Research Article

Multivariate analysis of phenotypic traits of indigenous sheep revealed new population in western part of Ethiopia

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Abstract

This study was carried out to phenotypically characterize and differentiate sheep populations of Western part of Ethiopia. Physical observations and body weight and linear measurements were studied. Multivariate canonical and discriminant analysis were employed to differentiate population. Three districts; Dendi, Guduru and Mida Kegn districts were selected purposely based on sheep production potential and previous characterization studies. For example, majority of male sheep in Dendi district had horn while majority are polled in Guduru and Mida Kegn districts. The two canonical variates extracted explain a total of 100% of the total variation (80.6% by Can1 and 19.4% by Can2). The Can1 and Can2 presented high weighing for ear length and pelvic width, respectively. It showed that these traits demonstrating their importance to discriminate and to classify the sheep population in the areas. Sheep population of Dendi, Guduru and Mida Kegn districts were correctly grouped into their own geographical area for about 71.15%, 54.62% and 69.23%, respectively. The largest mahalanobis distance was found between sheep population in Dendi and Guduru (2.27). The smallest distance was found between Guduru and Mida Kegni with mahalanobis distance of 0.649. These results showed that sheep population in Dendi was found to be unique and confirmed the existence of two populations (Dendi and Guduru-Mida Kegn) in the study area.

Introduction

Ethiopia has a diverse sheep population and its distribution is paralleled with its diverse ecology. According to CSA (2016/17) [1] report, 30.7 million sheep are estimated to be found in the country with at least 9 sheep breeds and 14 traditional sheep populations [2]. Despite low level of productivity due to several technical (genotype, feeding and animal health), institutional, environmental and infrastructural constraints [3], indigenous sheep breeds have great potential to contributing more to the livelihoods of the people in low-input, small-holder crop livestock and pastoral production systems [4].

According to Kassahun and Solomon [5], Horro sheep breed is widely distributed in Shewa to East and West Wollega, Illubabor and Jimma zones of Oromia Region. These areas encompass different agro-ecological conditions, marketing outlets and also cover wide areas. Characterization attempt so far were based on sampling known breeds from their main breeding tract without giving focus to populations far from the breeding tract. Dispersion of sheep population to different agro-ecologies or environments and distance from the main breeding tract might cause population stratification and morphological differences among populations. Study on three districts of South Wollo area revealed that the existence of

body weight and body measurement variations which might be evidence of population stratification in Wollo sheep breed [6]. Notable variation among indigenous population was observed within Wollo sheep population. This variation might be due to environment and /or genotype. Phenotypic comparison based on morphological characters can provide to an extent a reasonable representation of genetic differences among populations. Multivariate analyses of morphological traits have been proved to be suitable in assessing genetic variation within and between populations when all morphological variables are considered simultaneously. Discriminant analysis encompasses procedures for classifying observations into groups and describing the relative importance of variables for distinguishing among groups [7]. In this study, an attempt has been made to phenotypically characterize and differentiate sheep populations of western part of Ethiopia i.e. West Shewa and Horro Guduru Wollega zones based on phenotypic traits, using canonical discriminant analysis to see whether they are similar or distinct.

Although large number of sheep found in West Shewa [1], information on the morphological characteristics of sheep is limited. This population was classified under Horro sheep breed and most of the characterization and research interventions are focus in Horro Guduru Wollega Zone. However, there was a hypothesis that the sheep breed in West Shewa particularly in and around Dendi district exhibit different morphological character. Thus, conducting this study is useful to plan different developmental strategies like community-based genetic improvement program, to obtain better knowledge of their present and potential future uses for food and agriculture in defined environments, and to recognize indigenous sheep exist in and around Dendi district as morphologically distinct sheep breed from or similar with Horro sheep breed based on their phenotypic traits. Thus, this study was aimed to describe qualitative and quantitative characteristics of indigenous sheep breeds and to investigate phenotypic variation among geographical areas using canonical discriminant analysis in different location of western Ethiopia.

Materials and methods

Description of the study area

The study was conducted in three districts; Dendi and Mida Kegn districts of West Shewa Zone and Guduru district of Horro Guduru Wollega zone of Oromia Regional State. Horro Guduru Wollega zone is located at about 310 km of Addis Ababa. The area lies between 9º10'53''N-10º17'03''N and 36º39'36''E-37º40'13''E latitude and longitude, respectively [8] Figure 1.

