

Differentiation of Indigenous Goat Ecotypes Based on Morphometric Traits Using Canonical Discriminant Analysis

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ABSTRACT

Somalia maintains one of the largest goat populations in Africa, with approximately 11.6 million indigenous goats forming the backbone of the pastoral economy. These goats provide essential food, income, and cultural value to communities across arid and semi-arid rangelands. Understanding the morphometric variation is thus critical for designing evidence-based breeding and conservation programs. Previous morphometric studies in the region relied exclusively on univariate analysis, which cannot capture the complex covariation among biologically interrelated traits. This analytical limitation has left significant gaps in our understanding of how district-level populations differ phenotypically, hampering targeted genetic improvement and management strategies. This study aimed to identify the linear combination of morphometric traits that best discriminates among indigenous goat ecotypes. A total of 350 mature indigenous goats were sampled under traditional management systems. Ten morphometric traits were recorded and analyzed using SAS 9.4, where stepwise discriminant analysis ranked traits by discriminating power, and canonical discriminant analysis together with discriminant function analysis assessed multivariate differentiation and classification accuracy. Multivariate analysis yielded a highly significant overall model. Stepwise selection identified rump height, body weight, rump width, and chest girth as the four significant discriminators, with rump height explaining the greatest proportion of among-district variance. Two canonical functions were extracted, accounting for 53.31% and 46.69% of the variance, respectively. Mahalanobis distances indicated significant pairwise separation among all districts, with Gadogob and Jariban being the most divergent. Overall classification accuracy was 62.29%, with Galkacyo and Jariban correctly assigned at 74.14% and 67.52%, respectively, whereas Gadogob achieved only 45.30% correct classification. The high misclassification of Gadogob goats suggests substantial morphometric overlap among the three populations. The three districts differ significantly in multivariate morphometric space, yet phenotypic overlap is considerable. The moderate classification accuracy reflects shared genetic backgrounds and comparable extensive management systems across the study area. Multivariate morphometrics offers a practical, low-cost approach for preliminary population screening in resource-limited settings. Complementary molecular characterization should be pursued to clarify the relative contributions of genetic and environmental factors to the observed phenotypic patterns.

Keywords: Discriminant Analysis; Indigenous Goats; Morphometric Traits; Northern Mudug; Somalia

Abbreviations: BW: Body Weight; BL: Body Length; HW: Height at Withers; CG: Chest Girth; CW: Chest Width; RL: Rump Length; RH: Rump Height; RW: Rump Width; EL: Ear Length; TL: Tail Length ASCC: Average Squared Canonical Correlation

Introduction

Somalia has one of the largest goat populations in Africa, mainly due to its pastoral and agro-pastoral lifestyle and indigenous goats are the first populous livestock group in Somalia estimated to be about 11.6 million (FAO [1]). The unique traits of these goats, their adaptation to harsh environmental conditions, and the production systems and breeding practices employed by local farmers are crucial

for understanding their contributions to food security and economic stability (Hoffmann [2]). Despite their importance, indigenous goat production faces several challenges in the Northern Mudug Zone of Somalia, including limited access to veterinary services, inadequate feed resources, and the impacts of climate change. Additionally, socio-economic factors such as market fluctuations and land tenure issues complicate the sustainability of goat farming. Addressing these

challenges is critical for improving the livelihoods of pastoral communities (Kiprop, et al. [3]). There is also a lack of comprehensive data on the phenotypic traits of local goat breeds, which hampers effective breeding and management strategies (Mohanty, et al. [4-6]). Without targeted research and interventions, the potential of indigenous goats to contribute to local economies and food security may be significantly undermined (Farah, et al. [7]). Understanding these aspects is vital for enhancing productivity and sustainability in goat farming, which is essential for food security and economic stability in the region. Ultimately, this study sought to promote sustainable livelihoods and food security for communities reliant on goat production (Moges, et al. [8]). Despite the fact that research studies on morphometric traits of goats have been conducted in Somalia, the data obtained was evaluated using univariate analysis (Figure 1). The mechanisms un-

