index (TI) = [SW/CD]×100, Depth index (DI) = [CD/WH]×100, Height index (HI) = [WH/RH]×100, Thoracic development (TD) = [CG/WH]×100, Dactyl thorax index (DTI) = [CC/CG]×100, Conformation index (CI) = CG^2/WH, Relative cannon index (RCI) = [CC/WH]×100, Index of body weight (IBW) = [BW/WH]×100, Body index (BI) = [BL/CG]×100, Proportionality (Pr) = [WH/BL]×100, Area index (AI) = WH×BL.

According to DTI value the body of goat can be described as four categories of light animals (DTI<10.5), intermediary animals (10.6<DTI<10.8), light meat-type animals (10.9<DTI<11.0) and heavy meat-type animals (DTI>11.0) types. According to the BI value, the body of goats can be described as three categories of short or brevigline animals (BI<85), medigline animals (86<BI<88) and longline animals (BI>88) types (Esquivelzeta *et al.* 2011; Chacon *et al.* 2011).

Statistical Analysis

Thestatistics parameter ofmean, standard deviation and Pearson's coefficient of correlation (r) for body measurements and body indices were calculated with SPSS 16.0 computer program. Meanwhile, the morphometric characterization in sheeps was performed using three statistical analyses of principal component anaysis (PCA), canonical discriminant analysis (CDA) and hierarchical cluster analysis (HCA) using similar computer program. The PCA was used to define the underlying structure among the variables in the analysis (Yunusa *et al.* 2013). The CDA was used to classify an observation, or several observations, into already known groups (Asamoah-Boaheng and Sam 2016). The HCA was aimed at separating cases / objects into several groups which have different characteristics (Oliveira et *al.* 2018). In the PCA, Kaiser-Meyer-Olkin (KMO) measures of sampling adequacy, Bartlett's test of sphericity and communality were computed as the test validity. The KMO statistics vary between 0 and 1. The value close to 0 indicates that there are large partial correlations compared to the total of correlations. A value close to 1 indicates that the sampling is appropriate. It was possible to accept a measure of sampling adequacy greater than 0.50.The varimax criterion of the orthogonal rotation method was employed in the rotation of the factor matrix to enhance the interpretability of the factor analysis. In CDA, Mahalanobis distance (D^2), tolerance (T), Wilk's lambda (λ) values and linear discriminant function were computed to obtain the discriminating variable for Kacang goats at two different areas. Here CDA was applied with the method of backward stepping automatic elimination of the variables, with F value entry = 3.84 and F value removal = 2.71. The T value (0 to 1) was computed to detect the level correlation among variable in the duscriminant function. If a variable is highly correlated with one or more of the others, the T value is very small and the resulting estimates of the discriminant function coefficients may be unstables. The HCA was used to clusterize of Thin-tailed sheeps from different populations. The HCA in this study was performed using combination data (body weight, body measurements and body indices) with nearest neighbour method, euclidean distance measure and transform value of Z score, counted by following formula: $Z = (x-\mu) / \sigma$

x = observed value (raw score)

μ = population mean

σ = the standard deviation of the population

Z = Z Score (Standard Value)

RESULTS

Animal Morphometrics

Table 1 shows that the temperature, humidity, rainfall and duration of radiation in the highlands are lower than in the lowlands. The morphometrics of Thin-tailed sheeps was presented in Table 2. The average of BW, BL, WH, CG, SW, RH and RW of Thin-tailed population at highland were higher than lowland areas ($P<0.05$). Meanwhile, the body indices of Thin-tailed population at lowland and highland areas was not significantly different. However, the eight body indices of LI, TI, DI, TD, CI, RCI, IBW and Pr in highland sheeps were showed higher than lowland sheeps. Commonly, the body weight, body measurements and body indices in rams was higher than in ewes in each area. Nevertheless, the body indices of HI between rams and ewes in highland area was showed similar.

Phenotypic Correlation

The correlation value among BW and body measurements were ranged from 0.16 (BW-CG) to 0.65 (BW-WH) for lowland and 0.34 (BW-RW) to 0.65 (BW-CG) for highland (Table 3). Therefore, the r value among BW and body indices (without IBW) were ranged from -0.38 (BW-TI) to 0.08 (BW-CI) for lowland and -0.03 (BW-LI) to 0.64 (BW-AI) for highland (Table 4).

The grasses consumed by thin tail sheep in the lowlands are generally A. Compresssus, A. Compresssus, O. Nodosa, L. Hexandra and C. Dactylon with an average chemical composition, namely Crude Protein 9.33, Crude Fiber 30.70 , Crude fat 1.44 and Ash 10.55. In the highlands generally the grasses of L. Hexandra, B. muticum, D. ciliaris, O. Nodosa and E. Colona, with a chemical composition of Crude Fiber 10.12, Crude Fiber 29.61, Crude fat 1.63 and Ash 10.30 are presented in the table 5.