Sampling technique

Dendi, Guduru and Mida Kegn districts were selected purposively for this study. Guduru district was selected to represent Horro Guduru Wollega area, which is beloved to be the main breeding tract and origin of Horro sheep (Horro area) where most of the previous sheep characterization and interventions were focused on [9]. Dendi district was selected to represent Ginchi sheep (central highland sheep) which is well known in Addis Ababa market. Mida Keng district was selected as the area found between Guduru and Dendi and population sampled from this district were helped to assess how the morphological characters behave as we move from Guduru to Dendi district in other way from Horro Guduru Wollega to West Shewa zone. From each district, two rural *kebeles* were selected purposively considering the sheep flock population. According to FAO [10], physical measurements should be taken only from a representative set of adult animals (as judged by dentition): about 100-300 females and 10-30 males. Based on this, body weight and linear measurements were taken from a total of 780 adult sheep. Each experimental adult animal was classified by sex, district, and dentition. Dentition record was included, as this was the only reliable means to estimate the
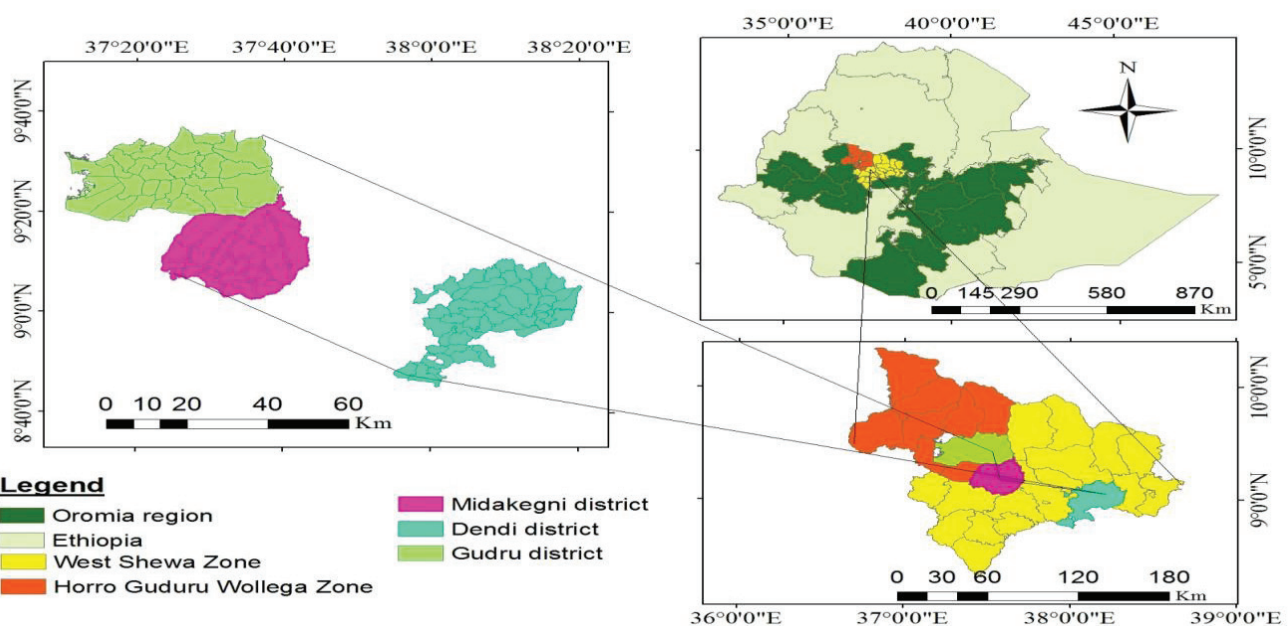

Figure 1: Map of the study area

approximate age of an animal. Adult sheep was classified into two age groups; 1 pair of permanent incisor (1PPI) and ≥ 2 pairs of permanent incisor (2 PPI).

Data collection

Data was collected through field measurement and observations which included morphological characters like: coat color type and pattern, head profile, ear form, presence of wattle and horn, horn shape and orientation and tail shape were observed and recorded using a format developed for the purpose whereas body measurements: chest girth (CG), body length (BL), height at wither (HW), rump height (RH), pelvic width (PW), ear length (EL), horn length (HL), tail length (TL), tail circumference (TC) and scrotum circumference (SC) were collected using tailors measuring tape while body weight was measured using suspended spring balance having 50kg capacity. Linear body measurements were taken by restraining and holding the animals in a stable condition. All measurements were carried out by the same person in order to avoid inter-individual variations.