derlying morphometric traits are too complex to be explained using univariate analysis because, on the one hand, each variable is examined separately, resulting in significant overlap of results, and, on the other hand, these traits are biologically related due to pleiotropy or linkage (Yakubu, et al. [9]) (Kefelegn et al., 2024) (Table 1). So, univariate analyses do not take into account all of the (co)variation between traits (Adebayo, et al. [10-11]). Canonical discriminant analysis (CDA), a multivariate statistical technique, provides a better resolution for analysing morphometric traits (Adenaike, et al. [12]). In CDA, all traits are taken into account at the same time while separating breed populations. This method produces a more powerful comparison of breed populations than univariate analysis can provide (Adebayo, et al. [6,10,11,13]).

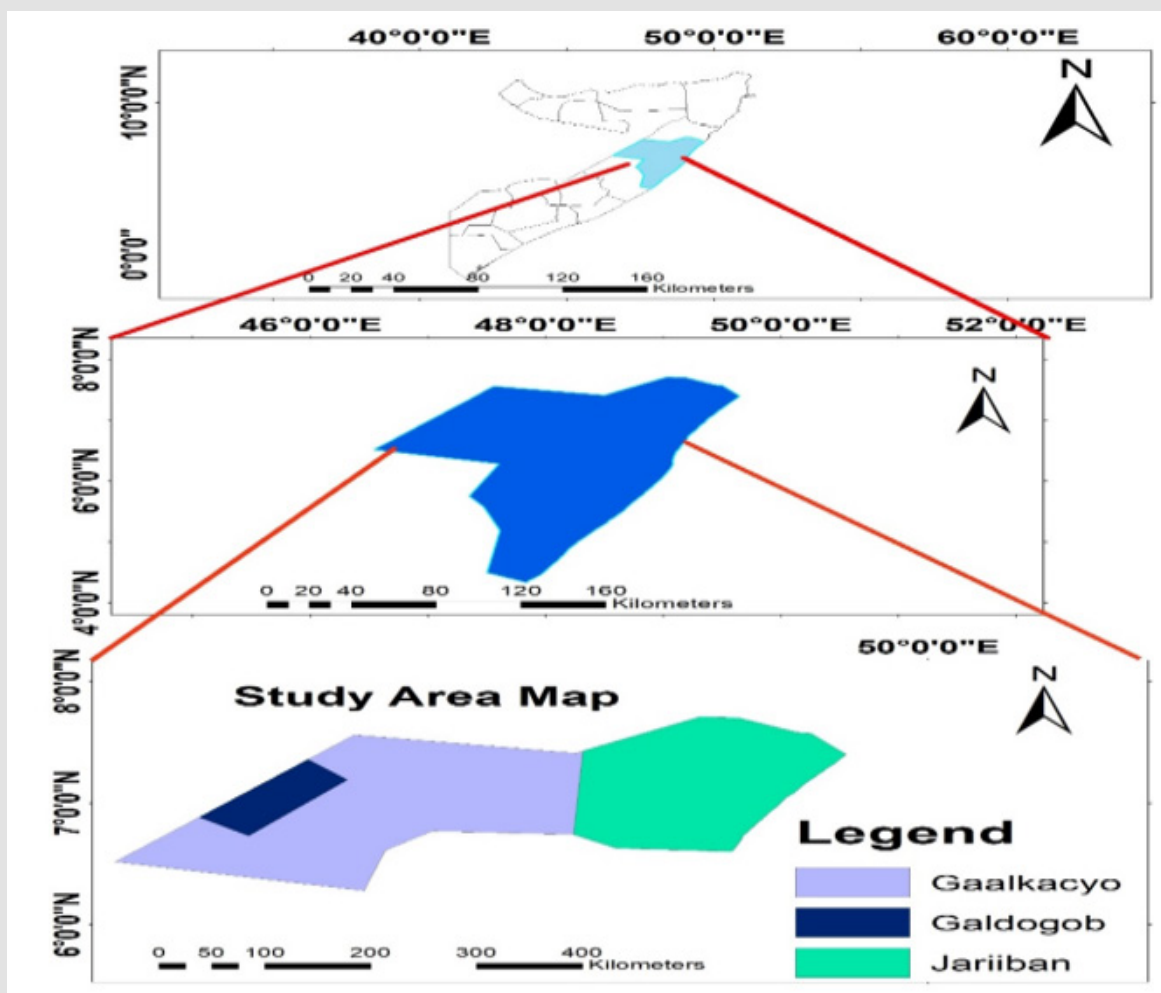


Figure 1: Map of the study area.

