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# Phenotypic characterization of Ethiopian indigenous goat populations

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A survey was conducted to study the morphological characteristics of indigenous goats in representative zones and districts of Amhara Region of Ethiopia as a first step towards characterization and designing of breeding programs. A pre-tested questionnaire was used for recording morphological features, body weights and linear body measurements. Both qualitative and quantitative traits were recorded on 158 goats randomly sampled from six goat populations and the data were analyzed using GenStat version 13 software. Live body weights were also associated and predicted using linear body measurements. Results confirmed that six distinct indigenous goat populations were identified and characterized in the region viz. Gumuz, Begia-Medir, Agew, Bati, Central Abergelle and Abergelle. There were clear morphological variations between and within these goat ecotypes in terms of body coat color, head profile, horn orientation, ear form and head shape. The Ethiopian goat ecotypes found in Amhara Region of Ethiopia could be clustered into two main groups viz. Gumuz, Agew and Begia-Medir cluster as one group and Bati, Abergelle and Central Abergelle as the second group. The high variations observed in the morphological traits suggest that these goat ecotypes have not yet been selected through structured selective breeding. The high correlation coefficients of heart girth with body weight for west ( $r = 0.899$ ) and east ( $r = 0.832$ ) Amhara Region goat populations demonstrated a strong relationship between these variables with regression equations of  $y = 1.273x - 61.329$ ,  $R^2 = 0.807$  and  $y = 0.486x - 5.798$ ,  $R^2 = 0.095$ , respectively, which allows for predicting live weight from heart girth in these goats. In general, the observed morphological characteristics of the goats' genetic resources in Amhara region together with the characterization at molecular level will contribute to designing of improvement strategies for these goat populations, which will need to be complemented with performance data.

**Key words:** Ethiopia, goat types, Amhara region, morphological features.

## INTRODUCTION

Goats (*Capra hircus*) contribute significantly to the livelihood of resource-poor farmers in Ethiopia (Alemu, 2004; Institute of Biodiversity Conservation, 2004; Sebsibe, 2006). Goats have a short reproductive cycle

and hence high multiplication rate as compared to large ruminants, which is ideal for poverty alleviation. Indigenous goat populations generally dominate the goat flocks in Ethiopia and have developed certain valuable genetic traits such as ability to perform better under low input condition and climatic stress, tolerance to infectious diseases and parasites as well as heat stresses (Philipsson et al., 2006; Kosgey and Okeyo, 2007). These traits enable them to cope with the stressful nature

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**Table 1.** Goat population studied in six administrative zones of the Amhara Region of Ethiopia.

Sampling zone	Goat ecotype	Sample size	Promising trait	Adaptive feature
North Gonder	Gumuz	30	Prolificacy	Heat stress
Agew-Awi	Agew	30	Growth	Cold stress
South Gonder-West Gojam	Begia-Medir	30	Growth	Cold stress
Oromia	Bati	30	Skin quality	Heat and drought stresses
Wag-Himra	Abergelle	8	Growth	Heat and drought stresses
South-North Wollo	Central Abergelle	30	Prolificacy	Heat and drought stresses

of the vast marginal lands of the region. They are also hardy animals and are important reservoirs of useful genes. Their morphological differences have important socio-cultural and economic values to the Ethiopian communities; as a result, most farmers have specific consideration and choices for goat coat colors followed by body sizes. For instance, black coat colored goat is less preferred in the Amhara Region and beyond (personal observation). Regardless of the above mentioned merits, the local goat genetic resources were regarded as less productive, hence, subjected to replacement and crossbreeding with imported goat breeds like Boer (<http://www.esgpip.org>) and other goat breeds introduced at different periods by different organization. However, indiscriminate crossbreeding of indigenous goats can cause genetic erosion, loss of genetic diversity and reduction of adaptive value and opportunities for efficient utilization of the existing adapted goat genetic resources. This threat is in line with the FAO report (FAO, 1999), which states that animal genetic resources in developing countries in general, are being eroded through the rapid transformation of the agricultural system, in which the main cause of the loss of indigenous Animal Genetic Resources (AnGRs) is the indiscriminate introduction of exotic genetic resources, before proper characterization, utilization and conservation of the untapped indigenous genetic resources.

