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Morphological characterization of indigenous goats in Western Ethiopia: implication for community-based breeding programmes

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Summary
An exploratory field survey was conducted in Horro Guduru Wollega Zone, Ethiopia, to phenotypically characterize indigenous goats. Eight qualitative and fifteen quantitative traits from 612 goats were considered. All data were analysed using SAS 9.2, version 2008. The dominant coat colour types in Guduru district were black (35.29 percent), whereas in Amuru district, the dominant coat colour types were white and brown with brown dominant (18.63 percent) and brown (17.65 percent). In Horro district, the dominant coat colour types were grey (21.57 percent) and black and white with black dominant (15.69 percent). Morphometric measurements (body weight (BW), heart girth and body length) indicated that the Amuru and Horro goats were significantly ($P < 0.05$) higher than the Guduru goats. Male goats were consistently higher than female goats in all variables except pelvic width (PW). BW could be predicted from the regression equation $y = -45.22 + 1.04x$ for does and $y = -59.71 + 1.25x$ for bucks, where y and x are the BW and the heart girth, respectively. This phenotypic information serves as a basis for designing appropriate conservation and breeding strategies for goats in the study area. However, it should be substantiated with genetic characterization to guide the overall goat breeding and conservation programmes.

Keywords: *Body weight, characterization, indigenous goats, linear body measurement*

Résumé
En la zona Horro Guduru Wollega de Etiopía se llevó a cabo un estudio exploratorio de campo para la caracterización fenotípica de las cabras autóctonas. Se consideraron ocho caracteres cualitativos y quince cuantitativos en 612 cabras. Todos los datos fueron analizados con el programa SAS 9.2 (versión 2008). El color de capa dominante en el distrito de Guduru fue el negro (35,29 por ciento), mientas que en el distrito de Amuru los colores de capa dominantes fueron el blanco y el marrón, con el marrón predominando sobre el blanco (18,63 por ciento) o simplemente color marrón (17,65 por ciento). En el distrito de Horro, los colores de capa dominantes fueron el gris (21,57 por ciento) y el negro y blanco, con el negro predominando (15,69 por ciento). Las medidas morfométricas (peso corporal, circunferencia torácica y longitud corporal) fueron significativamente ($P < 0,05$) mayores para las cabras de Amuru y Horro que para las cabras de Guduru. Para todas las variables, excepto para la anchura de la pelvis, los machos presentaron recurrentemente valores superiores a los de las hembras. Se pudo predecir el peso corporal a partir de la ecuación de regresión $y = -45,22 + 1,04x$ para las hembras e $y = -59,71 + 1,25x$ para los machos, siendo "y" el peso corporal y "x" la circunferencia torácica. Esta información fenotípica sirve de base para el diseño de estrategias adecuadas para la conservación y selección de las cabras de la zona de estudio. No obstante, esta información debería ser corroborada por la caracterización genética para guiar los programas de selección y conservación de cabras en su conjunto.

Mots-clés: *poids corporel, caractérisation, chèvres autochtones, mesure corporelle linéaire*

Resumen
Dans la zone Horro Guduru Wollega de l'Éthiopie, une étude d'exploration a été menée sur le terrain pour caractériser phénotypiquement les chèvres autochtones. Huit caractères qualitatifs et quinze caractères quantitatifs ont été considérés sur 612 chèvres. Toutes les données ont été analysées avec le logiciel SAS 9.2 (version 2008). La couleur de robe dominante dans le district de Guduru a été le noir (35,29 pour cent), alors que dans le district d'Amuru les couleurs de robe dominantes ont été le blanc et le marron, avec le marron étant prédominant (18,63 pour cent), voire la seule couleur (17,65 pour cent). Dans le district de Horro, les couleurs de robe dominantes ont été le gris (21,57 pour cent) et le noir et blanc, avec le noir étant prédominant (15,69 pour cent). Pour ce qui est des mesures morphométriques (poids corporel, périmètre thoracique et longueur du corps), les chèvres des districts d'Amuru et Horro ont présenté des valeurs significativement ($P < 0,05$) plus élevées que celles de Guduru. Pour toutes les variables, sauf pour la largeur du bassin, les mâles ont systématiquement présenté des valeurs plus élevées que les femelles. Il a été possible de prédire le poids corporel en utilisant l'équation de régression $y = -45,22 + 1,04x$ pour les femelles et $y = -59,71 + 1,25x$ pour les mâles, avec y et x étant le poids corporel et le périmètre thoracique, respectivement. Cette information phénotypique sert de base pour la conception de stratégies appropriées de conservation et de sélection pour les chèvres de la zone d'étude. Toutefois, cette

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information devrait être étayée par la caractérisation génétique afin de guider les programmes de conservation et de sélection de chèvres dans son ensemble.

Palabras clave: *peso corporal, caracterización, cabras autóctonas, medida corporal lineal*

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Introduction

Ethiopia is endowed with varied ecological zones and possesses diverse animal genetic resources (Janke, 1983; Workneh, 1992; Alemayehu, 1993; Nigatu, 1994; FARM-Africa, 1996; IBC, 2004; Getnet *et al.*, 2005). There is a long history of trade with Arab countries across the Red Sea, with Sudan in the West, Kenya in the south and Somalia in south and southeast. The waves of this trade and physical movement of people and animals have influenced the genetic makeup of domestic livestock, including goats of Ethiopia (Janke, 1983; Workneh, 1992; Alemayehu, 1993; Nigatu, 1994; FARM-Africa, 1996; IBC, 2004; Getnet *et al.*, 2005). According to CSA (2013) there are about 24.06 million goats in Ethiopia, of which, about 71.06 percent are females and 28.94 percent are males. With respect to breed, almost all of the goats are indigenous breeds, which account about 99.99 percent (CSA, 2013). Characterization of existing goat genetic resources is very important for breed improvement and to design appropriate breeding programme for breeds that have not been adequately characterized either phenotypically and/or genetically (Mwacharo *et al.*, 2006). Characterization is essential in breed identification and classification, and the first step of it is assessing variation of morphological traits (Delgado *et al.*, 2001). In Ethiopia, phenotypic characterization done by FARM – Africa long ago in 1996 has shown the presence of 14 goat types and that survey was the first step in breed characterization of Ethiopian goats. On the contrary, genetic characterization done by Alemu (2004) revealed that the presence of only eight distinctively different breed types in Ethiopia.