Table 1: Least square means ($\pm$ SE) of the morphometric traits by district.

Trait (unit)	District		
	Gadogob	Galkacyo	Jariban
BW	29.04 ^b $\pm$ 0.55	31.85 ^a $\pm$ 0.55	30.68 ^{ab} $\pm$ 0.55
BL	64.53 ^a $\pm$ 0.40	65.35 ^a $\pm$ 0.40	64.08 ^a $\pm$ 0.40
HW	68.67 ^a $\pm$ 0.49	69.43 ^a $\pm$ 0.49	69.09 ^a $\pm$ 0.49
CG	72.98 ^a $\pm$ 0.46	73.60 ^a $\pm$ 0.46	72.05 ^a $\pm$ 0.46
CW	12.91 ^a $\pm$ 0.09	13.00 ^a $\pm$ 0.09	12.89 ^a $\pm$ 0.09
RL	14.33 ^a $\pm$ 0.45	14.08 ^a $\pm$ 0.45	13.47 ^a $\pm$ 0.45
RH	68.76 ^a $\pm$ 0.50	69.81 ^a $\pm$ 0.50	69.46 ^a $\pm$ 0.50
RW	14.46 ^b $\pm$ 0.15	14.97 ^a $\pm$ 0.15	14.27 ^b $\pm$ 0.15
EL	18.30 ^a $\pm$ 0.25	18.48 ^a $\pm$ 0.25	17.94 ^a $\pm$ 0.25
TL	15.71 ^a $\pm$ 0.17	15.90 ^a $\pm$ 0.17	15.60 ^a $\pm$ 0.17

Note: ^{a,b} when different superscripts are indicated in the same row for a given trait, it means that there is a significant ($P < 0.05$) effect of district. BW = body weight, BL = body length, HW = height at wither, CG = chest girth, CW = chest width, RL = rump length, RH = rump height, RW = rump width, EL = ear length, and TL = tail length.

In this regard, there is paucity of information in Somalia regarding the differentiation of indigenous goat ecotype populations where CDA was applied to morphometric traits (Adebayo, et al. [4,5,6,10,13]). Therefore, this study aims to uncover a linear combination of these traits that best distinguishes the goat ecotypes through the application of a CDA (Table 2). Conclusively, this approach will enable quantification of the existing phenotypic variability in the goat population as a strategy to facilitate the rational development of such productively important goat genetic resources and to increase productivity in the management, conservation and breeding programs, as well as selection.

Table 2: Significant morphometric traits that discriminated among the goat ecotypes.

Trait	Partial R ²	F value	P-value
BW	0.0397	7.08	0.0010
BL	0.0157	2.74	0.0657
CG	0.0276	4.86	0.0083
RH	0.0414	7.40	0.0007
RW	0.0282	4.98	0.0074

Note: The P-values for both Wilks' lambda and ASCC (Average Squared Canonical Correlation) were highly significant ($P < 0.0001$). BW = body weight, BL = body length, CG = chest girth, RH = rump height, RW = rump width.

Materials and Methods

Study Area Location

The study was conducted in the Northern Mudug region of Somalia, 759 km from Mogadishu in distance. Somalia's terrain consists mainly of agricultural, plains, and highlands. Hot conditions prevail year-round, along with periodic monsoon winds and irregular rainfall. Conditions in Somalia range from arid in the northeastern and central regions to semiarid in the northwest with annual rainfall of less than 4 inches (100mm). The central plateaus receive 200-300 mm, while the north-western and south-western parts of the nation receive considerably more rain (Robert et al., 2015). The area is separated into the northern and southern halves of Mudug. The Northern Mudug region is home to a significant livestock population, with goats being one of the primary livestock species.

