Multivariate Analysis of Morphometric Traits Revealed Phenotypic Diversity of Arsi-Bale Goats Reared in Bale Eco-Regions, Ethiopia

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Summary

Ethiopia has genetically diverse goat ecotypes contributing to the rural livelihoods across various production agroecologies. As a result, this study aimed at evaluating the phenotypic diversity of Arsi-Bale goat populations using morphometric traits across the three eco-regions of the Bale zone. Multistage purposive sampling procedures were applied for the study. Sixteen morphometric traits were measured from 424 local goats. Multivariate analyses were performed to differentiate the studied goat populations using morphometric traits. Except body weight (BW), heart girth (HG), rump length (RL), and chest width (CW), variations for the rest morphometric traits were significant ($P < 0.05$) among the three agroecologies. All morphometric traits were affected by age ($P < 0.05$) while nonsignificant ($P > 0.05$) for sex. All 16 morphometric traits were subjected to stepwise discriminant analysis from which 13 of them were identified as having the best discriminating power traits. The canonical discriminate analysis showed that the characters tended to separate into two canonical (CAN) variables. The CAN1 explained about 89.1% of the variation while 10.9% of it was explained by CAN2. Thus, the largest Mahalanobis distance was observed between the highlands and the lowlands (11.2), while it was intermediate among the midlands (4.8) approaching the highlands. The quadratic discriminate function assigns about 80.0, 83.6 and 93.23% of the goat populations to their origin populations in highland, midland and lowland agroecologies, respectively. However, 20% from highland and 6.7% from lowland populations were misclassified to midlands, whereas 9.48 and 6.90% populations from midlands were misclassified to highlands and lowlands, respectively. This indicated the presence of assimilated populations in the midlands and highlands, with hit rates of 16 and 20%, respectively. Thus, the phenotypic diversities described were more appreciated for utilizing, preserving and improving interventions for existing genetic diversity across agroecologies.

Key words

agroecology, Arsi-Bale goats, morphometric traits, phenotypic diversity

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Introduction

Indigenous goat (*Capra hircus* Linnaeus, 1758) rearing is an elderly habit in Ethiopia that plays a key role in utmost rural livelihoods and is still promising for fiscal progress (Hassen et al., 2012). CSA, (2021) estimates that Ethiopia has a total population of 52.5 million heads, of which 99.97% are indigenous. Goats have dispersed agroecologically, with a large flock of up to 70% retained in drought-prone lowlands, while small flock sizes are reared in humid frosty highlands to midland areas (Alemu, 2004). Goat distribution in agroecological zones has resulted in the development of eco-friendly adaptations (Hoffmann, 2010). For inter- and an intraspecific genetic difference, the imprint of ecology is also unlimited (Pauls et al., 2013). Furthermore, faster global climate changes have both positive and negative effects on genetic diversity (Hoffmann, 2010). Generally, such long-term climatic changes and long-term associations with climatic changes encourage species to endorse new environments and/or disappear (Arandas et al., 2017). Hence, goats are resistant to climatic fluctuations. As a result, goat farming has been identified as alternative climate-smart agriculture aid to farmers in coping with the challenges brought on by climate change.

Indigenous goats develop phenotypic and genetic adaptation features for a wide range of ecological concerns over long distances, depending on the degree of impacts (Melesse et al., 2013; Colli et al., 2018). The study done by Melesse et al. (2013) indicates that adaptive approachability helps preserve changes in phenotypic uniformity. Moreover, production ecology modifications, genetic assimilation and/or inbreeding and genetic erosion have contributed to goat population differences in morphometric appearances (Darcan and Silanikove, 2018). Another study by Melesse et al. (2013) also reported that migratory husbandry practices and farmer selection intensity could disrupt genetic diversity in the agricultural environment. In view of that, in Ethiopia 13 goat populations have been distinguished (Alemu, 2004). According to a recent study by Mekuriaw, (2016), there are seven different goat genotypes identified in Ethiopia. Moreover, under recent global warming conditions, this evidence supports the existence of goat genetic difference in terms of productive, reproductive, and adaptive performance (Ojango et al., 2016).

Various researchers have attempted to identify goat breeds using morphological traits and a few DNA studies in the country. However, there is still a need to investigate more into phenotypic variances from their natural niche, particularly among and within agroecological distributions (Yakubu et al., 2010). In addition, phenotypic characterization of farm animals based on their morphometric traits is commanding measurement tips for determining the standing potential in production environments where genetic studies are unavailable due to financial constraints (Melesse et al., 2013; Abd-Allah et al., 2019). Similarly, Yakubu et al. (2010) and; Melesse et al. (2021) reported that multivariate analysis of morphometric traits was relatively the simplest and affordable technique to assess the existence of diversity at a phenotypic level among indigenous goat populations reared in various agroecological systems. Moreover, phenotypic and production ecology-based characterizations are an unavoidable step in genetic resource conservation and future intervention programmes (FAO, 2012; Melesse et al., 2013).

According to FARM-Africa, (1996), Arsi-Bale goat populations can be found across the Bale area of Oromia, from the Afro-alpine highlands of the Bale Mountains to the dry and semiarid lowlands. However, Asefa et al. (2015) indicated the dispersals of the Hararghe highland, Short-eared and Long-eared Somali goats in Bale eco-regions. Therefore, a study was conducted to evaluate the existence of phenotypic diversity of Arsi-Bale goat populations reared in three agro-ecologies of the Bale zone using morphometric traits with the aim of contributing to the enrichment of the information bank of goat resources in Ethiopia.