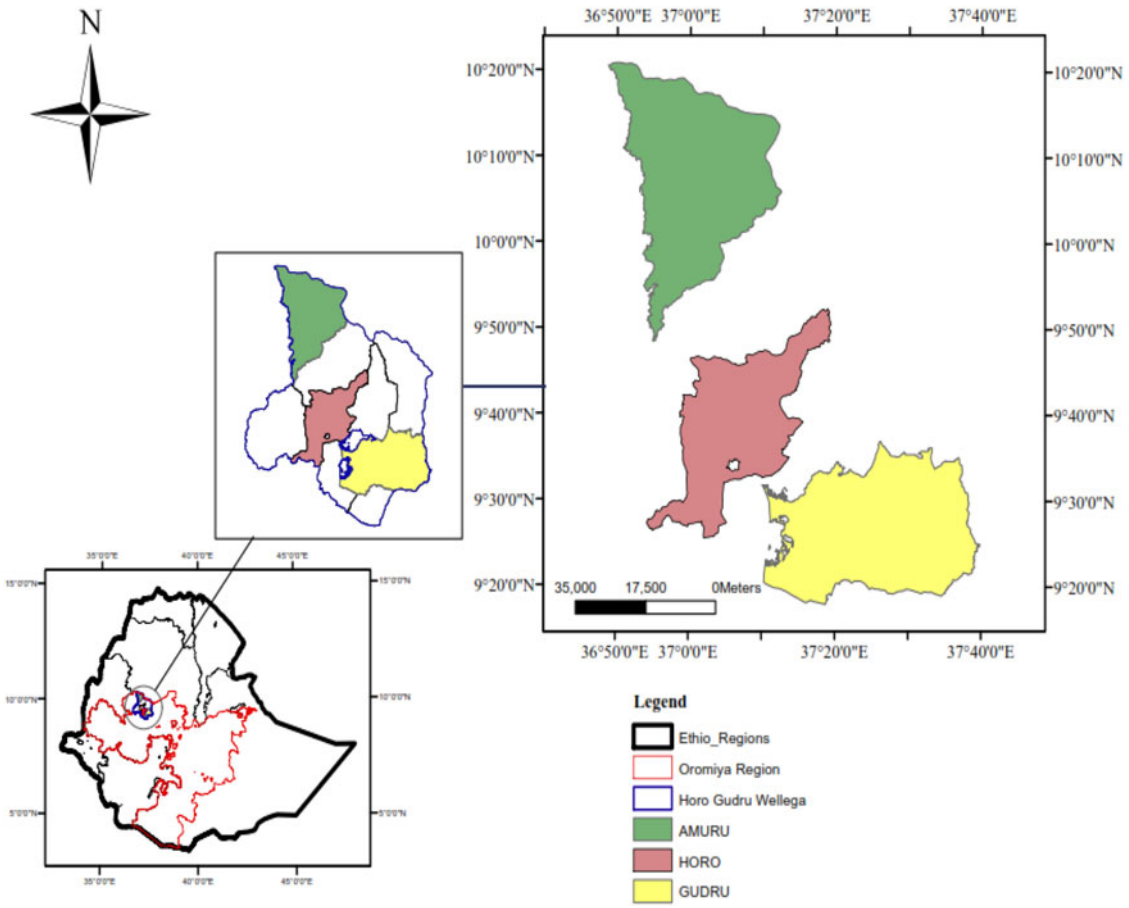


Figure 1. Map of the study area.

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Figure 2. Adult indigenous breeding buck (left) and doe (right) in Guduru district.

Horro Guduru Wollega Zone is one of the geographically well-known pocket areas in the western highlands of Ethiopia and is a home for many phenotypically unique livestock species, which are nationally and internationally recognized. Some of the well-known and phenotypically unique livestock species in this area include the Horro cattle (Mekonnen *et al*., 2012), Horro sheep (Zewdu, 2008) and more recently unique livestock species such as Horro horses (Kefena *et al*., 2012) and Horro chicken (Nigussie, 2011). Interestingly, any casual observer can note that the goat population inhabiting in this unique agro-ecology is phenotypically unique from any other goat populations explored in other parts of the country. However, there is no empirical evidence to substantiate this hypothesis. Therefore, the objective of this study is to phenotypically characterize the indigenous goats in this unique agro-ecological zone of Western Ethiopia and suggest sustainable breeding and conservation programmes to be adopted in the future.

Materials and methods

Description of study area

This study was conducted in three districts (Guduru, Horro and Amuru) of Horro Guduru Wollega zone, Western Ethiopia (Figure 1). Horro Guduru Wollega zone is found in the Western part of Ethiopia, 310 km west of Addis Ababa, the capital city of the country and the capital of the zone found 64 km to the North West of the main road from Addis to Nekemte. Horro Guduru Wollega zone is located between 09°29′N and 37°26′E, at an altitude of approximately 2296 m a.s.l, with a uni-modal rainfall ranging between 1200 and 1800 mm (Olana, 2006). The rainy season occurs from April to mid-October where maximum rain is received in months of June, July and August. Maximum temperature of 23–27 °C are reached from January to March, and minimum temperature of 7–15 °C are normal from October to November (CSA, 2006).

Sampling techniques and sample size determination

From nine districts of the zone, three sample districts were selected purposively based on the presence of relatively large goat population. From each district, three Kebeles (Peasant Associations) were selected because of the relatively large goat population. Sample goats from three kebeles were taken by using simple random sampling method.

The sample size was determined by the formula for phenotypic characterization of livestock for simple random sample (FAO, 2012) as follows.

$$n = (z/m)^2 p(1-p), \quad (1)$$

where z is the z value (e.g. 1.96 for 95 percent confidence level); m is the margin of error, and p is the estimated value for the proportion of the sample that will respond a given way to a survey question.