Measurement of Morphometric Traits

A total of 350 indigenous goats (i.e. 115 from Gadogob, 116 from Galkacyo, and 117 from Jariban districts) managed under traditional system, were selected for this study. The three districts were selected purposively based on the extent of goat production potential or the presence of a relatively large proportion of the goat population. Morphometric traits (i.e., body weight (BW), body length (BL), height at wither (HW), chest girth (CG), chest width (CW), rump length (RL), rump height (RH), rump width (RW), ear length (EL) and tail length (TL)) were measured using flexible measuring tape, while weight were measured using a suspended spring balance with a 100kg capacity. (Table 3) Heart girth measurements were taken by standing the animal with the head facing forward in a 'normal' position. Measurements were only taken from mature does, with the age of the doe estimated by examining the doe's teeth (Anne et al., 2016). All morphometric traits were recorded following the recommended descriptors for sheep and goats' genetic resources (FAO [1]).

Table 3: Univariate Test Statistics.

Trait	Pooled standard deviation	Between standard deviation	F value	P-value
BW	0.9846	0.2326	6.51	0.0017
BL	0.9955	0.1483	2.59	0.0776
HW	1.0011	0.0722	0.61	0.5455
CG	0.9947	0.1556	2.86	0.0588
CW	1.0018	0.0569	0.38	0.6869

Note: BW = body weight, BL = body length, CG = chest girth, RH = rump height, and RW = rump width.

Statistical Data Analysis

For all statistical analysis in this study, SAS-program version 9.4 (SAS, 2016) was used.

Univariate Analysis

Morphometric traits (BW, BL, HW, CG, CW, RL, RH, RW, EL and TL) were subjected to analysis of variance using the general linear model procedure (PROC GLM) of SAS 9.4 to determine the effects of district (Gadogob, Galkacyo, and Jariban). Treatment means were separated using Duncan's multiple range test at 95% confidence interval.

Multivariate Analysis

Multivariate analysis was conducted to investigate how similar or different the goat ecotypes were. Using the SAS 9.4 software, the stepwise discriminant analysis procedure (PROC STEPDISC) was run to rank the ten morphometric traits by their discriminating power in differentiating among the three districts. Selected significant traits from PROC STEPDISC were then subjected to canonical discriminant analysis (PROC CANDISC) and discriminant function analysis (PROC DISCRIM) to ascertain the existence of population-level phenotypic differences among the goat ecotypes investigated. The analysis was performed taking individual goat as a unit of classification.

The linear model employed was:

was:

$$Y_{ij} = \mu + D_i + \varepsilon_{ij}$$

where:

Y_{ij} = Observed value of the morphometric trait

μ = Overall mean

D_i = Fixed effect of the i th district (i = Gadogob, Galkacyo, and Jariban)

ε_{ij} = Random residual error term

Results and Discussions

Univariate Analysis

A one-way analysis of variance was conducted to examine the effect of district on the morphometric traits in goats sampled from Gadogob, Galkacyo, and Jariban. The analysis revealed significant district effects for body weight and rump width. The remaining eight traits—body length, height at wither, chest girth, chest width, rump length, rump height, ear length, and tail length—did not differ significantly across districts. Body weight varied significantly across districts. Galkacyo recorded the highest mean body weight (31.85 kg), followed by Jariban (30.68 kg) and Gadogob (29.04 kg). Goats from