Materials and Methods

Study Area

The present study was piloted in the Bale zone, southeastern Ethiopia (Fig. 1). Geographically, the province lies between 5°11’03”N - 8°09’27”N latitude and 38°12’04”E - 42°12’47”E longitude.

Agroecologically, the zone is broadly classified into highland, midland, and lowland with elevation ranges of >2300, 1500-2300 and <1500 m.a.s.l., respectively. Moreover, the area has ≥300 - 4377 m.a.s.l, the 2nd highest elevation point of Tulu-Dimitu of Bale National Park found in the country. The area has an average annual 800-1150 mm rainfall and 9-23 °C temperature range (Groos et al., 2022).

Sampling Procedure and Sample Size Determination

The research sites and goat populations were identified using multistage purposive sampling procedures. The altitude array and a relative number of goat population distributions across districts and kebeles were used to identify the study locations (Table1). The study goat populations were randomly identified from 178 households having ≥ 5 goats from selected *kebeles*. Finally, data were collected on 424 goats under the age of 5 years old from January to December 2021.

Data Collection Techniques

Data were recorded on body weight (LBW), heart girth (HG), chest width (CW), paunch girth (PG), shoulder width (SW), wither height (WH), rump height (RH), rump length (RL), body length (BL), sternum height (SH), head length (HDL), head width (HDW), neck length (NL), neck circumference (NC), fore leg length (FLL), and hind leg length (HLL) according to the guidelines of FAO, (2012). The data were documented on 104 males and 320 females. Plastic tape and a standing meter were used to measure length and height dimensions, while weight was measured using a digital suspended spring balance of 50 kg with a precision of 200 grams via a 50-gram handle sack. To minimize fluctuations owing to gut fill, records were taken in the morning before animals were moved for browsing. Animals were further classified via age using the pair of the permanent incisor (PPI) as 1 PPI (6 months - 1 year = 137), 2 PPI (> 1 - 2 year = 125), 3 PPI (>2-3 year = 115) and 4 PPI (>3-4 year = 47). The recall method (of the owners) and the dentition methodology were used to determine age (Elbeltagy et al., 2016). Pregnant does and ill goats were not included in the study.

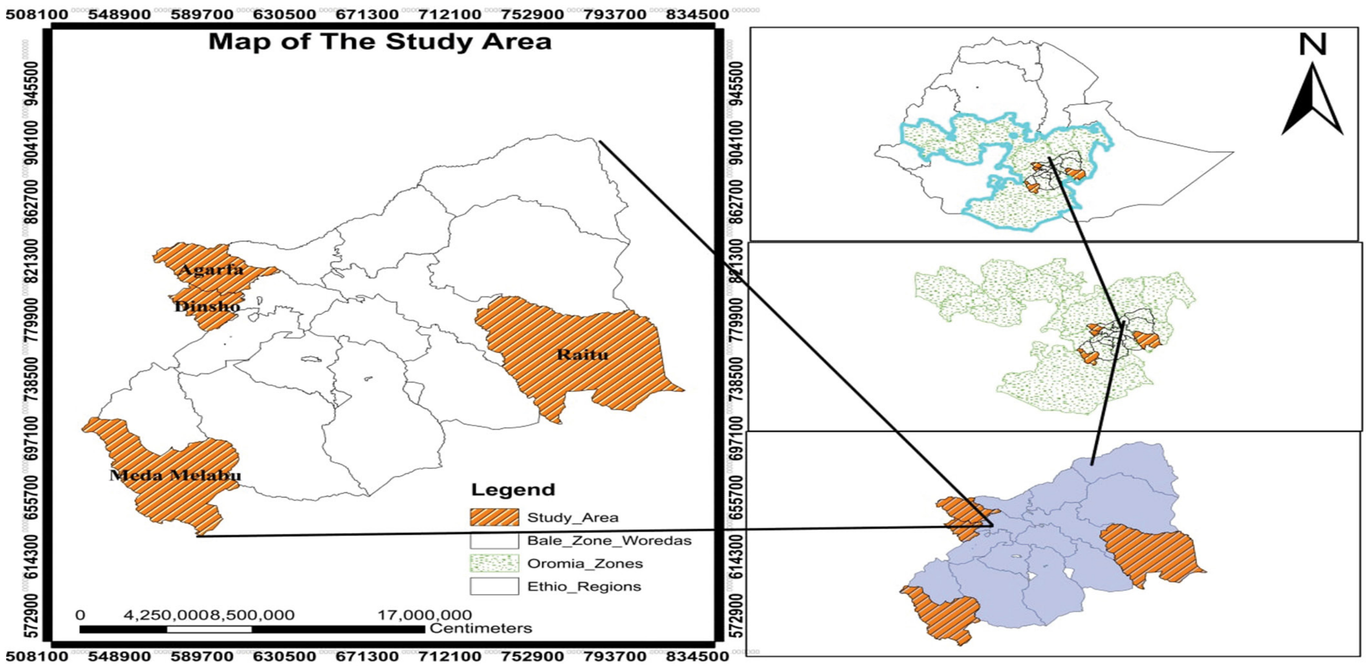

Figure 1. Study area map

Data Analyses

General linear model procedures of SAS, (2012) were used to analyze the quantitative traits. Duncan multiple range tests were used to differentiate among mean values. The model used for analysis was as follows:

$$Y_{ijk} = \mu + P_i + S_j + B_k + e_{ijk}$$

where

Y_{ijk} = the response of the observed variables

μ = the overall mean

P_i = fixed effect of the ith agro-ecology (i: 1 = Highland, 2 = Midland and 3 = Lowland);

S_j = fixed effects of the j^{th} sex (j: 1= Male, 2 = Female);

B_k = fixed effects of the k^{th} age (k: 1PPI = 6 month-1 year, 2PPI = >1-2 year, 3PPI = >2-3 year, and 4PPI = >3-4 years) and;

e_{ijk} = random error.