Principal Component Analysis

The PCA of body measurements in Thin-tailed sheeps was revealed 3PC's (lowland) and 2PC's (highland) as presented in Table 6. The PCA of body measurements was accounted 72.30% (lowland) and 65.84% (highland) of total variance in animal morphometrics. Hence, the PCA of body indices in Thin-tailed sheeps was revealed 4PC's (lowland) and 5PC's (highland) as presented in Table 7. The PCA of body indices was accounted 78.23% (lowland) and 84.99% (highland) of total variance in animal morphometrics. The component plot of body measurements and body indices of Thin-tailed sheeds were ilustrated in Figure 4 and Figure 5

Canonical Discriminant Analysis

The CDA revealed that one body measurements (CC) and five body indices (AI, RCI, DTI, CI and IBW) were identified as a the describing variables for Thin-tailed sheeps at lowland and highland areas (Table 8). The morphometric characterization in this study revealed moderate of canonical correlation value for body measurements (0.44) and body indices (0.47). Morever, about 67.50% (lowland) and 57.50% (highland) of Thin-tailed sheeps can be characterized based on body measurements (Table 9). Meanwhile, about 61.20% (lowland) and 65.60% of Thin-tailed sheeps can be characterized with body indices. The canonical plot of body measurements and body indices of Thin-tailed sheeps were ilustrated in Figure 6.

Hierarchical Cluster Analysis

The HCA based on body weight, body measurements and body indices was revealed two clusters of highland cluster (Kerinci/KR and Sungai Penuh/SP Regencies) and lowland cluster (Muaro Jambi/MJ and Batanghari/BA Regencies) as ilustrated in Figure 7. The lowest of Euclidean distance showed in KR-SP (12.70) and the highest showed in KR-BA (71.04) as presented in Table 10. Moreover, the Euclidean distance in MJ-BA (30.33) was closed to MJ-SP (32.05).

DISCUSSION

Animal Morphometrics

Table 1 shows that the temperature, humidity, rainfall and duration of radiation in the highlands are lower than in the lowlands. This difference will cause differences in livestock productivity. The difference in livestock productivity is closely related to temperature and humidity factors (Calderon et al. (2005). The interaction of temperature and humidity or "Temperature Humidity Index" (THI) can affect the comfort of life for livestock. and in turn will affect the condition and productivity of livestock. High rainfall Together with temperature and humidity are associated with livestock disease problems and internal and external parasites. Besides that, during the rainy season many of the soil minerals are leached out. As a result, many of the forage lacks minerals (Chantalakhana and Skunmun, 2002). Furthermore (Chantalakhana and Skunmun, 2002). The duration of exposure will affect / reduce the protein and mineral content of grasses (Sitorus and Siregar, 1978).

Thin-tailed sheep population at lowland and highland areas included of meaty and longline types of animal. Esquivelzeta *et al.* (2011) reported that the average of DTI and BI in Ripollesa sheeps were 9.60±0.70 and 83.90±6.10 respectively and included of light and brevigline types of animal. Cerqueira *et al.* (2011) reported that the average of DTI and BI values in Portuguese Bordaleira de Entre Douro e Minho (PBEDM) sheeps were 8.88 - 9.84 and 80.37 - 84.25 respectively and included of light and brevigline types of animal. In addition, according to DTI value the Pramenka sheeps included of light typy of animal (DTI = 8.05 - 9.31) as reported by Markovic *et al.* (2019). The BW of Thin-tailed sheeps in this study was lower than Ripollesa (51.40±6.63 kg), Djallonke (21.70±0.50 kg), Sahel (27.50 ±0.80 kg), Zulu (34.70±0.20 kg), Morada Nova (31.74±5.09 kg), Balami (60.87±14.31 kg), Koroji (64.12±16.42 kg), Uda (57.83±17.76 kg), Yankasa (51.09±8.47 kg), Sohagi (48.20±1.73 kg), Rampur-Bushair (25.72±0.16 kg), Istrian Pramenka (61.29±0.90 kg) and PBEDM (32.92±5.05 kg) sheeps (Esquivelzeta *et al.* 2011; Birteeb *et al.* 2012; Mavule *et al.* 2013; Silva *et al.* 2015;

Dauda *et al.* 2018; Elsaid and Elnahas, 2019; Sankhyan *et al.* 2018; Markovic *et al.* 2019; Cerqueira *et al.* 2019). Purwanti et (2019) reported body index of Ettawa Grade does of Indonesia did not affect the litter size. The results of the study, chest girth significantly effect (P<0.05) to body weight. The variation in BW could be due to breeds, management or environment. Productivity of sheep is affected by many factors, such as breed (genetic) and environmental factors (Petrovic *et al*. 2011)

Phenotypic Correlation

The correlation value between BW and CG in Thin-tailed sheeps at highland included of high category (0.61 < r < 0.80) and similar to Uda (0.74 - 0.83) and Zulu (0.74) sheeps (Yakubu and Akinyemi, 2010; Mavule *et al.* 2013). Moderate category of r value (0.40 < r < 0.60) between BW and CG was reported in Rampur-Bushair (0.47) and Sohagi (0.55) sheeps (Sankhyan *et al.* 2018; Elsaid and Elnahas, 2019). Very high category of r value (0.81 < r < 1.00) between BW and CG was reported in Morada Nova (0.93) and Pramenka (0.87) sheeps (Silva *et al.* 2019; Markovic e*t al.* 2019). The different results of this study compared to previous studies can be caused by genetic (breed), management and environmental factors. Indriani *et al.* (2020) reported that the cellulose and hemicellulose of grass at highland was lower than in lowland (P<0.05). Moreover, the fat deposit in lowland sheep was lower than in highland sheep because of high temperature. Thus, less fat deposit in the lowland is important to reduce body temperature. So, low correlation between BW and CG in lowland sheep may be caused by less fat deposit factor. Others factor that causes differences in the characteristics of sheep in the highlands and lowlands ware the species and quality of forage consumed by sheep. Forage in the lowlands will undergo a ripening process earlier 210 than in the highlands, causing a decrease in forage quality as a result of an increase in cell 211 walls, which are the main component of crude fiber. The crude fiber content in mature 212 plant tends to increase, even in certain plants, it exceeds the increase in crude fiber in 213 other plants (Nelson and