Statistical analysis

Both qualitative and quantitative data were analyzed by Statistical Analysis System (SAS, release 9.1, 2008). Qualitative data from individual animal observation was analyzed following the frequency procedures of SAS. GLM procedures of SAS were employed to analyze quantitative variables to determine effects of class variables (sex, district and dentition) and their interaction. For adult sheep; sex, district and age group of the sheep and their interaction were fitted as independent variables while body weight and linear body measurements were fitted as dependent variables. Scrotum circumference was analyzed by fitting age group and district as fixed factor.

Model for the least square mean analysis in females and males except scrotal circumference was: $Y_{ijk} = \mu + D_i + A_j + S_k + (A \times S)_{jk} + e_{ijk}$

Where: Y_{ijk} = Observed body weight or linear body measurements, μ = Overall mean, D_i = the fixed effect of ith district (Dendi, Guduru, Mida Kegn), A_j = the fixed effect of jth age classes (1PPI, ≥2PPI), S_k = the fixed effects of kth sex (male, female), $(A \times S)_{jk}$ = the interaction effects of jth age and k^{th} sex and e_{ijk} = random residual error

Model for the least square mean analysis in males for scrotal circumference was:

$$Y_{ij} = \mu + D_i + A_j + e_{ij}$$

Where: Y_{ij} = Observed/measured scrotal circumference, μ = Overall mean, D_i = the fixed effect of ith district (Dendi, Guduru, Mida Kegn), A_j = the fixed effect of jth age classes (1PPI, ≥2PPI) and e_{ij} = random residual error

Stepwise discriminant procedure was applied using PROC STEPDISC to determine which phenotypic traits have more discriminant power than others. The relative importance of the morphometric variables in discriminating of indigenous sheep types in the study area was assessed using the level

of significance ($P<0.05$) and partial R^2 values ≥0.01. The CANDISC procedure was used for univariate and multivariate one-way analysis that calculate the Mahalanobis distances of the phenotypic traits, and derive canonical functions (linear combinations of the continuous variables that summarize variation of sheep types among the areas. The ability of these canonical functions to assign each individual sheep to its sampling area was calculated as the percentage of correct assignment of each sheep types in each geographical area using the DISCRIM procedure. The number of misclassified individuals indicates the degree of similarities between the populations.

Results and discussion

Characterization of qualitative traits

Description of the physical characteristics of livestock breeds is very important for developing a breeding strategy in a particular production system [11]. The result indicated that all observed morphological characters were significantly associated ($P<0.01$) with districts except presence of wattle (Table 1). The main frequently observed coat color pattern of sheep were plain 51.9%, 83.1% and 78.8% and the main dominantly observed coat color type were red and white mix (24.6%), brown (48.8%) and brown (42.7%) for Dendi, Guduru and Mida Kegn districts, respectively. Current study result on qualitative traits of Horro sheep is in line with the previous work done by Zewdu [9]. Straight head profile 85.8%, 96.2% and 95.0% were mainly observed for sheep in Dendi, Guduru and Mida Kegn districts, respectively. The presence of horn was the main unique characteristics of male sheep in Dendi/Ginchi male sheep (96.7%) than for Guduru and Mida Kegn sheep. Spiral horn shape (89.7%) and lateral orientation of horn (89.7%) were observed for male sheep in Dendi district. Majority of sampled sheep population in Dendi (54.2%) possesses cylindrical and twisted at end, whereas in Guduru (80.0%) and Mida Kegn (81.2%) possesses cylindrical and straight tail shape. The most ear form of sheep observed was semi-pendulous 50.8%, 82.3% and 88.5% for Dendi, Guduru and Mida Kegn sheep populations, respectively. Wattle absence 92.7%, 95.4% and 95.7% was observed for Dendi, Guduru and Mida Kegn districts, respectively. Typical sheep types of the study areas are presented in Figures 2.

Live body weight and linear measurements

Information on live body weight and linear measurements of the existing breed types has a vital role in the selection Program [6].

District effect

There was significant difference for body weight and all recorded linear body measurements ($P<0.01$) among the districts. Average least squares means and standard errors of body weight and chest girth were 29.4±0.23, 28.2±0.23 and 29.8±0.24 for sheep in Dendi, Guduru and Mida Kegn, respectively (Table 2). Highest body weight was obtained for Dendi and Mida Kegn districts than Guduru district. It attributed to genetic as well as management difference. Feed

Table 1: Description of qualitative traits in the study areas.