The level of differences in the studied goat populations and regrouping to key agroecologies was determined using multivariate analysis. The STEPDISC technique was first utilized to find morphometric traits for their discriminating power. Following this, the analyses of cluster, canonical discriminant and quadratic discriminant functions were applied on those traits that showed a discriminating power. The homogeneity of variances was tested using chi-square. For a graphic elucidation, the TEMPLATE and SGRENDER procedures were employed to plot the canonical (CAN) variables in a scatter graph. The quadratic discriminate analysis was also used to assign goats to their source populations and determine probability of membership across ecology with their distance interval and overlapping.

Results

Morphometric Traits

Table 2 shows the morphometric traits of the assessments least square means (LSM) results for fixed effects of agroecological, sex and age groups. The overall CV in this study ranges from 5.9 to 24.5%. The finding noted that topographic elevation differences had a highly significant effect ($P < 0.0001$) in case of body length (BL), rump width (RW), head length (HDL), head width (HDW), neck length (NL), fore leg length (FLL) and hind leg length (HLL). Moreover, paunch girth (PG), rump height (RH), rump length (RL), sternum height (SH) and neck circumference (NC) were significant ($P < 0.01$) among the three agroecologies.

Table 1. Sampling procedure and sample size determination

Agro-ecology	Districts	Sampled Kebeles	Sampled households	Number of goats sampled
Highland	Dinsho	*Gojera* and *Granba Dima*	34	116
Midland	Agarfa	*Oda Negeso* and *Dera Honisho*	37	116
Lowland	Mada Walabu and Rayitu	*Ela Bidire, Hara Haji, Bore Dimtu* and *Hare Dube*	111	192

Table 2. Mean of body weight (in kg) and linear measurement traits (in cm) as affected by agroecologies, sex and age groups

	Variables	BW	HG	CW	PG	WH	RH	RL	BL	SH	RW	HDL	HDW	NL	NC	FLL	HLL
	Overall	27.2	67.4	14.4	78.9	60.3	63.9	12.6	46.9	37.7	12.9	18.8	12.5	27.0	28.8	45.8	47.1
	CV	24.5	14.8	24.3	14.7	15.1	14.5	18.5	14.1	11.4	12.0	15.3	15.2	16.0	15.0	12.4	5.9
Agroecology	Highland	26.6^{a}	67.0^{a}	14.2^{a}	76.1^{c}	58.6^{b}	61.6^{b}	13.2^{a}	45.3^{c}	36.3^{b}	13.3^{a}	16.4^{c}	11.4^{c}	25.8^{b}	28.4^{b}	42.8^{c}	43.7^{c}
	Midland	25.9^{a}	66.2^{a}	14.6^{a}	78.1^{b}	60.8^{a}	64.8^{a}	12.4^{b}	46.1^{b}	37.8^{a}	13.2^{a}	18.1^{b}	12.1^{b}	26.1^{b}	27.9^{b}	45.0^{b}	46.6^{b}
	Lowland	27.9^{a}	68.3^{a}	14.5^{a}	81.2^{a}	61.0^{a}	64.8^{a}	12.3^{b}	48.4^{a}	38.3^{a}	12.4^{b}	20.7^{a}	13.3^{a}	28.3^{a}	29.6^{a}	48.1^{a}	49.4^{a}
	P value	0.137	0.215	0.545	0.001	0.05	0.005	0.003	0.0001	0.002	<0.0001	<0.0001	<0.0001	<0.0001	0.003	<0.0001	<0.0001
Sex	Male	26.4^{a}	66.6^{a}	14.1^{a}	78.2^{a}	59.4^{a}	62.8^{b}	12.5^{a}	46.5^{a}	37.5^{a}	12.8^{a}	18.5^{a}	12.3^{a}	26.6^{a}	28.6^{a}	45.2^{b}	46.6^{a}
	Female	27.4^{a}	67.5^{a}	14.5^{a}	79.1^{a}	60.6^{a}	64.3^{a}	12.7^{a}	47.1^{a}	37.7^{a}	12.9^{a}	18.9^{a}	12.4^{a}	27.2^{a}	28.8^{a}	46.1^{a}	47.2^{a}
	P value	0.196	0.370	0.321	0.218	0.267	0.015	0.635	0.405	0.600	0.575	0.213	0.283	0.308	0.585	0.0452	0.363
Age	1 PPI	19.4^{d}	56.9^{d}	11.2^{d}	67.4^{d}	51.3^{d}	54.8^{d}	9.9^{d}	39.7^{d}	33.0^{d}	11.6	16.3^{d}	10.6^{d}	23.8^{d}	25.1^{d}	39.9^{d}	40.9^{d}
	2 PPI	27.1^{c}	66.7^{c}	13.4^{c}	77.5^{c}	59.9^{c}	63.6^{c}	13.3^{c}	46.5^{c}	37.9^{c}	12.8	18.1^{c}	12.3^{c}	25.0^{c}	27.0^{c}	45.7^{c}	47.0^{c}
	3 PPI	32.4^{b}	75.1^{b}	16.7^{b}	87.3^{b}	66.9^{b}	70.6^{b}	14.2^{ab}	52.2^{b}	40.7^{b}	13.6	20.8^{b}	13.8^{b}	29.9^{b}	32.2^{b}	50.2^{b}	51.6^{b}
	4 PPI	37.1^{a}	81.1^{a}	21.1^{a}	95.4^{a}	71.7^{a}	75.1^{a}	14.8^{a}	56.2^{a}	43.2^{a}	15.0	23.2^{a}	14.9^{a}	35.0^{a}	35.8^{a}	52.5^{a}	54.0^{a}
	P value	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Note: ^{abcd} Means with different subscript letters are significant at $P < 0.05$; Coefficient of variations (CV); body weight (BW); heart girth (HG); chest width (CW); paunch girth (PG); rump width (RW); wither height (WH); rump height (RH); rump length (RL); body length (BL); sternum height (SH); head length (HDL); head width (HDW); neck length (NL); neck circumference (NC); fore leg length (FLL); hind leg length (HLL).