Moser, 1994). Moreover, the fat deposit in lowland sheep was lower than in highland sheep because of high temperature. Thus, less fat deposit in the lowland is important to reduce body temperature. So, low correlation between BW and CG in lowland sheep may be caused by less fat deposit factor

Table 5. Shows that the quality of forage consumed by DET in the lowlands is lower than the forage in the highlands. The average forage PK and LK content consumed in the highlands is higher than the lowlands, while the SK and Ash content in the highlands is lower than in the lowlands. Turral et al., (2011) stated that in the lowlands and medium the temperature was higher, resulting in higher cellulose and hemicellulose content than in the highlands. Plants in the highlands develop with lower light intensity and air temperature, so that protein quality is higher and is inversely proportional to its fiber content. Rochana et al. (2016) stated that forage plants in the lowlands get full sun radiation so that the crude fiber content is greater. Furthermore, it was also stated that the content of NDF, cellulose and hemicellulose in the highlands and mediumlands was higher than in the highlands (Indriani et al., 2020). The more the crude fiber content increases, then the nutritional value decreases (Setiyaningrum et al., 2018). Crude fiber content will affect feed digestibility in ruminants. The higher the crude fiber content, then the lower the feed digestibility will be (Rustiyana et al., 2016). Based on the description above, it can be stated that the quality of forage is influenced by altitude.

Principal Component Analysis

The PCA of body measurements in Thin-tailed sheeps was revealed 3PC's (lowland) and 2PC's (highland) as presented in Table 4. The PCA of body measurements was accounted 72.30% (lowland) and 65.84% (highland) of total variance in animal morphometrics. The determinant of body size that significantly different (P <0.01) and the highest in the lowlands and highlands is the withers height, while the determinant of the shape in the highlands and lowlands was shoulder width.Hence, the PCA of body indices in Thin-tailed sheeps was revealed 4PC's (lowland) and 5PC's (highland) as presented in Table 5. The PCA of body indices was accounted 78.23% (lowland) and 84.99% (highland) of total variance in animal morphometrics. Previous studies obtained PCA of body measuements with accounting in total variance about 59.00% (2PC's) in Ripollesa sheep (Esquivelzeta *et al.* 2011); 70.47% (2PC's) in PBEDM sheep (Cerqueira *et al.* 2011); 87.19% (2PC's) in Ghanaian sheep (Birteeb *et al.* 2012); 62.13% (4PC's) in Zulu sheep (Mavule *et al.* 2013); 75.21% (3PC's) in Yankasa sheep (Yakubu, 2013); 66.91% (2PC's) in Balami sheep (Yunusa *et al.* 2013); 57.43% (2PC's) in Uda sheep (Yunusa *et al.* 2013); 72.28% (3PC's) in Morada Nova sheep (Silva *et al.* 2015); 61.53% (4PC's) in Rampur-Bushair sheep (Sankhyan *et al.* 2018); 57.80% (2PC's) in Sohagi sheep (Elsaid and Elnahas, 2019); 96.65% (3PC's) in Pramenka sheep (Markovic *et al.*2019) and 68.04% (3PC's) in Djallonke sheep (N'Goran *et al.* 2019). Unfortunately, study the PCA of body indices so far wasn't reported. However, previous studies reported that PCA of body indices was accounted 86.84% (4PC's) in Katjang does and 89.38% (4PC's) in Pasundan cow (Putra and Ilham, 2019; Putra *et al.* 2020). Amirudin *et al.* (2008) reported the main characteristic variable of body size for local hammer sheep was chest circumference. Furthermore, Gunawan et. al. (2011) also reported, the characteristic measure that has a positive correlation with the size score is the chest circumference of all types of Indonesian Garut sheep. The results of this study indicate that CG can be used as a selection parameter to increase the body size score of Thin-tailed sheep both in the highlands and lowlands in Jambi Province.

The KMO values in PCA of body measurements were higher than PCA of body indices. According to the KMO value, PCA of body measurements in Thin-tailed sheep at lowland and highland areas were accurate (KMO > 0.50). Hence, the KMO values in PCA of body indices in Thin-tailed sheep at highland area wasn't accurate (KMO < 0.50). The component plot of body measurements and body indices of Thin-tailed sheeds were ilustrated in Figure 3 and Figure 4 respectively. Garut sheep is one of Indonesian native Thin-tailed sheeps that has registered breeds standard (SNI) based on age, BW, WH, BL, CG and scrotum circumference (for male). Those parameters were classified into the first component for lowland and highland sheeps