Traits	Attribute	Districts						Overall	
		Dendi		Guduru		Mida Kegn			
		N	%	N	%	N	%	N	%
Coat color pattern	Plain	135	51.9	216	83.1	205	78.8	556	71.3
	Patchy	117	45.0	34	13.1	48	18.5	199	25.5
	Spotted	8	3.1	10	3.8	7	2.7	25	3.2
	X^2							80.919**	
Coat color type	White	52	20.0	41	15.8	29	11.2	122	15.6
	Brown	29	11.2	127	48.8	111	42.7	267	34.2
	Black	11	4.2	16	6.2	14	5.4	41	5.3
	Red	43	16.5	32	12.3	51	19.6	126	16.2
	Grey	6	2.3	11	4.2	6	2.3	23	2.9
	Black and white	39	15.0	10	3.8	6	2.3	55	7.1
	Red and white	64	24.6	17	6.5	40	15.4	121	15.5
	Red, white and black mix	16	6.2	6	2.3	3	1.2	25	3.2
	X^2							149.945**	
Head profile	Straight	223	85.8	250	96.2	247	95.0	720	92.3
	Slightly convex	37	14.2	10	3.8	13	5.0	60	7.7
	X^2							23.725**	
Ear form	Semi-pendulous	132	50.8	214	82.3	230	88.5	576	73.8
	Carried horizontally	128	49.2	46	17.7	30	11.5	204	26.2
	X^2							110.086**	
Tail shape	Cylindrical + straight	119	45.8	208	80.0	211	81.2	538	69.0
	Cylindrical + twisted at end	141	54.2	52	20.0	49	18.8	242	31.0
	X^2							98.216**	
Wattle	Present	19	7.3	12	4.6	12	4.3	43	5.5
	Absent	241	92.7	248	95.4	248	95.7	737	94.5
	X^2							2.412^{NS}	
Horn	Present	66	25.4	2	0.8	10	3.8	78	10.0
	Absent	194	74.6	258	99.2	250	96.2	702	90.0
	X^2							103.932**	
Horn shape	Curved	7	10.6	-	-	3	30.0	10	12.8
	Spiral	58	87.9	-	-	3	30.0	61	78.2
	Straight	1	1.5	2	100.0	4	40.0	7	9.0
	X^2							41.419**	
Horn orientation	Backward	6	9.1	-	-	3	30.0	9	11.5
	Lateral	58	87.9	-	-	3	30.0	61	78.2
	Upward	2	3.0	2	100.0	4	40.0	8	10.3
	X^2							36.543**	

N= Number of sheep exhibiting a particular qualitative character, **; significant at $P<0.01$, NS; not significant at $P<0.05$ level of significance
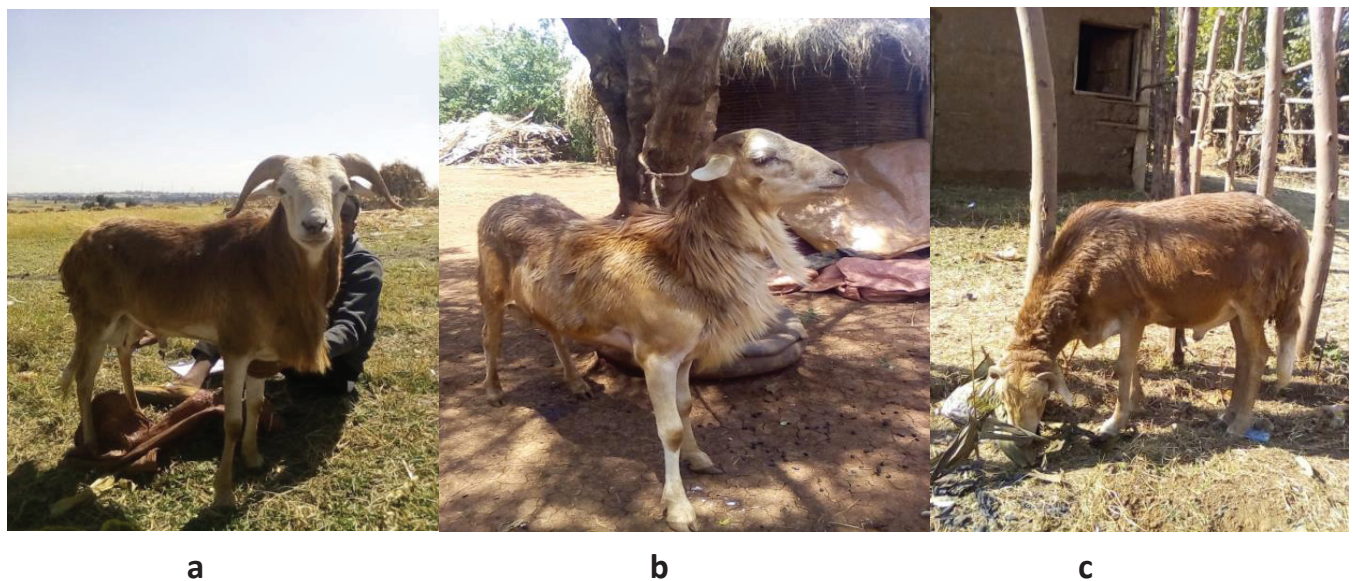