Additionally, the effect of the agroecology was significant ($P < 0.05$) for the wither height (WH). However, body weight (BW), heart girth (HG) and chest width (CW) were nonsignificant ($P > 0.05$). For RW, NL, and NC traits, the influence of agroecology was nonsignificant ($P < 0.05$) between highlands and midlands.

In comparison, the highest mean values were evaluated in lowlands for BW, HG, PG, RH, BL, HDL, NL, FLL, and HLL and not in midland and highland flocks. Values of FLL (42.8), HLL (43.7), NL (25.8), HDL (16.4), and RH (61.6) were the lowest in the highland populations. The lowlands, on the other hand, had the highest levels of PG (81.2), BL (48.4), HDL (20.7), NL (28.3), FLL (48.1), and HLL (49.4) (Table 2).

Among measured morphometric traits RH and FLL were higher in females while comparable results were obtained for all traits. In contrast, females were higher than males, owing to the large proportion of older (>3 years) females in the sample population. Also, among agro-ecologies the effect of age was found to be highly significant ($P < 0.05$). However, within age groups, the effect was nonsignificant ($P > 0.05$) across the three agroecologies. In addition, within age groups, BW and CW had the greatest CV values of 24.5 and 24.4%, respectively, but HLL had the lowest rating of 5.9% (Table 2).

Stepwise Discriminant Analysis

Sixteen morphometric traits were subjected to the STEP DISC analysis from which 13 were identified as having the best discriminating power (Table 3). The results of the analysis showed that the variations in morphometric traits within the study population were significantly higher ($P < 0.0001$). Among the highest discriminating power traits, HDL, BW, FLL, CW, RW and SH, Wilks' Lambda tests for within variance to total variation showed 70.8, 47.9, 41.6, 38.0, 35.2, 33.5 and 31.9 percent, respectively. In addition, HDW, NC, HG, HLL and BL were included with lower variations across highland, midland and lowland agroecologies, with a tolerance of <0.1 as the least discriminating power trait. This indicates that heterogeneity was higher among agroecologies than within populations in similar agroecology. The study has also shown that every trait has discriminative potential for populations that have adapted to an agroecological environment, with the exception of WH, NL and PG. Also, as evidenced by their partial discrete R^2 values, the most relevant traits for easily differentiating the study populations among agroecologies were HDL, BW, FLL, CW, and RW (Table 3).

Cluster Analysis

As per cluster report, the Arsi-Bale goat populations raised in three agroecologies of the Bale zone can be separated into two main groups with average distance of 5.1 between groups. Thus, cluster 1 has populations of both highland and midland agroecologies with a mean square distance of 0.78. Due to their difference in morphometric measurements and agroecology, the lowland ecology goats are categorized into a separate group cluster 2 with a mean square distance of 1.1 (Fig. 2).

Canonical Discriminant Analysis

Table 4 displays the Mahalanobis distance and area of mean separations among study populations for each of three agro-ecologies. The uppermost distance of 11.2 was found between lowland and highland goat populations while inter medium distance of 3.5 and 4.8 was observed between midland and respective highland and lowland populations (Table 4). As a result, the distances of the studied populations distributed across the three agroecologies were highly significant ($P < 0.0001$).

Table 3. Summary of stepwise discriminant analysis of variables

Steps	Variables	Partial R^2	Pr > F	Wilks' Lambda	Pr > Lambda	ASCC	Pr > ASCC	Tolerance
1	Head length	0.2922	<.0001	0.708	<.0001	0.146	<.0001	1.0000
2	Body weight	0.3235	<.0001	0.479	<.0001	0.261	<.0001	0.4244
3	Foreleg length	0.1309	<.0001	0.416	<.0001	0.293	<.0001	0.2365
4	Chest width	0.0868	<.0001	0.380	<.0001	0.316	<.0001	0.1531
5	Rump width	0.0730	<.0001	0.352	<.0001	0.337	<.0001	0.1069
6	Rump length	0.0497	<.0001	0.335	<.0001	0.349	<.0001	0.0811
7	Rump height	0.0479	<.0002	0.319	<.0001	0.371	<.0001	0.0735
8	Sternum height	0.0444	<.0001	0.305	<.0001	0.389	<.0001	0.0730
9	Head width	0.0345	0.0007	0.294	<.0001	0.396	<.0001	0.0602
10	Neck circumference	0.0367	0.0004	0.283	<.0001	0.411	<.0001	0.0551
11	Heart girth	0.0264	0.0041	0.276	<.0001	0.422	<.0001	0.0524
12	Hind leg length	0.0229	0.0086	0.270	<.0001	0.431	<.0001	0.0480
13	Body length	0.0129	0.0701	0.266	<.0001	0.433	<.0001	0.0463