Galkacyo differed significantly from those in Gadogob, whereas the Jariban mean did not differ significantly from either of the other two districts. This pattern suggests that goats in Galkacyo may experience conditions more favourable for growth and fat deposition (Table 4). Comparable district-level variation in body weight has been documented in indigenous goat populations across diverse agroecological zones, where localized management and feed availability shape live-weight profiles [Nantongo, et al. [14-15]]. Rump width also differed significantly by district. Galkacyo goats exhibited the greatest rump width (14.97 cm), while Gadogob (14.46 cm) and Jariban (14.27 cm) were statistically similar to each other but significantly lower than Galkacyo. Rump width is an important indicator of pelvic development and conformation, with relevance for both meat yield and reproductive performance [Dige, et al. [16]]. The divergence in this trait across districts may reflect differential selection pressures, breeding histories, or management practices. District-specific morphometric profiles have been observed in Creole goat populations, where certain body dimensions cluster distinctly by location, suggesting that localized husbandry can drive measurable phenotypic differentiation even within a shared breed [Haro-Reyes, et al. [15]].

Table 4: Canonical loadings, canonical correlations and total variations explained.

Trait	CAN1	CAN2
BW	-0.0913	0.9810
BL	0.6133	0.1887
HW	0.9158	-2.2681
CG	0.7875	-0.5108
CW	0.1140	0.2112
RL	0.3046	-0.1532
RH	-2.3354	2.0266
RW	0.5130	0.5234
EL	0.3303	-0.1817
TL	0.1241	0.3549
Eigenvalue	0.096	0.084
Variance accounted for (%)	0.5331	0.4669
Canonical correlation	0.2959	0.2784
Squared canonical correlation	0.0488	0.0494
P-value	<.0001	0.0011

Note: BW = body weight, BL = body length, HW = height at wither, CG = chest girth, CW = chest width, RL = rump length, RH = rump height, RW = rump width, EL = ear length, and TL = tail length.

In contrast, body length, height at wither, chest girth, chest width, rump length, rump height, ear length, and tail length did not differ significantly across the three districts. All districts shared the same statistical grouping for these traits, indicating comparable skeletal and

frame dimensions (Table 5). This uniformity suggests that the underlying genetic architecture governing overall frame size may be similar across districts, or that environmental influences on these linear traits are less pronounced than on body weight and rump width. Morphological characterization studies in Ethiopia and South Africa have similarly reported non-significant location effects for several linear body measurements in indigenous goats, attributing such patterns to shared genetic backgrounds or comparable extensive management systems across sampling sites (Seid, et al. [17-18]).

Table 5: Mahalanobis distances.

Ecotype	Gadogob	Galkacyo	Jariban
Gadogob	0	0.507	1.16
Galkacyo	*	0	0.836
Jariban	*	*	0

Note: *: $P < 0.05$;

The significant district effect on body weight likely reflects variation in feed availability, grazing systems, and husbandry practices. Galkacyo's higher body weight may indicate superior forage resources, more reliable water access, or more intensive management relative to Gadogob and Jariban. Environmental factors, including rainfall patterns and vegetation type, strongly modulate live weight in arid and semi-arid regions, where small ruminant production is often constrained by pasture quality (Paredes-Chocce, et al. [19]). In Uganda, indigenous goat breeds displayed marked body weight differences across agroecological zones, with animals in pastoral rangelands outperforming those in tethered cropping systems because of unrestricted grazing and greater feed access (Nantongo, et al. [14]). Comparable mechanisms may operate across the three Somali districts, although direct measures of feed intake and management intensity were not collected in the present study. Despite district differences in only two traits, the overall morphometric profile indicates a relatively homogeneous population with modest regional differentiation. Body weight and rump width are economically important traits, and their covariation with district highlights the value of morphometric screening in resource-limited settings where weighing scales are unavailable (Mathapo, et al. [20,21]). Path analyses in indigenous goats have demonstrated that linear body measurements frequently emerge as strong predictors of body weight, although the hierarchy of predictive traits varies by breed and environment (Mathapo, et al. [20]). The present findings align with broader evidence that morphometric traits serve as valuable proxies for live weight in smallholder systems, supporting their use in selection and breeding decisions where equipment is scarce (Paredes-Chocce, et al. [19]). These results carry practical implications for breeding and conservation. The phenotypic divergence between Galkacyo and the other districts, though limited to body weight and rump width, warrants targeted management interventions (Table 6). Morphometric indices are increasingly used to classify indigenous goats as meat, dairy, or dual-purpose types, and

district-level profiles can inform such classifications (Dea [22]).