Figure 2: Typical male sheep type in Dendi (a), Guduru (b) and Mida Kegn district (c)

053

shortage problem was more prevalent in Guduru district rather than Dendi and Mida Kegn districts. The current result of live body weight of sheep in Guduru district almost related with Zewdu [9] report; the body weight of Horro sheep was 27.65 ± 0.21. Highest value of ear length was obtained for Guduru (11.8±0.8) and Mida Kegn (11.7±0.7) sheep than for Dendi sheep (10.9±0.7). This implies that sheep in Dendi has shorter ear than sheep in Guduru and Mida Kegn. This show as the sheep population in Dendi is unique from the other population (Guduru and Mida kegn). Height at wither of Guduru sheep (69.6±0.20) and Mida Kegn (69.8±0.19) was higher than Dendi sheep (68.0±0.24) and also tail length was higher for Guduru sheep and Mida Kegn than Dendi sheep. This implies that sheep in Dendi has shorter ear than sheep in Guduru and Mida Kegn. The differences in body measurements among flocks in Guduru and Dendi and Mida Kegn and Dendi and the similarity among flocks in Guduru and Mida Kegn might indicate that sheep breed in Dendi and the other districts are different and sheep population in Guduru and Mida Kegn were however are same breed.

Sex effect

Sex of animals had significant effect (P<0.01) on the linear body measurements and live body weight. Highest body length, body weight, chest girth, height at wither, rump height, tail length and tail circumference except pelvic width and ear length were recorded for male sheep. The recorded body weight in this study for males and females was 31.0±0.28 and 26.4±0.16 kg, respectively (Table 2). Ear length 11.8±0.40 and 10.9±0.08 was obtained for females and males sheep, respectively. Similarly,

Taye, et al. [11] reported that the overall least square mean body weight, heart girth, body length and height at rump were affected by sex.

Age effect

Body weight and all recorded linear body measurements were significantly (P<0.01) affected by age group of animal. All measured traits show an increment with age of animal. Body weight 26.6±0.22 and 31.7±0.24, chest girth 71.0±0.24 and 76.0±0.26 were recorded for 1PPI and 2PPI age of group of animals, respectively (Table 2). Similarly, Kenfo, et al. [12-18] reported body weight of indigenous sheep (both sexes) showed an increment with an increase in age of the animals.

Age by sex effect

Age by sex interaction had significant effect (P<0.01) on EL, TL, and TC. However, the effect (P>0.05) was not observed on BL, BW, HW, RH, and PW. Large ear and tail length and tail circumference value were recorded for male sheep ≥2PPI, whereas high ear length was recorded for female sheep ≥2PPI.

Multivariate analysis

Stepwise discriminant analysis: Step-wise discriminant analysis was first applied to select the most important discriminator variables used for differentiation among sheep types under study. The result of the stepwise discriminant analysis is presented in Table 3. All of the nine variables considered in the analysis were found to be significant (P<0.01 and Partial R² >0.01 to P<0.0001 and Partial R² 0.1181). Ear

Table 2: Least squares means (LSM) ± standard error (SE) for the main effect of district, sex and dentition and sex by dentition interaction on the live body weight (Kg) and body measurements (cm) of sheep.