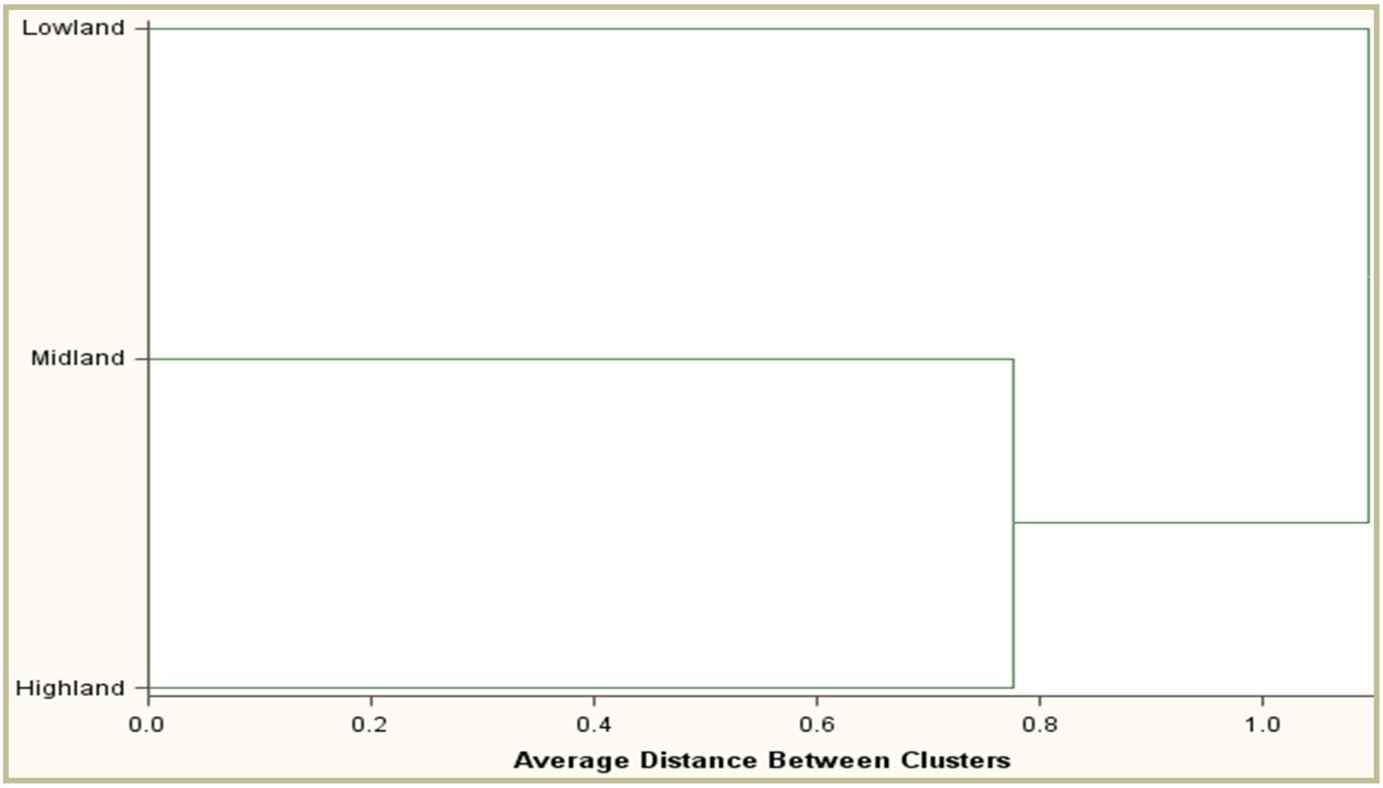

Figure 2. Dendrogram constructed by using average linkage values between groups of three agro-ecology goat populations

Table 4. Mahalanobis distance matrix and mean separations for Arsi-Bale goats across the three agroecologies

Agro-ecologies	Separation means					
	Highland	Midland	Lowland	*P* value	CAN1	CAN2
Highland		3.454	11.204	<.0001	-1.89	-0.46
Midland	<.0001		4.794	<.0001	-0.52	0.78
Lowland	<.0001	<.0001		<.0001	1.44	-0.20

For measured variables among agroecologies, CAN1's separation mean distances, which ranged from -1.89 to 1.44, were greater than CAN2's, which ranged from -0.46 to 0.78, but the difference was lower within agroecologies (Table 4).

The graphic elucidations for differences in CAN variables of the studied goat populations are clearly shown on a scatter graph (Fig. 3).

The canonical variables (CAN) identifying CAN1 and CAN2 associations with eigenvalues and likelihood ratios are presented in Table 5. The canonical variables indicate that, CAN1 has the highest adjusted canonical correlation and squared canonical correlation within variables. For that reason, the analysis recognizes two statistically significant ($P < 0.0001$) canonical variables (CAN) of CAN1 and CAN2 proportionally accounting for 89.1 and 10.9% of the total variations, respectively, with likelihood ratios of 0.267 and 0.903. Thus, CAN1 variables such as HDL, FLL, HDW, BL and HLL were 115, 75.9, 44.8, 38.2 and 25.6%, respectively, which shows that they contributed to variations pooled within-class standardized canonical coefficients. Moreover, CAN2 variables of HLL, SH, RW, HDL and BL had the highest variations for standard canonical coefficients of 118.4, 117.6, 41.1, 36.9 and 25.8%, respectively.