Canonical Discriminant Analysis

Previous studies reported that the body measurements can be used to characterize 70-100% of Ripollesa sheeps at nine different populations (Esquivelzeta *et al.* 2011); 54.18-74.59% of Algerian sheeps at three different populations (Dekhili, 2014) and 76.27-92.80% of Djallonke ewes at three different populations (N'Goran *et al.* 2019). Moreover, the body measurements was used Asamoah-Boaheng and Sam (2016) reported that 65.20% of Djallonke sheeps; 88.90% of Sahel sheeps and 79.30% of Djallonke × Sahel sheeps can be characterized with body measurements. The classification percentage in this study was lower than previous studies and needed of more morphometric measurements. The cephalic measurements is important to obtain in CDA. Popoola and Oseni (2018) obtained four cephalic measurements of skull width, head width, head length and head depth as the describing variable to characterize four Nigerian sheep breeds. Moreover, Asamoah-Boaheng and Sam (2016) obtained head width and face length as the describing variable in Three African sheep breeds. Meanwhile, Nunes *et al.* (2020) reported that about 57.1% (kept at Ceara region) and 54.5% (kept at Rio Grande do Norte region) of Marada Nova sheeps can be classified into the original population based on their body indices. The different of body measurements, presumably due to differences in the environment, especially altitude. Indriani et al., (2020) stated that the content of NDF, cellulose and hemicellulose in the highlands and medium is higher than in the highlands. The more the crude fiber content increases, then the nutritional value decreases (Setiyaningrum et al., 2018). Crude fiber content will affect feed digestibility in ruminants. The higher the crude fiber content, then the lower the feed digestibility will be (Rustiyana et al., 2016). The r_c value in this study included of moderate category and reveals that about 40% of lowland and highland sheeps can be classified with body measurements or body indices. Hence, about 60% of both sheeps may be classified by other factors such as phenotypic traits and genetic diversity

Hierarchical Cluster Analysis

The Euclidean distance between lowland and highland sheeps were ranged from 12.70 to 71.04. Previous studies obtained the euclidean distance of 1.87 to 8.87 among Pramenka sheep from six different populations in Slovenia (Markovic *et al.* 2019) and 2.34 to 7.77 among Black Creole sheepss from seven different populations in Mexico (Jarquin *et al.* 2019). The different of animal management, selection, geographical area, agro-climatic conditions and natural resource can be affected to phenotypic variation in a breed at each population.

CONCLUSION

Five body measurements (BW, BL, WH, CD and RH) and two body indices (TD and CI) were identified as the first component for explaining sheep morphometrics at lowland and highland areas. 67.5% (lowland) and 57.5% (highland) of Thin-tailed sheeps can be characterized with body measurements. Hence, about 61.2% (lowland) and 65.6% (highland) of Thin-tailed sheeps can be characterized with body indices. The cluster analysis in four Thin-tailed populations revealed two cluster of cluster 1 (Kerinci and Sungai Penuh) and cluster 2 (Muaro Jambi and Batanghari). 60% of Thin-tailed sheep can be characterized through their body indices, so that it can be used as a reference for selection and sheep breeding programs in the future.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

ACKNOWLEDGMENTS

This work was funded by DIPA PNPB Faculty of Animal Science of Jambi University, Indonesia (grant number 269/UN21.17/PP/2017).

AUTHORS' CONTRIBUTIONS

D, G and WPBP contributed the experiment and sample collection and wrote the article. YA contributed to the statistical analysis and data interpretation. HS carried out the analysis and wrote the article.

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Table1. Climatic condition of the study area

Description	Highland		Lowland	
	Sungai Penuh city	Kerinci Districst	Batanghari Districst	Muaro Jambi Districts
Temperature (^{o}C)	22.50	22.80	26.80	26.80
Wind speed (m/sec.)	4.30	4.00	5.42	5.42
Humidity (%)	82.00	82.00	85.00	85.00
Air pressure (mb)	923.89	923.89	1009.50	1009.50
Rainy day	190.00	190.00	207.00	207.00
Sun ilumination (%)	57.00	57.00	116.97	124.58
Rainfall (mm)	2.052,80	2.052,80	2.500.00	2.500,00
Regional high (asl)	>1000	>1000	20	25

Source: Central Bureau of Statistic, Jambi Province year 2019

Table 2. The average of morphometric traits in Thin-tailed sheep at two different areas