Knowledge of the adapted goat genetic resources is a pre-requisite for designing appropriate breeding and utilization programs. Characterization of livestock breeds based on their morphological traits variations (Delgado et al., 2001) are the first step towards the use of the available AnGRs (Lanari et al., 2003). Morphometric measurements have been used to evaluate the characteristics of various breeds of animals, and could provide first hand information on the suitability of animals for selection (Nesamvuni et al., 2000; Mwacharo et al., 2006; Martins et al., 2009; Yakubu, 2010a) and for further characterization studies using modern molecular methods. This paper compares the morphological features of six Ethiopian indigenous goat populations in Amhara Region and thus, complements the characterization of the same genotypes at molecular level

published earlier (Halima et al., 2012).

## MATERIALS AND METHODS

### Description of the study areas and morphological traits measured

The study areas were chosen based on previous informal and/or formal field surveys carried out for characterizing goat production systems, production and reproduction performances (Alemayehu, 1994; Ameha, 2001; Derebe, 2008). Agew-Awi, South Gonder-West Gojam, North Gonder, Wag-Himra, South-North Wollo and Oromia administrative zones of the Amhara Region were selected (for more information on site selection see Halima et al., 2012). The goat populations in these zones are traditionally recognized by ethnic and/or geographic nomenclatures (Table 1); they were sampled in areas where each genotype is predominantly found following the guidelines by Ayalew and Rowlands (2004).

Quantitative (body weight, height at withers, body length, heart girth, ear length, rump width and sacral pelvic width) and qualitative traits (coat color and pattern, head profile, head shape, ear form, horn orientation and hair type) were documented using a semi-structured questionnaire along with visual appraisal of the appearance of the goat types and measurements following the descriptor lists of the Food and Agriculture Organization of the United Nations (FAO, 1986). Besides, focus group discussions were held with livestock keepers and knowledgeable key informants for generating general information regarding the history of the various goat types, special distinguished features of the targeted goats, production systems, and knowledge on the husbandry practices, challenges and opportunities of indigenous goats. As farmers did not have birth record of their animals, age of each sampled goat was estimated from dentition as suggested by Pace and Wakeman (2003). For each goat population, 30 individual goats (except for Abergelle goats,  $n = 8$ ) from different villages and flocks (one to three animals per flock) across the different districts were sampled and the morphological measurements were collected from adult female goats having three to four pairs of permanent incisors.

### Statistical analyses

The data collected from the quantitative and qualitative variables were analyzed with General Linear Model (GLM) procedures of the GenStat version 13 software (Payne et al., 2010). The qualitative variables were computed using GenStat software. Hierarchical cluster analysis was performed using quantitative variables and dendrogram was constructed based on Euclidean distance between goat populations using unweighted pair-group method to group the

goat populations into their morphological similarity, which was analyzed on GenStat software. After cluster analysis, Pearson correlation coefficient ( $r$ ) values for the two goat populations (west and east Amhara Region goats' populations) were also computed using same software to assess the relationship between body measurement traits. In addition, regression analyses in GenStat of GLM were used to predict body weights of the two goat populations from heart girth and body length measurement traits.

## RESULTS AND DISCUSSION

### Phenotypic characterization

The physical body characteristics for the six Ethiopian goat populations obtained in the present study are presented in Tables 2, 3 and Figure 1. The results show the presence of clear morphological variations between and within these indigenous goat ecotypes. The most frequent coat color was white with spots (20.7%), followed by brown with patch (17.5 %) and brown (15.4%) (Table 2). In general, black coats with or without spots or patches were less frequent than brown or white ones. There were different coat color types in Ethiopian goat populations in which black with spot (26.7%), brown with patch, brown and black with spots (25%) and brown were found more frequently in Gumuz, Abergelle and Central Abergelle goats, respectively, than other goat ecotypes.