The morphometric features for linear combinations of continuous variables that reflect diversity in goat populations in the locations were evaluated using univariate and multivariate statistics.

Table 6 presents the results of the univariate test statistics. The results of the univariate test showed that, BL, RW, HDL, HDW, FLL and HLL variables were highly significant ($P < 0.0001$). In addition, the reported values for RH, SH, RL and NC were ($P < 0.01$) significantly different. However, among the measured morphometric traits, BW, HG and CW were nonsignificant ($P > 0.05$). The highest partial R^2 was reported for HDL (0.295), and the lowest was reported for WH (0.003) (Table 6).

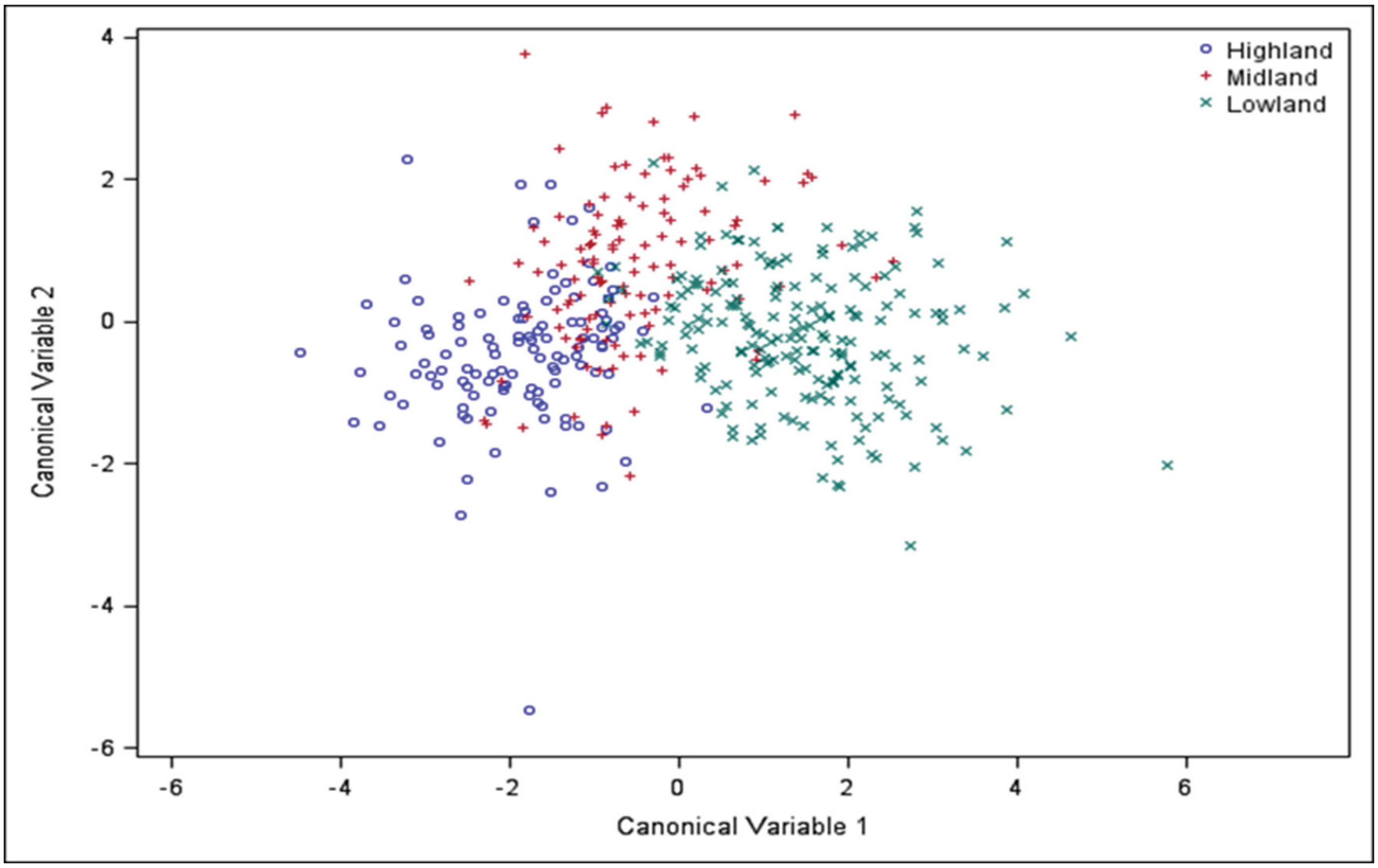

Figure 3. Canonical representations of Arsi-Bale goat populations among agroecologies using morphometric traits

Table 5. Summary of the canonical variable correlations, eigenvalues and likelihood ratios

Function	ACC	SCC	Eigen-values			Likelihoods	Approximate F value	Pr > F
			Eigen-value	Proportion	Cumulative			
CAN1	0.811	0.668	2.007	0.891	0.891	0.267	24.77	<.0001
CAN2	0.422	0.198	0.246	0.109	1.000	0.803	7.36	<.0001

Note: CAN1: canonical variable 1; CAN2: canonical variable 2; ACC: adjusted canonical correlation; SCC: squared canonical correlation

According to the multivariate test statistics used to examine traits that differentiate across agroecologies, all multivariate statistical tests were highly significant ($P < 0.0001$). Thus, Roy's Greatest Root was the maximum for differentiation (F value, 63.2). Furthermore, Wilks' Lambda was almost at the exact point of discernment (29.4) (Table 7).