Parameter	Lowland			Highland		
	Ram (N=80)	Ewe (N=80)	Total (N=160)	Ram (N=80)	Ewe (N=80)	Total (N=160)
Body weight (kg)	16.46±3.27	15.25±2.33	15.86±2.89[a]	18.85±2.44	16.23±3.21	17.54±3.13[b]
Body measurements (cm)						
Body length	50.43±5.01	48.37±4.52	49.40±4.87[a]	53.26±4.40	49.94±5.31	51.60±5.14[b]
Withers height	51.63±4.20	49.15±2.71	50.39±3.74[a]	53.76±4.13	50.57±4.49	52.16±4.59[b]
Chest girth	54.61±14.80	51.28±3.71	52.4±10.89[a]	56.73±3.34	53.64±4.51	55.18±4.25[b]
Chest depth	23.74±2.35	21.60±4.09	22.67±3.49	24.13±1.97	23.27±4.27	23.70±3.34
Shoulder width	11.54±1.10	10.51±1.09	11.02±1.21[a]	13.00±0.80	10.68±1.25	11.84±1.56[b]
Rump height	53.33±4.79	51.26±3.72	52.30±4.40[a]	56.00±3.70	52.79±5.34	54.40±4.85[b]
Rump width	12.71±2.05	11.81±1.21	12.26±1.74[a]	14.19±2.78	12.57±1.47	13.38±2.36[b]
Cannon circumferance	6.89±0.61	5.98±0.51	6.44±0.72	7.80±0.54	6.53±0.32	7.17±0.78
Body indices						
Length index	97.72±6.06	98.40±6.55	98.06±6.30	99.26±6.73	98.94±7.77	99.10±7.25
Thoracic index	48.99±5.95	49.42±6.53	49.20±6.23	54.05±3.21	46.63±6.57	50.34±6.35
Depth index	46.07±4.03	43.89±6.95	44.98±5.77	45.11±4.63	46.05±7.16	45.58±6.03
Height index	97.13±7.26	96.27±7.79	96.70±7.52	96.02±4.27	96.19±7.59	96.10±6.14
Thoracic development	106.24±29.30	104.36±5.60	105.30±21.05	105.92±7.37	106.40±8.32	106.16±7.84
Dactyl thorax index	26.55±13.62	23.12±2.79	24.84±9.95	24.99±4.56	23.57±3.21	24.28±3.99
Conformation index	62.03±28.64	53.65±5.65	57.84±21.00	60.15±6.15	57.23±7.48	58.69±6.98
Relative cannon index	24.67±3.99	24.03±2.14	24.35±3.21	26.51±5.34	24.99±3.16	25.75±4.44
Index of body weight	31.78±5.15	30.95±3.83	31.36±4.54	35.12±4.21	31.95±4.88	33.54±4.82
Body index	102.72±42.32	94.65±9.49	98.68±30.84	94.00±7.32	93.48±10.08	93.74±8.78
Proportionality	2620.02±442.89	2384.71±338.33	2502.37±410.19	2874.97±413.47	2540.73±462.93	2707.85±468.53
Area index	102.72±6.37	101.99±5.73	102.36±6.05	101.20±6.83	101.61±7.05	101.41±6.92

N: number of animal. Superscript in the similar raw differ significantly (P<0.05)

Table 3. Person's correlations between body weight and body measurements of Thin-tailed sheep at lowland (above diagonal) and highland (under diagonal) areas

Body mesurements	BW	BL	WH	CG	CD	SW	RH	RW	CC
Body weight (BW)	-	0.61**	0.65**	0.16*	0.55**	0.23**	0.64**	0.48**	0.42**
Body length (BL)	0.55**	-	0.73**	0.09	0.43**	0.18**	0.47**	0.43**	0.32**
Withers height (WH)	0.64**	0.69**	-	0.24**	0.51**	0.28**	0.66**	0.43**	0.40**
Chest girth (CG)	0.65**	0.51**	0.62**	-	0.18**	0.06	0.27**	-0.26**	0.24**
Chest depth (CD)	0.49**	0.36**	0.35**	0.40**	-	0.22**	0.46**	0.43**	0.39**
Shoulder width (SW)	0.54**	0.39**	0.40**	0.40**	0.25**	-	0.23**	0.47**	0.38**
Rump height (RH)	0.57**	0.55**	0.81**	0.53**	0.31**	0.39**	-	0.39**	0.49**
Rump width (RW)	0.34**	0.37**	0.23**	0.36**	0.32**	0.55**	0.23**	-	0.39**
Cannon circumferance (CC)	0.53**	0.43**	0.45**	0.43**	0.25**	0.73**	0.41**	0.44**	-

*(P<0.05); **(P<0.01)

Table 4. Person's correlations between body weight and body indices of Thin-tailed sheep at lowland (above diagonal) and highland (under diagonal) areas

Body indices	BW	LI	TI	DI	HI	TD	DTI	CI	RCI	IBW	BI	Pr	AI
Body weight (BW)	-	0.16*	-0.38*	0.27**	-0.09	-0.10	0.14	0.08	0.04	0.92**	0.18*	0.17*	-0.67**
Length index (LI)	-0.03	-	-0.13	0.12	-0.01	-0.09	0.14	-0.08	0.09	0.23**	0.31**	-0.98**	0.39**
Thoracic index (TI)	0.09	-0.03	-	-0.52**	0.11	-0.02	-0.03	-0.10	0.03	-0.31**	-0.06	0.16*	-0.35**
Depth index (DI)	0.10	0.25**	-0.47**	-	-0.19*	0.08	0.12	0.13	0.27**	0.33**	0.05	-0.14	0.06
Height index (HI)	0.05	-0.06	-0.01	-0.12	-	-0.16*	0.01	-0.12	-0.32**	-0.23**	0.13	0.04	0.22**
Thoracic development (TD)	-0.07	0.28**	-0.05	0.38**	-0.17*	-	-0.82**	0.96**	-0.25**	-0.06	-0.91**	0.13	-0.18*
Dactyl thorax index (DTI)	0.06	0.09	0.38**	-0.02	-0.05	-0.37**	-	-0.78**	0.28**	0.15*	0.93**	-0.18*	0.12
Conformation index (CI)	0.37**	0.15	-0.001	0.25**	-0.06	0.81**	-0.43**	-	-0.36**	0.05	-0.82**	0.14	0.04
Relative cannon index (RCI)	0.03	0.29**	0.36**	0.24**	-0.16*	0.36**	0.72**	0.18*	-	0.10	-0;02	-0.12	-0.02
Index of body weight (IBW)	0.87**	0.14	0.07	0.30**	-0.07	0.27**	0.08	0.46**	0.25**	-	0.15	-0.25**	0.37**
Body index (BI)	0.04	0.58**	0.01	-0.11	0.08	-0.61**	0.40**	-0.58**	-0.08	-0.10	-	-0.33**	0.27**
Proportionality (Pr)	0.04	-0.99**	0.03	-0.27**	0.08	-0.30**	-0.10	-0.15	-0.31**	-0.15	-0.55**	-	-0.34**
Area index (AI)	0.64**	0.17*	0.05	-0.19*	0.21**	-0.44**	0.03	0.10	-0.27**	0.25**	0.49**	-0.12	-