Levels	N	BL	BW	CG	HW	RH	PW	EL	TL	TC	N	SC
		LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE		LSM±SE
Overall	780	69.1±0.12	29.2±0.15	73.7±0.16	69.1±0.12	70.0±0.12	18.3±0.06	11.5±0.04	35.1±0.17	20.1±0.13	180	26.6±0.16
R²		0.23	0.40	0.31	0.21	0.21	0.32	0.32	0.10	0.53		0.546
CV%		4.08	12.25	5.22	4.04	4.00	7.03	8.41	11.09	17.42		17.199
District		**	**	**	**	**	**	**	**	**		**
Dendi	260	68.2±0.20ᵃ	29.4±0.23ᵃ	74.2±0.26ᵃ	68.0±0.24ᵃ	69.1±0.23ᵃ	18.1±0.11ᵃ	10.9±0.7ᵃ	34.5±0.32ᵃ	21.8±0.27ᵃ	60	26.9±0.32ᵃ
Guduru	260	69.2±0.19ᵇ	28.2±0.23ᵇ	72.6±0.25ᵇ	69.6±0.20ᵇ	70.4±0.20ᵇ	18.0±0.09ᵃ	11.8±0.7ᵇ	35.8±0.28ᵇ	19.0±0.24ᵇ	60	25.4±0.26ᵇ
Mida Kegn	260	70.0±0.19ᶜ	29.8±0.24ᵃ	73.7±0.27ᵃ	69.8±0.19ᵇ	71.7±0.23ᶜ	18.7±0.11ᵇ	11.7±0.8ᵇ	35.2±0.30ᵇ	19.8±0.25ᵇ	60	27.6±0.27ᵃ
Sex		*	**	**	**	**	**	**	**	**		Na
Female	600	68.4±0.1	26.4±0.16	71.7±0.18	68.1±0.13	69.1±0.12	18.6±0.06	11.8±0.04	33.9±0.18	16.2±0.15		
Male	180	69.8±0.2	32.0±0.28	75.3±0.30	70.2±0.22	71.1±0.22	18.0±0.11	10.9±0.08	36.4±0.30	24.1±0.25		
Age		**	**	**	**	**	**	**	**	**		**
1PPI	274	67.8±0.18ᵃ	26.6±0.22ᵃ	71.0±0.24	67.9±0.17	68.8±0.17	17.6±0.08	11.1±0.06	34.2±0.23	19.4±0.20	115	25.7±0.19ᵃ
≥2PPI	506	70.4±0.19	31.7±0.24	76.0±0.26	70.3±0.22	71.3±0.20	19.0±0.09	11.6±0.07	36.2±0.26	21.0±0.22	65	27.5±0.27ᵇ
Sex by age		NS	NS	*	NS	NS	NS	**	**	**		Na
Female1PPI	159	67.1±0.23	23.8±0.29	68.8±0.31ᵃ	67.1±0.23	68.1±0.22	17.9±0.11	11.3±0.08ᵃ	33.4±0.31ᵃ	15.8±0.26ᵃ		
Female≥2PPI	441	69.6±0.13	28.9±0.16	74.5±0.18ᵇ	69.0±0.13	70.0±0.13	19.3±0.06	12.2±0.04ᵇ	34.4±0.18ᵇ	16.6±0.15ᵃ		
Male, 1PPI	115	68.4±0.26	29.4±0.32	73.3±0.35ᶜ	68.8±0.26	69.7±0.26	17.3±0.12	10.9±0.09ᵃ	34.9±0.35ᵇ	22.9±0.29ᵇ		
Male, ≥2PPI	65	71.3±0.37	34.5±0.45	77.4±0.49ᵈ	71.5±0.36	72.6±0.36	18.7±0.17	11.0±0.12ᵃ	38.0±0.49ᶜ	25.4±0.41ᶜ		

Means with different superscripts within the same column and class are statistically different (at least P<0.05). Ns = non significant; Na = not applicable. * Significant at 0.05; **significant at 0.01. 1PPI = 1 pair of permanent incisor and ≥ 2 PPI = 2 or more pairs of permanent incisors.

length was found to be the most discriminating trait followed by body length, chest girth, height at wither and pelvic width in decreasing order of discriminating power. This implies that taking these basic measurements (EL, BL, CG, HW and PW) consistently could be more important in differentiating between the three geographical areas than acquiring numerous additional measurements.

Canonical discriminant analysis: The univariate and multivariate test statistics are presented in Tables 4,5, respectively. The univariate statistic testing shows that all variables are highly significant ($P<0.0001$) except chest girth ($P<0.001$). The resulting partial R^2 values ranged from 0.0173 for chest girth to 0.1181 for ear length. The multivariate test for differences among the districts is also highly significant ($P<0.0001$), in all of the four types of multivariate tests (Wilks' Lambda, Pillia's Trace, Hotelling–Lawley Trace, and Roy's Greatest Root).