Quadratic Discriminant Function

The covariance matrices' test for population homogeneity demonstrated high significance ($P < 0.0001$) rejecting the null hypothesis which assumes equality of variances. In consequence, quadratic discriminant function was used for unequal covariance and accurately classified 80, 83.62, and 93.23% of the goats into their original populations of highland, midland and lowland agroecologies, respectively. Moreover, high accuracy rate was reported in the lowlands while lower accuracy rate was reported in the highlands and midlands with error count of 0.20 and 0.16, respectively.

In addition, the cross-validations summary showed lower consistency of membership in each agroecology with an average success rate of 78.9%, with 67.24, 76.72 and 92.71% for highland, midland and lowland agroecologies, respectively. The overall misclassified error count level was 0.187 (18.7%) within the three agroecologies (Table 8).

Table 6. Univariate tests of the discriminant analysis

Variable	Total S.D's	Pooled S.D's	Between S.D's	R^2	R^2 / (1-RSq)	F - value	Pr > F
Body weight	6.697	6.676	0.833	0.0103	0.0104	2.19	0.1127
Heart girth	9.998	9.983	1.072	0.0077	0.0077	1.63	0.1981
Rump height	9.410	9.314	1.816	0.0249	0.0255	5.36	0.0050
Body length	6.756	6.628	1.697	0.0422	0.0440	9.24	0.0001
Chest width	3.5157	3.5193	0.2234	0.0027	0.0027	0.57	0.5671
Sternum height	4.3635	4.3063	0.9342	0.0306	0.0316	6.64	0.0015
Rump length	2.3427	2.3186	0.4535	0.0250	0.0257	5.39	0.0049
Rump width	1.6310	1.5824	0.5013	0.0631	0.0674	14.15	<.0001
Head length	3.4381	2.8943	2.2831	0.2947	0.4178	87.73	<.0001
Head width	2.1105	1.9532	0.9918	0.1476	0.1731	36.35	<.0001
Neck circumference	4.3916	4.3417	0.8870	0.0273	0.0280	5.88	0.0030
Fore leg length	6.1116	5.6727	2.8226	0.1425	0.1662	34.91	<.0001
Hind leg length	6.3935	5.9470	2.9146	0.1389	0.1613	33.87	<.0001

Note: SD - standard deviation; R^2 - coefficient of determination

Table 7. Multivariate test statistics and F-approximation

Statistics	Value	F value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.267	29.37	26	816	<.0001
Pillai's Trace	0.865	23.98	26	818	<.0001
Hotelling-Lawtey Trace	2.553	35.29	26	709.7	<.0001
Roy's Greatest Root	2.007	63.15	13	409	<.0001

Table 8. Classifications and cross-validation summary of the Arsi-Bale goats reared in three agroecologies

Classifications	Highland	Midland	Lowland	Total
Highland	92 (80.00)	24 (21.07)	0 (0.00)	116 (100)
Midland	11 (9.46)	97 (83.62)	8 (6.90)	116 (100)
Lowland	0 (0.00)	13 (6.77)	179 (93.23)	192 (100)
Error count rate	0.20	0.16	0.07	0.13
Prior	0.27	0.27	0.45	
	104 (25.23)	133 (31.44)	187 (44.21)	424 (100)
Cross-validation				
Highland	78 (67.24)	35 (30.43)	3 (2.61)	116 (100)
Midland	17 (14.66)	89 (76.72)	10 (8.62)	116 (100)
Lowland	0 (0.00)	14 (7.29.75)	178 (92.71)	192 (100)
Error count rate	0.330	0.073	0.233	0.187
Prior	0.272	0.454	0.274	

Discussion

Diversity found in morphometric traits dimension was larger in Arsi-Bale goat populations. The effect of agroecology was outstanding for PG, BL, HDL, FLL and HLL whereas WH, RL and SH were similar among midland and lowland populations. However, RL and RW were the highest in highlands (Table 2). This indicated that goats in lowland and midland parts were higher for lengthy traits when compared for body conformation traits. The differences could be due to morphometric advancements targeted at increasing environmental stress response approaches (Darcan and Silanikove, 2018; Depison et al., 2020). However, growth rate forecasting traits like BW, HG, CW and RW were similar across the three agroecologies. This was due to the ecological impacts on feed resources and feeding habits to achieve comparable growth domino cumulative effect rather than seasonal (Ojango et al., 2016). Apart from this, the integration of genetically distinct goat populations due to uncontrolled breeding across the topography was also a factor (Darcan and Silanikove, 2018). Conversely, the occurrence of drought and long period of hot temperature influenced the long-term advance of resistance characteristics to heat stress in the lowlands creating diversity within migratory husbandry practices (Pauls et al., 2013; Araujo et al., 2017; Henry et al., 2018).