Based on the above formula, 612 goats (204/district and 68/kebeles) which had one and above pair of permanent incisor (1PPI) were used for body measurements and qualitative trait descriptions. Pregnant females and castrated males were not included in sample goats to avoid inaccuracy for body weight (BW) and linear body measurements (LBMs). Based on FAO (2012), from the total sample size, 10 percent of goats were males, whereas the other 90 percent were females.

Methods of data collection

All data were recorded based on breed morphological characteristics descriptor list of FAO (2012) for phenotypic characterization of goat. Data forheart girth (HG), body length (BL), wither height (WH), rump height (RH), chest depth (CD), shoulder width (SW), pelvic width (PW), ear length (EL), rump length (RL), rump width (RW), horn length (HoL), cannon bone length (CBL),

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Table 1. Qualitative traits of indigenous goats in Horro Guduru Wollega zone by sex and district.

Traits and attributes	District								
	Guduru			Amuru			Horro		
	F *N* (percent)	M *N* (percent)	Total *N* (percent)	F *N* (percent)	M *N* (percent)	Total *N* (percent)	F *N* (percent)	M *N* (percent)	Total *N* (percent)
Coat colour pattern									
Plain	140 (74.47)	14 (87.50)	154 (75.49)	113 (64.94)	16 (53.33)	129 (63.24)	106 (56.99)	8 (44.44)	114 (55.88)
Pied	22 (11.70)	2 (12.50)	24 (11.76)	54 (31.03)	12 (40.00)	66 (32.35)	56 (30.11)	5 (27.78)	61 (29.90)
Patchy	26 (13.83)	–	26 (12.75)	7 (4.02)	2 (6.67)	9 (4.41)	17 (9.14)	5 (27.78)	22 (10.78)
Shaded	–	–	–	–	–	–	7 (3.76)	–	7 (3.43)
χ^2 *value*	*49.401**								
Coat colour type									
White	10 (5.32)	–	10 (4.90)	23 (13.22)	4 (13.33)	27 (13.24)	15 (8.06)	–	15 (7.35)
Black	63 (33.51)	9 (56.25)	72 (35.29)	12 (6.90)	2 (6.67)	14 (6.86)	24 (12.90)	2 (11.11)	26 (12.75)
Brown	30 (15.96)	1 (6.25)	31 (15.20)	35 (20.11)	2 (6.67)	36 (17.65)	24 (12.90)	–	24 (11.76)
Light brown	–	–	–	1 (0.57)	–	1 (0.49)	–	–	–
Grey	35 (18.62)	4 (25.00)	39 (19.12)	23 (13.22)	4 (13.33)	27 (13.24)	39 (20.97)	5 (27.78)	44 (21.57)
Red	2 (1.06)	–	2 (0.98)	22 (12.64)	5 (16.67)	27 (13.24)	5 (2.69)	1 (5.56)	6 (2.94)
Roan	26 (13.83)	–	26 (12.75)	5 (2.87)	2 (6.67)	7 (3.43)	7 (3.76)	2 (11.11)	9 (4.41)
Red + White	1 (0.53)	–	1 (0.49)	6 (3.45)	–	6 (2.94)	4 (2.15)	–	4 (1.96)
Black + White	14 (7.45)	2 (12.50)	16 (7.84)	18 (10.34)	3 (10.00)	21 (10.29)	29 (15.59)	3 (16.67)	32 (15.69)
White + Brown	7 (3.72)	–	7 (3.43)	30 (17.24)	8 (26.67)	38 (18.63)	18 (9.68)	1 (5.56)	19 (9.31)
Black + Brown	–	–	–	–	–	–	21 (11.29)	4 (22.22)	25 (12.25)
χ^2 *value*									*196.25**
Horn presence									
Present	171 (90.96)	16 (100.0)	187 (91.67)	155 (89.08)	22 (73.33)	177 (86.76)	140 (75.27)	11 (61.11)	151 (74.02)
Absent	17 (9.04)	–	17 (8.33)	19 (10.92)	8 (26.67)	27 (13.24)	46 (24.73)	7 (38.89)	53 (25.98)
χ^2 *value*							*25.38**		
Horn shape									
Straight	51 (29.82)	7 (43.75)	58 (31.02)	55 (35.26)	13 (61.90)	68 (38.42)	69 (49.64)	5 (45.45)	74 (49.00)
Curved	32 (18.71)	6 (37.50)	38 (20.32)	36 (23.08)	5 (23.81)	41 (23.16)	9 (6.47)	1 (9.09)	10 (6.62)
U shaped	88 (51.46)	3 (18.75)	91 (48.66)	57 (36.54)	3 (14.29)	60 (33.89)	61 (43.88)	5 (45.45)	66 (43.71)
Spiral	–	–	–	8 (5.13)	–	8 (4.52)	–	–	–
χ^2 *value*							*41.58**		
Horn orientation									
Backward	16 (9.36)	4 (25.00)	20 (10.69)	56 (35.90)	9 (42.86)	65 (36.72)	57 (41.01)	5 (45.45)	62 (41.06)
Upward	155 (90.64)	12 (75.00)	167 (89.31)	100 (64.10)	12 (57.14)	112 (63.28)	82 (58.99)	6 (54.55)	88 (58.28)
χ^2 *value*							*46.99**		
Ear Orientation									
Dropy	89 (47.34)	7 (43.75)	96 (47.06)	58 (33.33)	7 (23.33)	65 (31.86)	59 (31.72)	8 (44.44)	67 (32.84)
Lateral	86 (45.74)	9 (56.25)	95 (46.57)	113 (64.94)	21 (70.00)	134 (65.69)	84 (45.16)	9 (50.00)	93 (45.59)
Forward	13 (6.91)	–	13 (6.37)	3 (1.72)	2 (6.67)	5 (2.45)	38 (20.43)	–	38 (18.63)
Backward	–	–	–	–	–	–	5 (2.69)	1 (5.56)	6 (2.94)
χ^2 *value*							*61.63**		