Table 6: Classification results.

From Ecotype	Gadogob	Galkacyo	Jariban	Total
Gadogob	53 (45.30)	36 (30.77)	28 (23.93)	117 (100)
Galkacyo	12 (10.34)	86 (74.14)	18 (15.52)	116 (100)
Jariban	14 (11.97)	24 (20.51)	79 (67.52)	117 (100)
Total	79 (22.57)	146 (41.71)	125 (35.71)	350 (100)

Additionally, multivariate approaches such as principal component analysis and discriminant function analysis could reveal whether districts form distinct morphometric clusters despite the limited univariate differences observed here (Haro-Reyes, et al. [15]). Nevertheless, the current findings establish a baseline for understanding regional variation in Somali goat morphology and provide a foundation for evidence-based breeding strategies.

Multivariate Analysis

A discriminant function analysis was performed to determine whether goats from Gadogob, Galkacyo, and Jariban could be classified correctly based on ten morphometric explanatory variables. The overall multivariate model was highly significant. Both Wilks' lambda and the average squared canonical correlation (ASCC) yielded p values below 0.0001, indicating that the three districts differed markedly in their combined morphometric traits. This result confirms that the linear combination of the morphometric traits carries sufficient discriminatory power to separate the district populations. The stepwise discriminant analysis procedure identified four traits that contributed significantly to district discrimination. Rump height (RH) explained the greatest proportion of among-district variance, with $p = 0.0007$. Body weight (BW) followed closely, recording a $p = 0.0010$. Rump width (RW) and chest girth (CG) also entered the model significantly, with $p = 0.0074$ and $p = 0.0083$, respectively. Body length (BL) approached significance but did not meet the conventional threshold ($p = 0.0657$). The remaining predictors—height at wither, chest width, ear length, tail length, and rump length—did not improve model discrimination and were excluded from the final function. These findings suggest that district-level phenotypic divergence is concentrated in traits related to overall body mass, pelvic conformation, and thoracic capacity rather than general frame dimensions.

Canonical Discriminant Analysis

Univariate statistics provided additional context for these multivariate results. Body weight differed significantly across districts ($p = 0.0017$), corroborating its prominent role in the discriminant function. Chest girth and body length showed marginal trends ($p = 0.0588$ and $p = 0.0776$, respectively), whereas height at wither and chest width were clearly non-significant ($p = 0.5455$ and $p = 0.6869$). The discrepancy between the multivariate and univariate outcomes for chest girth illustrates an important principle of discriminant anal-

ysis: a trait may contribute meaningfully to group separation only when evaluated jointly with other correlated measurements, even if its independent effect falls short of significance. This multivariate synergy has been observed in other indigenous goat populations, where stepwise procedures select traits that jointly maximize among-group dispersion rather than relying on univariate differences alone. Rump height emerged as the single strongest discriminator among the three districts. This trait reflects pelvic structure and hindquarter development, which are closely associated with locomotor efficiency, meat yield, and adaptive capacity to terrain. Its primacy in the model suggests that goats in these districts may experience differential selection pressures related to topography, grazing mobility, or localized breeding preferences. Body weight, the second most powerful predictor, captures cumulative effects of nutrition, health status, and management intensity. The joint contribution of BW and RH indicates that district differentiation is driven by both overall body condition and specific skeletal conformation. Comparable studies have identified heart girth and body length as leading discriminators in Serbian autochthonous goats, highlighting that the relative importance of morphometric predictors varies with population history and environmental context.