*(P<0.05); **(P<0.01)

Tabel 5. Nutritional content of forage in highland (Kerinci Sub-districts and Sungai Penuh city) and lowland (Batanghari and Muaro Jambi Sub-districts) areas

Location	Grass Species	CP	CF	EE	Ash
High land	*L. hexandra*	9.84	27.97	1.33	8.30
	B. muticum	10.48	28.00	1.52	10.77
	D. ciliaris	10.66	31.22	2.03	11.70
	O. nodosa	9.74	31.26	1.37	10.25
	E. colona	9.89	29.59	1.90	10.47
Means		10.12	29.61	1.63	10.30
Low land	*A. compresssus*	9.45	33.05	1.67	11.20
	B. muticum	8.92	30.97	1.43	9.95
	O. nodosa	8.38	30.04	1.40	10.23
	L. hexandra	9.19	33.08	1.43	11.09
	C. dactylon	9.91	26.38	1.29	10.28
Means		9.33	30.70	1.44	10.55

CP = Crude Protein, CF = Crude Fiber, EE = Ether Extract

Table 6. Eigenvalues, total variance, cumulative, communalities, Kaiser-Meiyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity in the body measurements of Thin-tailed sheep at two different areas

Body measurements	Lowland				Highland		
	PC1	PC2	PC3	EC	PC1	PC2	EC
Body weight	0.83*	0.18	0.02	0.73	0.73*	0.41	0.70
Body length	0.84*	0.03	-0.10	0.71	0.73*	0.27	0.61
Withers height	0.86*	0.17	0.10	0.78	0.91*	0.13	0.85
Chest girth	0.16	0.07	0.92*	0.88	0.72*	0.30	0.61
Chest depth	0.66*	0.26	0.06	0.50	0.49*	0.26	0.30
Shoulder width	0.07	0.88*	-0.06	0.79	0.27	0.85*	0.80
Rump height	0.74*	0.25	0.24	0.66	0.84*	0.12	0.73
Rump width	0.37	0.56*	-0.52	0.82	0.12	0.79*	0.70
Cannon circumferance	0.49	0.66*	0.27	0.65	0.34	0.76*	0.64
Eigenvalues	4.18	1.31	1.02	-	4.72	1.21	-
Variance (%)	46.39	14.53	11.38	-	52.42	13.42	-
Cumulative (%)	46.39	60.92	72.30	-	52.42	65.84	-
KMO		0.81				0.84	
Barlett's test		**				**	

*main component; EC: extraction communality; **(P<0.01)

Table 7. Eigenvalues, total variance, cumulative, communalities, Kaiser-Meiyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity in the body indices of Thin-tailed sheep at two different areas

Body indices	Lowland					Highland					
	PC1	PC2	PC3	PC4	EC	PC1	PC2	PC3	PC4	PC5	EC
Length index	0.08	0.98*	0.09	-0.02	0.97	0.11	0.98*	0.13	-0.02	-0.07	0.99
Thoracic index	0.06	-0.01	-0.83*	0.19	0.73	0.08	-0.01	0.27	0.003	0.88*	0.85
Depth index	0.01	0.00	0.75*	0.33	0.67	0.28	0.14	0.26	-0.13	-0.81*	0.84
Height index	0.14	-0.04	-0.19	-0.74*	0.61	-0.05	-0.11	-0.08	0.45	0.004	0.22
Thoracic development	-0.97*	-0.01	0.02	0.15	0.96	0.81*	0.17	0.01	-0.53*	-0.10	0.97
Dactyl thorax index	0.96*	0.08	0.12	0.11	0.95	-0.14	0.12	0.97*	0.04	0.04	0.98
Conformation index	-0.92*	-0.01	0.17	0.04	0.87	0.95*	0.05	-0.01	-0.02	-0.01	0.91
Relative cannon index	0.57*	0.15	0.13	0.56	0.68	0.24	0.18	0.92*	-0.19	0.01	0.97
Index of body weight	0.09	0.24	0.65*	0.17	0.52	0.65*	0.06	0.19	0.42	-0.13	0.66
Body index	0.93*	0.22	0.10	-0.11	0.94	-0.60	0.66*	0.11	0.42	0.02	0.98
Proportionality	-0.12	-0.97*	-0.11	-0.03	0.96	-0.12	-0.97*	-0.15	0.06	0.08	0.98
Area indeks	0.11	0.39	0.47	-0.57*	0.72	0.02	0.22	-0.02	0.89*	0.12	0.85
Eigenvalues	4.20	2.50	1.60	1.26	-	3.18	2.76	1.68	1.44	1.13	-
Variance (%)	34.96	20.79	13.36	9.12	-	26.54	22.99	13.98	12.03	9.45	-
Cumulative (%)	34.96	55.75	69.11	78.23	-	26.54	49.53	63.61	75.54	84.99	-
KMO			0.53					0.41			
Barlett's test			**					**			