The total canonical structure, canonical correlation and total variation explained by each canonical variable for sheep populations are presented in Table 6. In this study, canonical discriminant analysis showed how each trait aligned to the two canonical variations; weighing each original trait according to its contribution on each canonical variable.

Table 5: Multivariate test statistics of canonical discriminant analysis.

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.62600032	22.55	18	1538	<.0001
Pillai's Trace	0.40364874	21.63	18	1540	<.0001
Hotelling-Lawley Trace	0.55008059	23.48	18	1277.9	<.0001
Roy's Greatest Root	0.44322018	37.92	9	770	<.0001

Table 6: Total canonical structure and correlation and total variation of morphological variables of sheep.

Variable	Can1	Can2
Body length	0.469388	0.460100
Body weight	0.046542	0.544578
Chest girth	-0.056933	0.411282
Height at wither	0.538871	0.212654
Rump height	0.517942	0.230355
Pelvic width	0.090136	0.767431
Ear length	0.617072	0.111740
Tail length	0.251402	-0.185660
Tail circumference	-0.377133	-0.028182
Variation (%)	80.6	19.4
Canonical correlation	0.554171	0.310715

The first canonical variable explained 80.6% of the total variation and Can2 explained 19.4% of the total variation, the two canonical varieties extracted explains a total of 100% of the total variation. EL, HW and RH had higher weighing in extracting Can1 while PW, BW and BL loaded high in Can2. The first and second canonical variables presented high weighing for ear length and pelvic width, respectively. It showed that these traits demonstrating their importance to discriminate and to classify the sheep population in the area. Canonical discriminant analysis measures the strength of the overall relationship between the linear composite of the predictor and criterion set of variables. In this analysis the predictor is the canonical variate and the criterion is the sheep population. The significant canonical correlation between the sheep population and the first canonical variate (rc =0.554) and the sheep population and the second canonical variate (rc=0.311), indicate that the canonical variate explain the differentiation of the sheep population, though the first Can1 was more into explaining the most of the variation. Canonical variates (can1 and can2) explain the differentiation of the sheep population is showed in Figure 3.

Discriminant analysis: Discriminant function analysis to determine the percentage of individuals correctly grouped into their own geographical area is presented in Table 7. The results indicate that 65% of sheep populations were correctly grouped into their location, whereas the error count estimates was 35%. Dendi, Guduru and Mida Kegn were correctly grouped into their own geographical area for about 71.15%, 54.62% and 69.23%, respectively.

Mahalanobis distance matrix among districts is presented in Table 8. Mahalanobis distance was estimated from the mean values of variables having more discriminant power. All pair

Table 3: Summary of stepwise selection of traits.

Step	Variables entered	Partial R²	F-value	Pr > F	Wilks' lambda	Pr< lambda	Average squared canonical correlation	P>ASCC
1	EL	0.1181	52.05	<.0001	0.881815	<.0001	0.059072	<.0001
2	BL	0.0611	25.26	<.0001	0.827949	<.0001	0.086858	<.0001
3	CG	0.0730	30.51	<.0001	0.767512	<.0001	0.118474	<.0001
4	HW	0.0658	27.28	<.0001	0.716978	<.0001	0.144517	<.0001
5	PW	0.0388	15.59	<.0001	0.689178	<.0001	0.163294	<.0001
6	TL	0.0261	10.35	<.0001	0.671180	<.0001	0.174567	<.0001
7	TC	0.0267	10.60	<.0001	0.653226	<.0001	0.184302	<.0001
8	BW	0.0221	8.71	0.0002	0.638775	<.0001	0.194455	<.0001
9	RH	0.0200	7.85	0.0004	0.626000	<.0001	0.201824	<.0001

EL: Ear Length; BL: Body Length; PW: Pelvic Width; HW: Height at Wither; TC: Tail Circumference; TL: Tail Length; BW: Body Weight; RH: Rump Height; CG: Chest Girth; ASCC: Average Squared Canonical Correlation

Table 4: Univariate test statistics of canonical discriminant analysis.