Beard									
Absent	101 (53.72)	4 (25.00)	105 (51.47)	96 (55.17)	5 (16.67)	101 (49.51)	98 (52.69)	2 (11.11)	100 (49.02)
Present	87 (46.28)	12 (75.00)	99 (48.53)	78 (44.83)	25 (83.33)	103 (50.49)	88 (47.31)	16 (88.89)	104 (50.98)
χ^2 *value*	*0.27*^{NS}								
Ruff									
Absent	132 (70.21)	7 (43.75)	139 (68.14)	119 (68.39)	1 (3.33)	120 (58.82)	66 (35.48)	–	66 (32.35)
Present	56 (29.79)	9 (56.25)	65 (31.86)	55 (31.61)	29 (96.67)	84 (41.18)	120 (64.52)	18 (100.0)	138 (67.65)
χ^2 *value*	*56.47**								

*=$P < 0.05$ for both sexes across district, NS = $P > 0.05$

cannon bone circumference (CBC) and head length (HL)) were measured using tailors measuring tape while BW was measured using suspended spring balance. Data were collected for qualitative traits (coat colour pattern, coat colour type, horn presence, horn shape, horn orientation, ear orientation, ruff presence and bear presence) through visual observations.

Statistical data analysis

All data gathered during the study period were coded and recorded. Different types of statistical analysis were used based on the nature of the data. Both qualitative and quantitative data were analysed using Statistical Analysis System (SAS version 9.2, 2008). Chi-square (χ^2) test was carried out to assess the statistical significance among categorical variables (qualitative variables). Multiple correspondence analyses were carried out for variables which were significant by χ^2 and fisher test to show the association among different categories of qualitative traits. General linear model procedure (PROC GLM) of SAS was used to identify district, sex and age group effect on quantitative traits. Tukey's comparison test was used to compare the sub factor brought significant difference.

$$y_{ijk} = \mu + A_i + S_j + D_k + e_{ijk},$$

where

y_{ijk}, the observation of BW and LBMs excluding scrotum circumference in the ith age group, jth sex and kth district; μ, overall mean; A_i, the effect of ith age group (i = one pair of permanent incisors, two pairs of permanent incisors, three pairs of permanent incisors, four pairs of permanent incisors); S_j is the effect of jth sex (j = female, male); D_k is the effect of kth district (k = Guduru, Amuru, Horro), and e_{ijk} is the random residual error.

To estimate BW from LBMs, the maximum adjusted R^2 method of SAS (2008) was used. The small sample size of bucks in this study may decrease the accuracy of the result if separate age groups were used. Thus, instead of using separate equation for different age groups, it seems logical to pool age groups of male and female goats separately. Stepwise procedures were used to screen out the best fitted model. In the first step, all LBMs were entered together into the model for each sex and a group of variables having the maximum adjusted R^2 and minimum MSE were selected. In addition, Akaike's information criteria (AIC), the mallow's parameters C (P), Schwarz Bayesian criteria (SBC) were considered. In the second step, the variables which are selected by maximum adjusted R^2 and minimum MSE were entered together into the model to find the best fitted regression equation.

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + e_j,$$

where y is the dependent variable (BW); β_0, the intercept; $X_1, \ldots, X_n$, the independent variables (HG, BL, WH, RH, CD, PW, SW, EL, HoL, RL, RW, HL, CBC, CBL); $\beta 1 \ldots$,

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Figure 3. Adult indigenous breeding buck (left) and doe (right) in Amuru district.



Figure 4. Adult indigenous breeding buck (left) and doe (right) in Horro district.

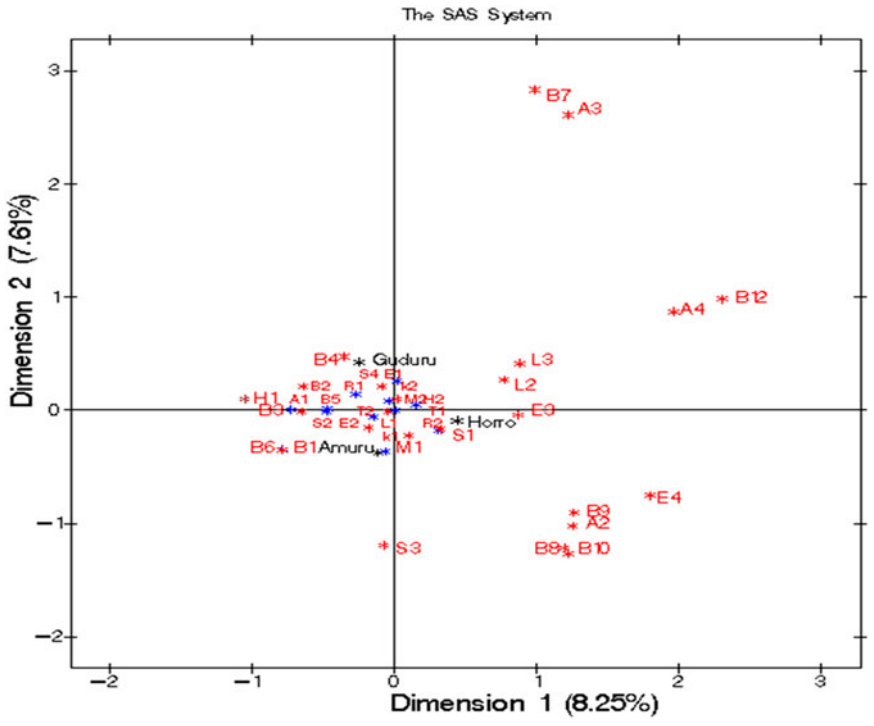


Figure 5. Bi-dimensional plot showing the associations among the categories of the different morphological variables.

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Table 2. Least-squares means for body quantitative traits as affected by district, sex and age group.