Although the overall model was significant, the partial R^2 values for individual traits remained modest, none exceeding 0.05. This pattern implies that substantial morphological overlap persists among the three districts. In other words, district membership can be predicted better than chance, yet many individuals share phenotypic profiles common to more than one location. Such partial overlap is typical of indigenous livestock populations that are geographically proximate and may share ancestral gene pools or management practices. Research on West African goats has similarly revealed weak differentiation between adjacent populations, with intermediate morphotypes appearing because of continuous gene flow and farmer-mediated crossbreeding. From an applied perspective, the four significant traits—rump height, body weight, rump width, and chest girth—offer a practical tool for rapid field classification. Where laboratory facilities are unavailable, these measurements can be collected with minimal equipment and used to assign animals to their most likely district of origin. This approach aligns with broader efforts to characterize animal genetic resources through phenotypic screening. In Botswana, canonical discriminant analysis of Tswana goat populations successfully separated animals across agro-ecological regions, demonstrating that multivariate morphometrics can support conservation decisions when molecular data are lacking. Nevertheless, the modest effect sizes in the present study suggest that classification accuracy may be moderate.

Analysis Discriminant Function

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The standardized canonical loadings revealed distinct biological contributions to each function. On CAN1, rump height loaded most heavily in the negative direction (-2.3354), whereas height at wither (0.9158), chest girth (0.7875), and body length (0.6133) loaded positively. This axis therefore contrasts rump height against general frame dimensions. On CAN2, body weight loaded strongly and positively (0.9810), as did rump height (2.0266), while height at wither loaded strongly and negatively (-2.2681). This second axis distinguishes goats with greater body mass and rump height from those with greater wither height. The remaining traits—chest width, rump length, ear length, and tail length—contributed relatively little to either function. These findings align with the univariate analysis, in which body weight and rump-related dimensions emerged as the principal sources of district-level variation. Mahalanobis distances

quantified the pairwise morphological separation among districts. All three pairwise distances were statistically significant ($p < .05$). The distance between Gadogob and Jariban was largest (1.16), followed by Galkacyo and Jariban (0.836), while Gadogob and Galkacyo were closest (0.507). This ordering indicates that Gadogob and Jariban represent the most divergent morphological extremes, whereas Gadogob and Galkacyo share greater phenotypic similarity. Nevertheless, all distances remained relatively small, reinforcing the impression that these populations occupy broadly overlapping morphometric space.

The classification results mirrored this partial overlap. Overall, 62.29% of the 350 goats were correctly assigned to their district of origin. Galkacyo goats were classified with the highest accuracy (74.14%), suggesting that this district possesses the most distinct multivariate phenotype. Jariban followed with 67.52% correct classification. Gadogob performed poorest, with only 45.30% of animals returning to their true district; the majority of misclassified Gadogob goats were assigned to Galkacyo (30.77%) or Jariban (23.93%). This high rate of misclassification implies that Gadogob goats may represent an intermediate or admixed morphotype between the other two districts. The modest canonical correlations and moderate classification rates are consistent with studies of geographically proximate indigenous goat populations. In Serbian autochthonous goats, canonical correlations exceeded 0.87 and classification accuracy approached 99%, but those populations were genetically distinct breeds subjected to divergent selection histories (Mijić, et al. [23]). By contrast, the present districts likely share a common genetic background and comparable management systems, which constrains phenotypic divergence. Similarly, research on Tswana goats found that CAN1 explained 93.4% of among-population variance, yet some regional populations remained morphologically overlapping (Maletsanake [24]). In the present study, the variance was divided more evenly between CAN1 and CAN2, indicating that no single trait complex dominates district differentiation. The classification accuracy observed here is comparable to results reported for indigenous goats in South Africa, where correct assignment across agro-ecological zones ranged from 38% to 60% (Selolo, et al. [18]). Such moderate accuracy is typical when populations are connected by gene flow and similar husbandry practices. (Traoré, et al. [25]) documented weak morphometric differentiation among adjacent goat populations in Burkina Faso and emphasized that continuous farmer-mediated breeding homogenizes phenotypic profiles across short geographic distances [26-34].