Variable	Total Standard Deviation	Pooled Standard Deviation	Between Standard Deviation	R²	R² / (1-RSq)	F Value	Pr > F
BL	3.2013	3.0610	1.1630	0.0881	0.0966	37.53	<.0001
BW	4.4738	4.4135	0.9373	0.0293	0.0302	11.73	<.0001
CG	4.5882	4.5541	0.7392	0.0173	0.0176	6.85	0.0011
HW	3.1315	2.9852	1.1723	0.0935	0.1032	40.09	<.0001
RH	3.1424	3.0056	1.1378	0.0875	0.0959	37.26	<.0001
PW	1.5841	1.5384	0.4724	0.0594	0.0631	24.51	<.0001
EL	1.2012	1.1295	0.5054	0.1181	0.1340	52.05	<.0001
TL	4.0493	4.0082	0.7473	0.0227	0.0233	9.04	0.0001
TC	4.5993	4.5033	1.1775	0.0438	0.0458	17.78	<.0001

wise distances were significant ($P<0.0001$). The largest distance was found between sheep found in Dendi and Guduru, and Mida Kegn, which was 2.27 and 2.01 distance, respectively. This implies that sheep in Dendi district vary on those measured linear body measurements from sheep in Guduru and Mida
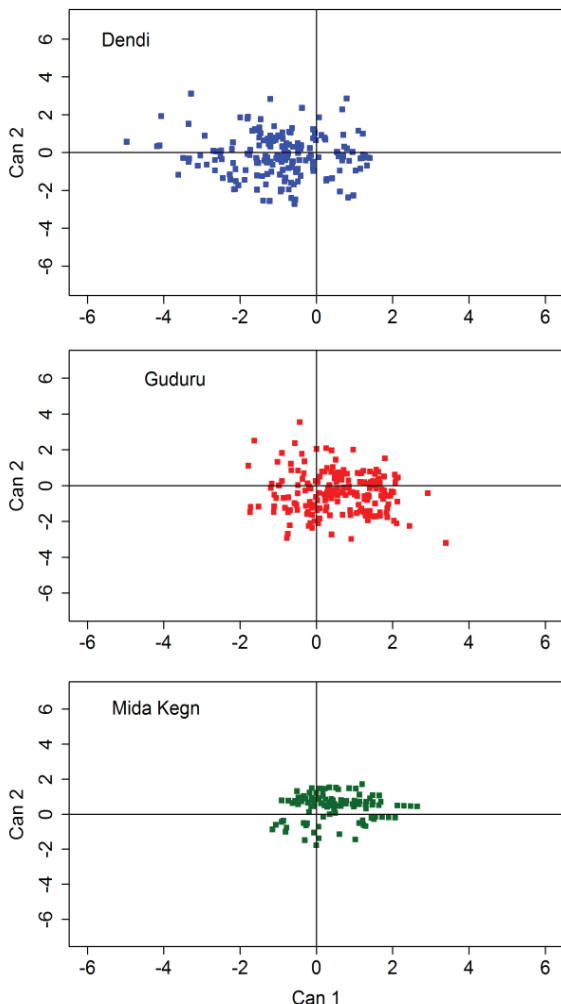

Figure 3: Canonical discriminiant analysis plots of Can1 and Can 2 of indigenous sheep populations in Dendi, Guduru and Mida Kegn districts.

Table 7: Number of observations and percent classified into district.

Districts		Dendi	Guduru	Mida Kegn	Total
Dandi	N (%)	185(71.2)	44 (16.9)	31(11.9)	260 (100)
Guduru	N (%)	44(16.92)	142(54.62)	74(28.46)	260(100)
Mida Kegni	N (%)	36(13.85)	44(16.92)	180(69.23)	260(100)
Total	N (%)	265(33.97)	230(29.49)	285(36.54)	780(100)

N: Number of observations

Table 8: Mahalanobis distance between the three areas.

Districts	Dendi	Guduru	Mida Kegn
Dendi	0	2.270	2.012
Guduru	P<.0001	0	0.649
Mida Kegn	P<.0001	P<.0001	0

In the lower triangular probability of significance is shown ** Significant at p<0.0001

Kegn district. However, the smallest distance was found between Guduru and Mida Kegni district with mahalanobis distance of 0.649 indicating the sheep populations in the two districts are same breed.

Conclusion

Morphological features of sheep population in Dendi were different from features of Horro sheep. The largest distance was found between sheep found in Dendi and Guduru and Mida Kegn. Largest distance was observed between sheep in Dendi and other population. The current work revealed that, sheep populations in Mida Kegn and Guduru areas are belong to the same breed (Horro). In general, this result showed that sheep population in Dendi was found to be unique in morphological and quantitative measurements from those sheep population found in Guduru and Mida Kegn districts. However, sheep populations found in the later two districts are same breed. Multivariate canonical analysis and morphological trait variation confirmed the existence of two populations (Dendi and Guduru–Mida Kegn) in the study areas.

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