*main component; EC: extraction communality; **(P<0.01)

Table 8. Factor selected by stepwise discriminant analysis to characterize Thin-tailed sheep at two different areas

Factor / Step	Variables entered	Tolerance	F_{remove}	D^2	Wilk's λ
Body measurements (r_c = 0.44)					
Step 1	Cannon circumferance	1.00	76.40	0.96	0.81
Body indices (r_c = 0.47)					
Step 1	Area index	0.78	28.70	0.68	0.86
Step 2	Relative cannon index	0.36	50.59	0.40	0.91
Step 3	Dactyl thorax index	0.18	46.95	0.44	0.90
Step 4	Conformation index	0.30	28.63	0.68	0.86
Step 5	Index of body weight	0.82	6.73	0.99	0.80

D^2: Mahalanobis distance; r_c: canonical correlation

Table 9. Percentage (%) of individual classification per breed based on discriminant analysis

Factor	Parameter	Area	Predicted group membership (N)		Total (N)
			Lowland	Highland	
Body measurements	Original	Lowland	70.0 (112)	30.0 (48)	100.0 (160)
		Highland	45.5 (68)	57.5 (92)	100.0 (160)
	Cross-validated	Lowland	67.5 (108)	32.5 (52)	100.0 (160)
		Highland	42.5 (68)	57.5 (92)	100.0 (160)
Body indices	Original	Lowland	62.5 (100)	37.5 (60)	100.0 (160)
		Highland	33.1 (53)	66.9 (107)	100.0 (160)
	Cross-validated	Lowland	61.2 (98)	38.8 (62)	100.0 (160)
		Highland	34.4 (55)	65.6 (105)	100.0 (160)

N: number of animal

Table 10. Euclidean distance between Thin-tailed sheep from different population based on body weight, body measurements and body indices

Population	Kerinci	Sungai Penuh	Muaro Jambi	Batanghari
Kerinci	0.00	12.70	49.51	71.04
Sungai Penuh	-	0.00	32.05	56.38
Muaro Jambi	-	-	0.00	30.33
Batanghari	-	-	-	0.00

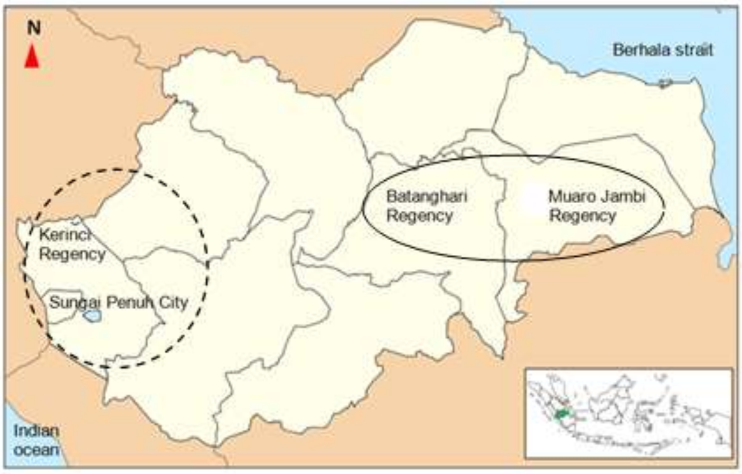

Figure 1. The Thin-tailed sheeps population in Jambi Province of Indonesia spread at lowland area (Batanghari and Muaro Jambi Sub-districts) and highland (Kerinci Sub-districts and Sungai Penuh city) areas

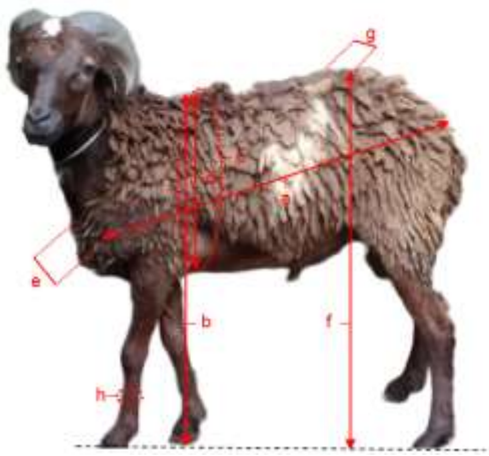

Figure 2. Body measurements scheme in Thin-tailed sheep.a:body length (BL). b: withers height (WH). c: chest girth (CG). d: chest depth (CD). e: shoulder width (SW). f:rump height (RH). g: rump width (RH). h: cannon circumference (CC).