Effects and levels	BW LSM ± SE	HG LSM ± SE	BL LSM ± SE	WH LSM ± SE	RH LSM ± SE	EL LSM ± SE	HoL LSM ± SE	PW LSM ± SE	SW LSM ± SE
Overall	28.7 ± 0.3	70.8 ± 0.2	56.9 ± 0.2	67.2 ± 0.2	69.4 ± 0.2	14.9 ± 0.1	10.2 ± 0.2	6.4 ± 0.0	14.6 ± 0.0
CV percent	15.6	6.7	6.2	5.0	4.8	10.1	24.8	10.8	11.0
R^2	0.5	0.4	0.5	0.4	0.3	0.2	0.5	0.5	0.2
District	*	*	*	*	*	*	*	*	*
Guduru	27.9 ± 0.4^{b}	70.5 ± 0.4^{b}	57.0 ± 0.3^{b}	66.8 ± 0.3^{b}	69.0 ± 0.3^{b}	14.0 ± 0.1^{c}	10.2 ± 0.3^{c}	5.5 ± 0.1^{c}	14.6 ± 0.2^{b}
Amuru	30.5 ± 0.4^{a}	71.8 ± 0.4^{a}	58.4 ± 0.3^{a}	68.5 ± 0.3^{b}	70.7 ± 0.3^{a}	15.0 ± 0.1^{b}	10.8 ± 0.3^{b}	6.4 ± 0.1^{a}	14.5 ± 0.2^{b}
Horro	31.3 ± 0.4^{a}	72.3 ± 0.4^{a}	58.6 ± 0.3^{a}	68.7 ± 0.3^{a}	70.8 ± 0.3^{a}	15.7 ± 0.1^{a}	11.8 ± 0.3^{a}	6.0 ± 0.1^{b}	15.5 ± 0.2^{a}
Sex	*	*	*	*	*	ns	*	*	*
Female	26.8 ± 0.2^{b}	69.2 ± 0.2^{b}	55.5 ± 0.1^{b}	66.2 ± 0.1^{b}	68.6 ± 0.1^{b}	14.9 ± 0.1	9.1 ± 0.1^{b}	6.4 ± 0.0^{a}	14.3 ± 0.1^{b}
Male	33.0 ± 0.6^{a}	73.8 ± 0.7^{a}	60.5 ± 0.5^{a}	69.7 ± 0.4^{a}	71.9 ± 0.4^{a}	14.9 ± 0.2	12.8 ± 0.4^{a}	5.5 ± 0.1^{b}	15.4 ± 0.2^{a}
Age group	*	*	*	*	*	*	*	*	ns
1PPI	23.8 ± 0.4^{d}	67.2 ± 0.4^{c}	53.2 ± 0.3^{d}	65.2 ± 0.3^{c}	67.2 ± 0.3^{c}	14.4 ± 0.1^{b}	9.2 ± 0.3^{b}	5.4 ± 0.1^{d}	14.4 ± 0.2
2PPI	27.1 ± 0.6^{c}	69.7 ± 0.7^{b}	56.3 ± 0.5^{c}	66.3 ± 0.5^{c}	68.9 ± 0.5^{b}	15.0 ± 0.2^{a}	11.4 ± 0.6^{a}	5.7 ± 0.1^{c}	15.0 ± 0.2
3PPI	32.4 ± 0.7^{b}	73.6 ± 0.7^{a}	60.0 ± 0.5^{b}	69.2 ± 0.5^{b}	71.6 ± 0.5^{a}	15.1 ± 0.2^{a}	11.2 ± 0.5^{a}	6.2 ± 0.1^{b}	15.0 ± 0.3
4PPI	36.4 ± 0.8^{a}	75.6 ± 0.8^{a}	62.5 ± 0.6^{a}	71.2 ± 0.6^{a}	73.1 ± 0.5^{a}	15.2 ± 0.2^{a}	11.1 ± 0.8^{a}	6.6 ± 0.1^{a}	14.9 ± 0.3
Overall	14.7 ± 0.1	30.0 ± 0.1	14.3 ± 0.1	13.4 ± 0.1	13.9 ± 0.0	9.3 ± 0.0			
CV percent	8.3	6.7	8.9	9.7	6.3	10.9			
R^2	0.3	0.4	0.3	0.3	0.1	0.1			
District	*	*	*	*	*	*			
Guduru	14.1 ± 0.1^{c}	29.4 ± 0.1^{b}	13.6 ± 0.1^{b}	13.0 ± 0.1^{c}	13.8 ± 0.0^{b}	9.8 ± 0.1^{a}			
Amuru	14.8 ± 0.1^{b}	30.8 ± 0.1^{a}	13.8 ± 0.1^{b}	13.4 ± 0.1^{b}	13.9 ± 0.0^{b}	9.1 ± 0.1^{b}			
Horro	15.6 ± 0.1^{a}	30.9 ± 0.1^{a}	15.2 ± 0.1^{a}	14.0 ± 0.1^{a}	14.2 ± 0.0^{a}	9.5 ± 0.1^{c}			
Sex	*	*	ns	*	*	*			
Female	14.5 ± 0.1^{b}	29.3 ± 0.1^{b}	14.1 ± 0.0	13.2 ± 0.0^{b}	13.8 ± 0.0^{b}	9.1 ± 0.1^{b}			
Male	15.2 ± 0.2^{a}	31.4 ± 0.2^{a}	14.3 ± 0.1	13.7 ± 0.1^{a}	14.2 ± 0.1^{a}	9.8 ± 0.1^{a}			
Age group	*	*	*	*	ns	ns			
1PPI	14.3 ± 0.1^{c}	28.7 ± 0.1^{d}	13.8 ± 0.1^{b}	14.0 ± 0.2^{a}	13.9 ± 0.0	9.3 ± 0.1			
2PPI	14.7 ± 0.1^{bc}	29.9 ± 0.3^{c}	14.1 ± 0.1^{ab}	14.2 ± 0.2^{a}	14.1 ± 0.1	9.7 ± 0.2			
3PPI	14.8 ± 0.2^{b}	30.9 ± 0.3^{b}	14.6 ± 0.2^{a}	13.2 ± 0.1^{b}	13.9 ± 0.1	9.5 ± 0.2			
4PPI	15.5 ± 0.2^{a}	31.9 ± 0.3^{a}	14.5 ± 0.2^{a}	12.5 ± 0.1^{c}	14.1 ± 0.1	9.5 ± 0.2			

^{a,b,c,d}Means on the same column with different superscripts within the specified sex, district and dentition group are significantly different ($P < 0.05$); ns, non-significant ($P > 0.05$).