The substantial confusion of Gadogob goats with both Galkacyo and Jariban fits this pattern and suggests that the three districts may not represent reproductively isolated populations. From an applied perspective, the two canonical functions provide a usable, low-cost tool for field-level classification. Body weight, rump height, height at wither, and chest girth can be measured with minimal equipment and used to assign goats to their most probable district. However, the 45% correct classification for Gadogob signals a need for caution. Breeders and conservationists should not rely solely on morpho-

metric assignment for this district without corroborating molecular or pedigree data. Future work should incorporate these factors and apply cross-validation to verify whether the observed classification rates hold in independent samples. The discriminant model confirms that Gadogob, Galkacyo, and Jariban goats differ significantly in multivariate morphometric space, yet the overlap is considerable. Rump height and body weight emerge as the strongest discriminators, while general frame traits contribute secondary information. These results establish a baseline for phenotypic differentiation in Somali goats and underscore both the promise and the limits of multivariate morphometrics for rapid, field-based population screening.

Conclusion

Univariate analysis detected significant district effects for only two of the ten measured traits: body weight and rump width. Goats from Galkacyo exhibited the highest mean values for both traits, differing significantly from Gadogob in body weight and from both Gadogob and Jariban in rump width. The remaining eight morphometric trait did not differ significantly across districts. This pattern suggests that the general skeletal frame of these goat populations is relatively uniform, and that district-level variation is concentrated instead in traits reflecting body condition, pelvic conformation, and overall mass. The multivariate analysis confirmed that the three districts occupy statistically distinct positions in morphometric space. Both canonical functions were significant, together explaining the full spectrum of among-group variance. However, the squared canonical correlations remained modest, and the individual partial effect sizes for the four significant discriminators—rump height, body weight, rump width, and chest girth—were small. This indicates that while the linear combination of traits successfully separates the districts better than chance, considerable phenotypic overlap persists. Rump height emerged as the strongest single discriminator, followed closely by body weight. Their joint contribution underscores that district-level divergence is driven not merely by differences in general size, but by specific variation in pelvic structure and cumulative body condition. The two canonical axes captured distinct biological contrasts: the first function distinguished rump height from general frame dimensions such as height at wither, chest girth, and body length, while the second function separated goats with greater body mass and rump height from those with greater wither height. Mahalanobis distances reinforced the interpretation of partial divergence. All pairwise distances were statistically significant, yet their magnitudes remained relatively small. The largest separation occurred between Gadogob and Jariban, while Gadogob and Galkacyo were the closest. This configuration implies that Gadogob goats may represent an intermediate or transitional morphotype between the other two districts. The classification matrix lent further support to this hypothesis. Overall correct assignment was moderate at 62.29%, with Galkacyo and Jariban achieving reasonably robust classification rates of 74.14% and 67.52%, respectively.

In contrast, fewer than half of the Gadogob goats were correctly reassigned to their district of origin, with the majority misclassified into Galkacyo or Jariban. Such asymmetrical misclassification points to substantial morphometric intermingling and suggests that Gadogob goats either share ancestral gene flow with both neighbouring populations or are subject to comparable environmental and management pressures that homogenize their phenotypic expression. This study relied exclusively on phenotypic data. Without complementary molecular or pedigree information, it remains impossible to disentangle genetic differentiation from environmentally induced plasticity. The moderate classification rates, particularly for Gadogob, may therefore reflect either shared genetic ancestry or convergent phenotypic responses to similar arid rangeland conditions rather than true reproductive isolation. Despite these constraints, the study provides the first systematic, multivariate baseline for phenotypic variation among indigenous goats in the Northern Mudug Zone. It demonstrates that canonical discriminant analysis can extract meaningful district-level signals from morphometric data. The identification of rump height, body weight, rump width, and chest girth as the principal discriminators offers a practical, low-cost toolkit for field-level screening and preliminary genetic resource characterization in settings where laboratory infrastructure is unavailable. Nevertheless, the considerable overlap among districts cautions against over-reliance on morphometric assignment alone for conservation or breeding decisions, particularly for animals originating from Gadogob. Finally, the integration of molecular markers with morphometric profiling is essential to validate the population structure inferred here and to guide evidence-based conservation and selective breeding strategies for Somalia's indigenous goat genetic resources.

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