In the highlands, cold stress triggers a variety of responses, including qualitative morphology, short fore and hind legs (Henry et al., 2018; Depison et al., 2020). As a result, goats reared in the highland agroecology had the lowest values for PG, WH, RH, BL, HDL, HDW FLL and HLL (Table 2). These variations were maintained due to flock feeding regimens being affected by cold stress and the shrinking of browsing and grazing pasture lands. In addition, the appearance of a qualitatively dark, silver and black color hair would help to absorb solar radiation to cope with cold stress (Araujo et al., 2017; Getachew et al., 2020; Sejian et al., 2021). Frequent occurrence and long period of exposure to cold stress initiates evolving of short leg characteristics in order to adapt and maintain body temperature near the surface (Getachew et al., 2020). Similarly, shrinkages of range lands are conjoint to the midlands for crop cultivation activities affecting growth rate. So, to minimize biasness in data collection, considerations are needed for seasonal effects. Also, different goat breeds respond to heat stress by developing morphological traits and physiological features to maintain themselves homeostasis (Sejian et al., 2021). Thus, the highest values reported in the lowlands for PG, BL, HDL, NL, FLL and HLL in cm were due to their naturally adapted characteristics for climbing feeding nature and to far apart from high soil heat flow. This is in line with studies of Zergaw et al. (2017), Nguluma et al. (2018), and Melesse et al. (2021) who report that breed genetics and adaptive performance inequality are shown in linearly assessed traits between and within agroecologies.

The sex effect shows that females are higher in body dimension than males. This is generally due to a small number of male goats within the populations due to the fact that farmers sell male goats at their earlier age to cover a family expense, which is consistent with Celik, (2019), who reported similar observations for Pakistan goats. Hence, if equal sample size were considered and compared from the study populations' indicated variations were collective. Thus, equal proportion sample size consideration was more imperative to accurately signify the variations. In contrary, males are superior to females in yearling Boer goats (Mathapo and Tyasi, 2021) and Borana goat populations (Edea et al., 2019), with equal proportion of male to female ratio in sample size, respectively.

Morphometric dimensions were common within increasing age indicating there was more diversity across age groups than within ages. Accordingly, except HLL, higher differences were observed with coefficient of variations from 5.5-24.5% for age agroecology interaction effects. Similarly, it was reported by Abd-Allah et al., (2019) for Shami goats of 9.7-20% variations due to age effects and environmental adaptabilities. Similarly various authors reported that age effect was highly significant within and across the production locality for several Ethiopian goats due to their daily feed computing and conversation abilities (Yemane et al., 2020; Tade et al., 2021; Melesse et al., 2021; Takele et al., 2021). Hence, the discrepancies in morphometric traits were not only influenced by production ecology, rather it was the cumulative effects of genotype, animals self-adjustments for adaptations to seasonal changes and the severity of keepers' selection for product of specific and social value (Seid et al., 2016; Zergaw et al., 2017; Depison et al., 2020; Melesse et al., 2021; Takele et al., 2021).

Per study, the majority of morphometric traits have discriminating power, except WH, PG and NL, which is an indication of a high opportunity for selection and breeding interferences. Thus, Wilks' Lambda ratios show diversity among the examined populations for traits of HDL, BW, CW, FLL, RW, RL and SH (Table 3). These variations could be ascribed to ecological restrictions and management's influence on adaptations to develop emergent morphometric characteristics (Agaviezor et al., 2012; Muhammad et al., 2021; Melesse et al., 2021). In addition, production ecology imposes socio-economic impacts on maximum genetic return from goat flock diversity (Muhammad et al., 2021). This is due to different aptitudes of keepers' interests for their economic and socio-cultural values. Also, the variations are due to differences in responses conditionally using morphometric and physiological features to additives. Thus, they can be classified into two canonical variables with CAN1 explaining about 89.1% of the variation while 10.9% of it was explained by CAN2 showing the largest variation. It was similar for Hararghe highland goats in routine agroecologies for their genetic differences of 68.2 and 31.8 for CAN1 and CAN2, respectively for their adaptive nature (Takele et al., 2021). So, the recent study report confirms the report of Asefa et al., (2015), who reported the presence of goat genetic diversity in the lowlands of Bale zone. Thus, the existence of heterogeneity was confirmed within covariance matrices at 0.1 significant levels.

The heterogeneity of the study population shows a total grouping accuracy rate of 85.6%, with an error count rate of 0.13. Aside from their niche, the enhanced low precision of grouping into their origin might be due to observable agroecological effects. Accordingly, the presence of observable variances within breeds for adaptation limits to the environment is a critical factor in reducing breeding programme selection errors (Yakubu et al., 2010). But, there was an indication of overlap in the agroecology of the midlands. The maximum heterogeneity within agro-ecologies may be attributed to indiscriminate mating and routine marketing interchange for those adaptable to repeated ecological disasters (Ouchene-Khelifi et al., 2018; Onzima, 2019). The aggregate error-count estimates for highland and midland agroecology of

20 and 16% respectively, showing the group's likenesses. This was the treat for the genetic diversity of the studied populations. In general, the study clarifies the availabilities of adaptive divergence via morphological characters across ecological arrays.

Conclusion

In general, the study revealed that morphometric traits of Arsi-Bale goat populations were divergent among agroecologies for head length, body length, head width, fore leg length, rump width, hind leg length and paunch girth. Moreover, 13 quantifiable traits were the most discriminating power traits for the studied goat populations while comparable for wither height, paunch girth and neck length. The far-apart distances were observed between highland and lowland populations while the closest distance was evaluated between midland and highland goat populations. The quadratic discriminant analysis accurately classified 85% of the studied goat ecotype into their source populations indicating phenotypic diversity between the three agro-ecologies. So, phenotypic dissimilarities of the studied goat populations require further molecular study to conclude whether the observed morphometric inconsistencies are either genotypic or eco-friendly emergent phenomena.

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Availability of data and materials

Ready when requested from corresponding author.

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