BW, body weight; BL, body length; HG, heart girth; WH, wither height; RH, rump height; HoL, horn length; EL, ear length; PW, pelvic width; SW, shoulder width; 1PPI, 1 pair of permanent incisors; 2PPI, 2 pair of permanent incisors; 3PPI, 3 pairs of permanent incisors; 4PPI, 4 pairs of permanent incisors; HL, head length; CD, chest depth; RW, rump width; RL, rump length; CBL, cannon bone length; CBC, cannon bone circumference; 1PPI, 1 pair of permanent incisors; 2PPI, 2 pair of permanent incisors; 3PPI, 3 pairs of permanent incisors; 4PPI, 4 pairs of permanent incisors; NA, not applicable.

βn, the regression coefficients of the variables $X_1, \ldots, Xn$; and *ej*, the residual random error.

Results

Qualitative traits

The most observed coat colour pattern in the study districts was plain (75.49 percent in Guduru, 63.24 percent in Amuru and 55.88 percent in Horro). Pied coat colour pattern was relatively observed in Amuru (32.35 percent) and Horro (29.90 percent) district goats than in Guduru district goats (11.76 percent). Eleven types of coat colours were identified in sample districts. From those colours, black and grey accounted 35.29 and 19.12 percent, respectively, in Guduru district goats (Figure 2 and Table 1), whereas in Amuru district goats, the dominant coat colour types were white and brown with brown dominant (18.63 percent) and brown (17.65 percent) (Figure 3 and Table 1). In Horro district goats, grey (21.57 percent) and black and white with black dominant (15.69 percent) were the frequently occurred coat colour types (Figure 4 and Table 1).

Majority of goats (91.67 percent in Guduru, 86.76 percent in Amuru and 74.02 percent in Horro) were horned and most of these horned goats had upward horn orientation. In Guduru, 48.66 percent of goats had U shaped horn; however, in Amuru and Horro, 38.42 and 49.00 percent of goats had straight horn shape, respectively. Most of goats in sample districts had Lateral and dropy ear orientations. Most of qualitative traits were not influenced by sex except beard and ruff presence which was mostly expressed in male goats.

Multiple correspondence analysis

The common qualitative characteristics among goats of the three districts were investigated by a multiple correspondence analysis. A bi-dimensional graph representing the associations among different categories of qualitative traits

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Table 3. Correlation coefficients among BW and linear measurements ofHorro Guduru Wollega goats (values above the diagonal are for males and below the diagonal are for females).

	HoL	EL	HL	CD	SW	HG	CBL	CBC	RW	RL	PW	BL	WH	RH	BW
HoL		0.21^{ns}	0.24^{ns}	0.30*	0.21^{ns}	0.30*	0.23^{ns}	0.09^{ns}	0.30*	0.08^{ns}	0.18^{ns}	0.23^{ns}	0.45*	0.39*	0.31*
EL	0.13*		0.58*	0.48*	0.56*	0.38*	0.58*	−0.05^{ns}	0.43*	0.38*	0.39*	.52*	0.34*	0.35*	0.35*
HL	0.31*	0.41*		0.57*	0.59*	0.44*	0.53*	0.01^{ns}	0.46*	0.55*	.31*	0.52*	0.53*	0.56*	0.38*
CD	0.32*	0.37*	0.47*		0.52*	0.81*	0.60*	0.19^{ns}	0.75*	0.46*	0.64*	0.78*	0.82*	0.82*	0.79*
SW	0.18*	0.31*	0.47*	0.38*		0.43*	0.62*	0.15^{ns}	0.55*	0.44*	.27*	0.45*	0.44*	0.49*	0.32*
HG	0.35*	0.23*	0.40*	0.60*	0.38*		0.40*	0.24^{ns}	0.73*	0.49*	0.58*	0.77*	0.83*	0.83*	0.89*
CBL	0.06^{ns}	0.28*	0.20*	0.35*	0.32*	0.25*		0.10^{ns}	0.47*	0.40*	0.33*	0.37*	0.49*	0.49*	0.38*
CBC	0.08*	0.09*	0.13*	0.30*	0.40*	0.29*	0.36*		0.26^{ns}	0.20^{ns}	−0.04^{ns}	−0.01^{ns}	0.16^{ns}	0.15^{ns}	0.18^{ns}
RW	0.33*	0.19*	0.35*	0.43*	0.39*	0.50*	0.25*	0.23*		0.48*	0.54*	0.73*	0.73*	0.73*	0.66*
RL	0.17*	0.34*	0.44*	0.43*	0.34*	01.37*	0.36*	0.20*	0.27*		0.25*	0.46*	0.44*	0.50*	0.40*
PW	0.24*	0.25*	0.35*	0.42*	0.25*	0.51*	0.21*	0.08^{ns}	0.49*	0.28*		0.68*	0.65*	0.64*	0.59*
BL	0.37*	0.29*	0.43*	0.68*	0.39*	0.70*	0.33*	0.37*	0.57*	0.42*	0.56*		0.72*	0.77*	0.82*
WH	0.32*	0.30*	0.39*	0.62*	0.31*	0.65*	0.37*	0.22*	0.53*	0.40*	0.53*	0.70*		0.97*	0.81*
RH	0.31*	0.34*	0.40*	0.62*	0.35*	0.62*	0.39*	0.25*	0.51*	0.40*	0.51*	0.66*	0.92*		0.81*
BW	0.41*	0.35*	0.46*	0.71*	0.44*	0.81*	0.32*	0.30*	0.55*	0.46*	0.58*	0.75*	0.72*	0.69*	

ns, non-significant ($P > 0.05$); *, significant at 0.05 level.
BL, body length; HG, heart girth; WH, wither height; RH, rump height; RW, rump width; RL, rump length; CD, chest depth; PW, pelvic width; SW, shoulder width; HL, head length; CBL, cannon bone length; CBC, cannon bone length; HoL, horn length; EL, ear length; BW, body weight; SC, scrotal circumference.

is presented in Figure 5. The interpretation is based on points found in approximately the same direction from the origin and in approximately the same region of the space. Around 16 percent of the total variation is explained by the two dimensions (8.25 percent by the first and 7.61 percent by the second dimensions). On the dimensions identified, goat populations from the three districts shared some common characteristics. This might be due to the geographic proximity and possible gene flow among the three districts.