Thin tailed sheep in the highlands

Thin tailed sheep in the lowlands

Figure 3. Thin tailed sheep in the highlands and lowlands in Jambi Province (The sheep in the highlands have various colors, in the lowlands generally light brown)

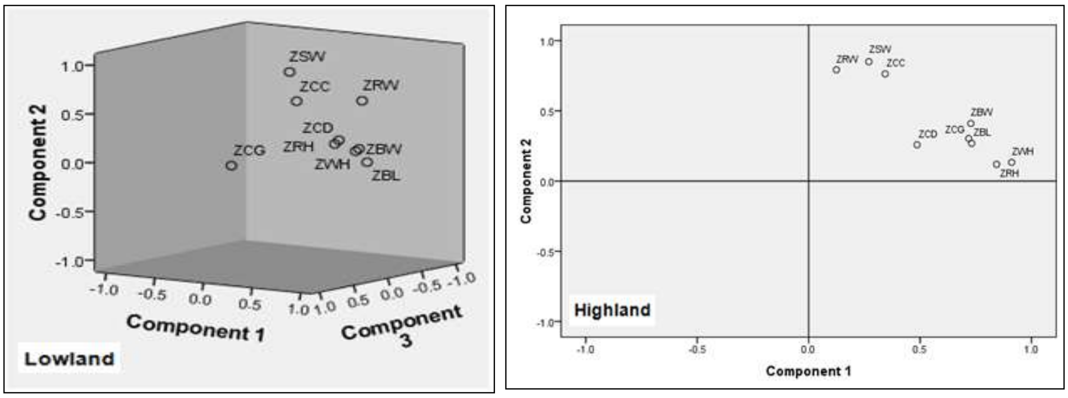

Figure 4. Component plot in rotated space forbody measurements(included body weight) inThin-tailed sheep.

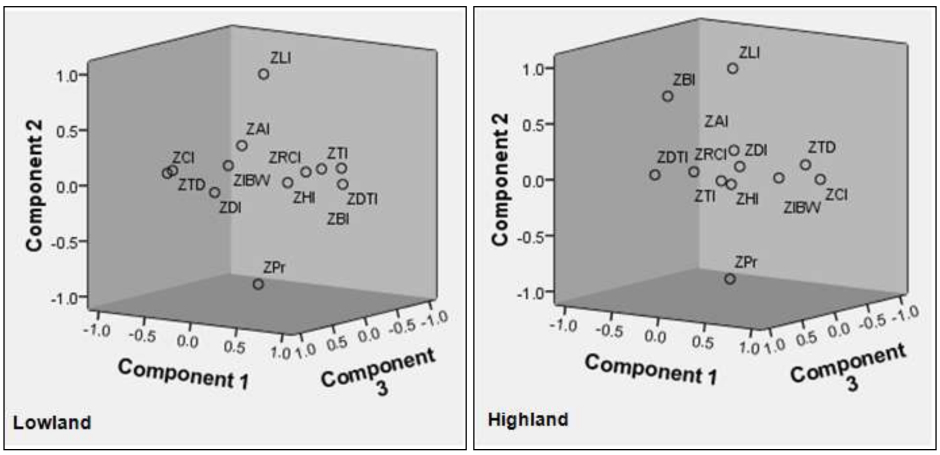

Figure 5. Component plot in rotated space for body indices in Thin-tailed sheep

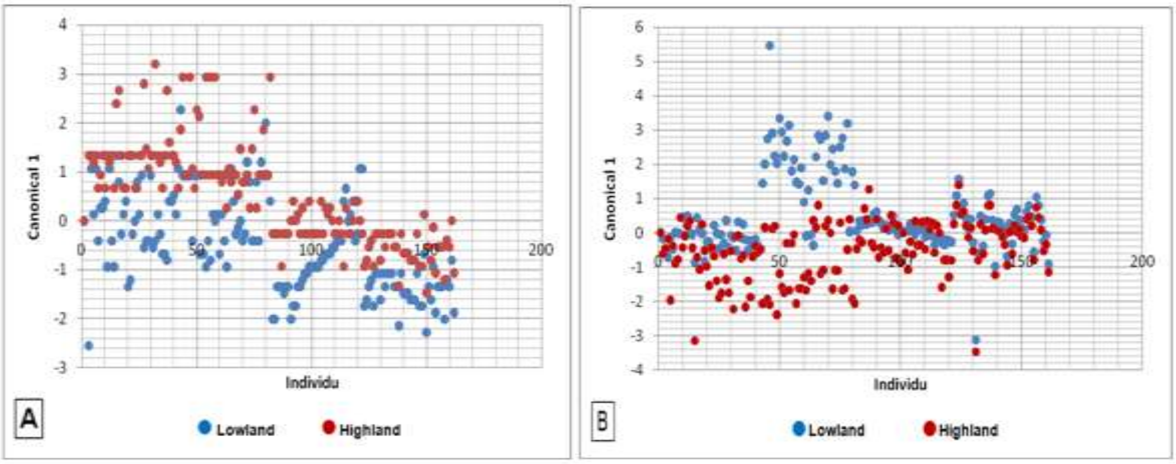

Figure 6. Canonical discriminant plot in the body measurements (A) and body indices (B) to characterize of Thin-tailed sheep at two different areas

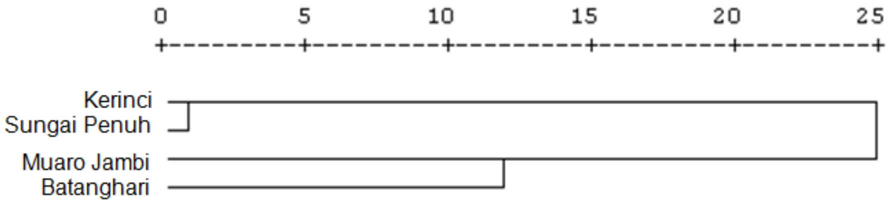

Figure 7. Dendogram distances among four different populations of Thin-tailed sheep based on body weight, body measurements and body indices.