Quantitative traits

Sex effect: The least-squares means for the effect of sex had significant effect ($P < 0.05$) on all quantitative traits except EL and RL. This indicates that, sexual dimorphism was observed in most of quantitative traits. Male goats were consistently higher than female goats in all quantitative traits except PW, which is slightly higher for female goats (Table 2).

District effect: District had significant effect ($p < 0.05$) on all quantitative variables. For all quantitative traits except for CBC the Amuru and Horro district goats were significantly ($P < 0.05$) higher than Guduru goats (Table 2). At the scope of this study, it is very difficult to link this difference to any genetic background and it might be due to different management practice of the farmers.

Age effect: BW and all body measurements were significantly affected ($P < 0.05$) by age group except CBL. BW, CD, heart girth, BL, RH, EL and HL were increased as the age increased from the youngest (1PPI) to the oldest (4PPI) age group (Table 2). Though, is very difficult to generalize, a good observation from this study was that CBL hardly increases after goats replace their milk incisor teeth to permanent incisor teeth.

Correlation between BW and LBMs

BW was significantly ($P < 0.05$) correlated with all quantitative traits of both male and female goats except CBC in male (Table 3). The quantitative traits in both male and female goat population depicted weak to strong correlations and most of the traits had significant ($P < 0.05$) and positive associations.

In male goats, heart girth had strong positive correlation ($r = 0.89$) with BW followed by BL ($r = 0.82$), WH ($r = 0.81$), RH ($r = 0.81$). In female goats heart girth had also strong positive correlation with BW ($r = 0.81$).The strong positive and significant correlation between BW and heart girth suggested that these variables could provide a good estimate in predicting live BW of goats.

Prediction of BW from LBMs

Heart girth was the first variable to explain more variation than other variables in both female (79 percent) and male (82 percent) goats of Horro Guduru Wollega. As shown in Table 4, adjusted R^2 did not always increase as new

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Table 4. Multiple regression analysis of live BW on different body measurements of female and male goats in the study area in all age groups

For female goats Model	b0	Parameters							Adj. R^2	C (P) AIC	MSE	SBC	
		b1	*b2*	*b3*	*b4*	*b5*	*b6*	*b7*					
HG	−45.22	1.04							0.79	135.4	1148.6	2.86	1157.2
HG + BL	−46.78	0.78	0.36						0.82	48.30	1073.7	2.67	1086.6
HG + BL + CD	−48.22	0.71	0.31	0.30					0.83	27.71	1054.3	2.62	1071.5
HG + BL + CD + RL	−49.53	0.69	0.30	0.27	0.28				0.83	17.56	1044.5	2.59	1065.9
HG + BL + CD + RL + EL	−50.74	0.69	0.30	0.23	0.23	0.20			0.83	12.26	1039.2	2.58	1065.0
HG + BL + CD + RL + EL + WH	−53.20	0.66	0.28	0.22	0.22	0.19	0.12		0.83	8.13	1035.0	2.57	1065.2
HG + BL + CD + RL + EL + WH + HoL	−52.33	0.64	0.27	0.21	0.22	0.19	0.11	0.05	0.83	6.62	1033.5	2.56	1067.9
For male goats													
HG	−59.71	1.25							0.82	28.54	152.56	3.30	156.85
HG + BL	−62.03	0.87	0.50						0.86	12.20	139.75	2.96	146.18
HG + BL + RW	−62.55	1.03	0.52	− 0.9					0.87	6.32	134.13	2.81	142.70
HG + BL + RW + EL	−60.07	1.02	0.59	− 0.9	− 0.4				0.88	4.45	132.03	2.75	142.74
HG + BL + RW + EL + CD	−62.44	0.93	0.54	− 1.1	− 0.5	0.50			0.88	3.19	130.35	2.69	143.21

HG, heart girth; BL, body length; CD, chest depth; RL, rump length; EL, ear length; WH, wither height; HoL, horn length, R^2, coefficient of determination, AIC, Alkaike's information criteria; C (P), the mallow's parameters; SBC, Schwarz Bayesian criteria; MSE, mean square error.

variable was added to the model but the addition of new variables decreased the C (P), AIC, MSE and SBC with little or no influence on the adjusted R^2. It should be noted that when new variable was added to the model, C (P), AIC, MSE and SBC usually decreased but addition of unnecessary variable to the model might increase the error. Thus the result of the multiple regression analysis indicated that the addition of other LBMs to heart girth did not result in significant increase in adjusted R^2, but it significantly improved the accuracy of prediction by decreasing the error even though the amount was small. Therefore, at farmers level, where weighing scales are not available and complex formula is not understandable, BW could be predicted from the regression equation $y = -45.22 + 1.04x$ for does and $y = -59.71 + 1.25x$ for bucks, where y and x are the BW and heart girth, respectively.

Discussions

In this study, the physical description of goats for most of qualitative traits was different from the results of different authors in different areas (Farm-Africa, 1996; Mahilet, 2012; Gebreyesus *et al.*, 2013; Abegaz *et al.*, 2013). Around 65 percent of goats in the study area had plain coat colour pattern with 18.30 percent black and 17.97 percent grey. The result showed that the phenotypic characteristics of traits like coat colour pattern and coat colour type for Horro Guduru Wollega goats represent totally different population of goat than the previous report of Farm-Africa (1996) who reported that 51 percent of western highland goats had plain coat colour pattern with 42 percent white and 42 percent fawn. Most (84.15 percent) of goats in the study area were horned goats. Similarly, Farm-Africa (1996) reported that, 86 percent of goats in western highland of Ethiopia had horn.

The significant performance difference ($P < 0.05$) of male goats and female goats for most of quantitative traits shown in this study was in line with the results of Mahilet (2012) in Eastern Hararghe and Gebreyesus *et al.*, (2013) in Diredewa. The overall average BW of male (33 kg) and female (26.8 kg) indigenous goats in the study area differed from the average BW of Hararghe goats as reported by Mahilet (2012) with 27 and 24 kg for males and females, respectively. A significant effect of age is also reported by Mekasha (2007) who shows the effect of age on BW and other body measurements in different goat breeds of Ethiopia. The strong positive and significant correlation between BW and heart girth reported in this study strongly agrees with the results of Gebreyesus *et al.*, (2013) and Mahilet (2012).

Conclusions

This study provided that goat population in Horro district was significantly different from goat population in Guduru district in both qualitative and quantitative characters. In addition, goat population in the study area had shown different phenotypic characteristics with relative

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to western highland breed. At the scope of this study, it is very difficult to link this difference to any genetic background and it might be due to different management practice of the farmers. Further genetic study may fully describe this unique goat population and should be focus of future research.

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Statement of interest

The authors declare that there is no conflict of interest involved in this study.

References

Abegaz, S., Sölkner, J., Gizaw, S., Dessie, T., Haile, A. & Wurzinger, M. 2013. Description of goat production systems and morphological characteristics of Abergelle and Western low-land goat breeds in Ethiopia: implications for community-based breeding programmes. *Anim. Genet. Resour*. 53: 69–78.

Alemayehu, R. 1993. *Phenotypic characterization of indigenous goats and goat husbandry practices in East and South East Ethiopia*. Alemaya University of Agriculture, Alemaya, Ethiopia. (M.Sc. thesis). pp.135.

Alemu, T. 2004. *Genetic characterization of indigenous goat populations of Ethiopia using Microsatellite DNA markers*. National Dairy Research Institute, Deemed University, Haryana, India. (Ph.D. thesis).

CSA. 2013. Agricultural sample survey, 2012/13 (2005 E.C). Volume II, report on livestock and livestock characteristics (private peasant holdings). Statistical bulletin, 570, April 2013, Addis Ababa, Ethiopia.

CSA and ORC Macro. 2006. *Ethiopia demographic and health survey 2005*. Central Statistical Agency and ORC Macro, Addis Ababa, Ethiopia and Calverton, Maryland, USA.

Delgado, J.V., Barba, C., Camacho, M.E., Sereno, F.T.P.S., Martinez, A. & Vega-Pla, J.L. 2001. Livestock characterization in Spain. *AGRI* 29: 7–18.

FAO. 2012. *Phenotypic Characterization of Animal Genetic Resources. FAO Animal Production and Health Guidelines No. 11. Rome*. Rome, Italy (available at http://www.fao.org/docrep/015/i2686e/i2686e00.htm).

FARM-Africa. 1996. Goat Types of Ethiopia and Eritrea. *In* Published jointly by FARM-Africa, London, UK and ILRI, eds. *Physical description and management systems*, 76 pp. Nairobi, Kenya, International Livestock Research Institute.

Getnet, A., Hegde, B.P., Bekele, T., Enyew, N. & Workneh, A. 2005. Phenotypic characterization of goat types in northwestern Ethiopia. *Ethiopian J. Anim. Prod*. 5: 13–32.

Gebreyesus, G., Haile, A. & Dessie, T. 2013. Breeding scheme based on community-based participatory analysis of local breeding practices, objectives and constraints for goats around Dire Dawa, Ethiopia. *Livest. Res. Rural Dev*. 25.

IBC (Institute of Biodiversity Conservation). 2004. The State of Ethiopia's Farm animal Genetic Resources: Country Report. A Contribution to the First Report on the State of the World's Animal Genetic Resources. IBC, May 2004. Addis Ababa, Ethiopia.

Janke, H.E. 1983. *Livestock production system and livestock development in tropical Africa*. Kiel, Germany, Kieler Wissenschaftsverlag Vauk. 273 pp.

Kefena, E., Dessie, T., Han, J.L., Kurtu, M.Y., Rosenbom, S. and Beja-Pereira, A. 2012. Morphological diversities and ecozones of Ethiopian horse populations. *Anim. Genet. Resour*. 50: 1–12.

Mahilet, D. 2012. *Characterization of Hararghe Highland Goat and Their Production System in Eastern Hararghe*. Haramaya University, Dire Dawa, Ethiopia. (M.Sc. thesis).

Mekonnen, A., Haile, A., Dessie, T. & Mekasha, Y. 2012. On farm characterization of Horro cattle breed production systems in western Oromia, Ethiopia. *Livest. Res. Rural. Dev*. 24(6): 23.

Mekasha, Y. 2007. *Reproductive Traits in Ethiopian Male Goats. With special reference to breed and nutrition*. Swidish University of Agricultural Science, Uppsala, Sweden. (Ph.D. Dissertation).

Mwacharo, J.M., Okeyo, A.M., Kamande, G.K. & Rege, J.E.O. 2006. The small East African Shorthorn zebu cows in Kenya. I: Linear body measurements. *Trop. Anim. Health Prod*. 38: 65–74. doi: 10.1007/s11250-006-4266-y.

Nigatu, A. 1994. *Characterization of Indigenous Goat Types & husbandry Practices in Northern Ethiopia*. Alemaya University of Agriculture, Alemaya, Ethiopia. (M.Sc. thesis). pp86.

Nigussie, D. 2011. *Breeding programs for indigenous chicken in Ethiopia Analysis of diversity in production systems and chicken populations*. Department of Animal Science, School of Graduate Studies, Haramaya University, Dire Dawa, Ethiopia. (AMsc thesis submitted).

Olana, B.T. 2006. *Environmental and socio- economic changes induced by a reservoir in Finca'a water shade Western Ethiopia*. Wageningen University, The Netherlands. (Ph.D. thesis).

SAS (Statistical Analysis System). 2008. *SAS for windows*. Release 9.2, Cary, NC, USA, SAS Institute, Inc.

Workneh, A. 1992. *Preliminary survey of indigenous goat types and goat husbandry practices in Southern Ethiopia*. Alemaya University of Agriculture, Dire Dawa, Ethiopia. (M.Sc. thesis).

Zewdu, E. 2008. *Characterization of Bonga and Horro indigenous sheep breeds of smallholders for designing community based breeding strategies in Ethiopia*. Department of Animal Science, School of Graduate Studies, Haramaya University. (A M.Sc. thesis submitted). 0.33pp.

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