There were varied coloration patterns amongst the goat populations sampled with predominantly spotted (36.1 %) followed by patchy (32.4 %) and plain (30.4 %) of various colors (Table 2, 3). Similar coat pattern and color as in the studied goat populations were reported for indigenous goat types from other regions in Ethiopia (Alemayehu, 1994; Farm-Africa, 1996; Ameha, 2001) and for other local goat breeds elsewhere in Africa (Yakubu et al., 2010b). However, in some administrative zones of the study area, there were distinct colorations (Figure 1) in which *inter se* mating could lead to formation of specific ecotypes that agrees with the findings of Banerjee et al. (2000) who observed that coloration could be an adaptive trait or selected through farmers' preference for a specific coat color (Molefe, 1986; Indetie et al., 1998; Manzi et al., 2011). In Ethiopia, goat coat color has a direct effect on goat marketing value. Due to cultural taboo, for instance, goat with full black coat color is not preferred for slaughtering for home meat consumption (personal observation). Black colored animals including goats, however, are believed to have superior adaptation to seasonal cold weather or cold nights as the dark pigment helps them to warm up earlier than goats with other coat colors (Robertshaw, 2006).

Variations between and within goat ecotypes were also observed in head profile, horn orientation, ear form and head shape. Most of the goat ecotypes in Amhara Region of Ethiopia have slightly concave head profile, horizontal

ear form, spiral horn shape and upward horn orientation. For instance, nearly 87% of the Agew and Abergelle goat ecotypes had straight and slightly concave head profile, respectively. Also, more than 80% of the Bati goats have a straight horn shape (Table 3). Nearly 6% of the studied goats were polled in which the presence of horns in animals is considered as an advantage for the drainage of blood through the cavernous sinus as a control mechanism for thermal homeostasis (Robertshaw, 2006) as well as for better reproductive performances (Hasan and Shaker, 1990; Al-Ghalban et al., 2004; Kridli et al., 2005). More than 50% of the Gumuz and Agew goats had beard, while other goat populations had less than that, which is in line with other findings (Manzi et al., 2011).

All goats had smooth and short hair type with the absence of long hair on their thighs and abdomen. The Bati goats do not have wattle/toggles, while all other goat populations had toggles with varying proportions and percentages, which are in line with findings by Manzi et al. (2011), which was studied on Rwanda goat populations found in Bugesera and Nyagatare districts. Toggles are more commonly found in dairy and pygmy goat types (<http://www.dairygoatjournal.com>) and Spanish goats (Rodero et al., 1996). Such similar results were also reported in the literature (Odubote, 1994; Adedeji et al., 2006; Oseni et al., 2006) regarding morphological trait variations in small ruminants.

Average body weight of adult goats varied significantly ( $P < 0.001$ ) among the goat populations. The Gumuz goat (34.7 kg) population was significantly heavier than Central Abergelle (27.9 kg) and Abergelle goat (28.1 kg) ecotypes with an overall mean of 31.14 kg (Table 4). There were also significant ( $p < 0.001$ ) variations in linear body measurements among the goat populations: the Begia-Medir goat with an average height of 71 cm at withers was significantly taller than all other goat ecotypes, while Gumuz goats were the shortest with 65 cm height at withers. According to Peters and Horst (1981), body size is a suitable criterion for classification since it gives clues to potential performance. Devendra and Burns (1983) have classified tropical goats based on body size: large (>65 cm at the withers), small (51 to 65 cm) and dwarf (<50 cm).

The heart girth of Gumuz, Agew and Begia-Medir was significantly ( $p < 0.001$ ) larger than that of Bati, Abergelle and Central Abergelle goat ecotypes. Abergelle goats had shorter ears than all other goat genotypes.

### Population structure analysis

The hierarchical cluster analysis generated a phylogenetic tree that clustered the six goat populations of Amhara Region into two main groups (namely, east and west Amhara Region goat populations) that were

**Table 2.** Mean observed (%) values for body coat color in Ethiopian indigenous goats.

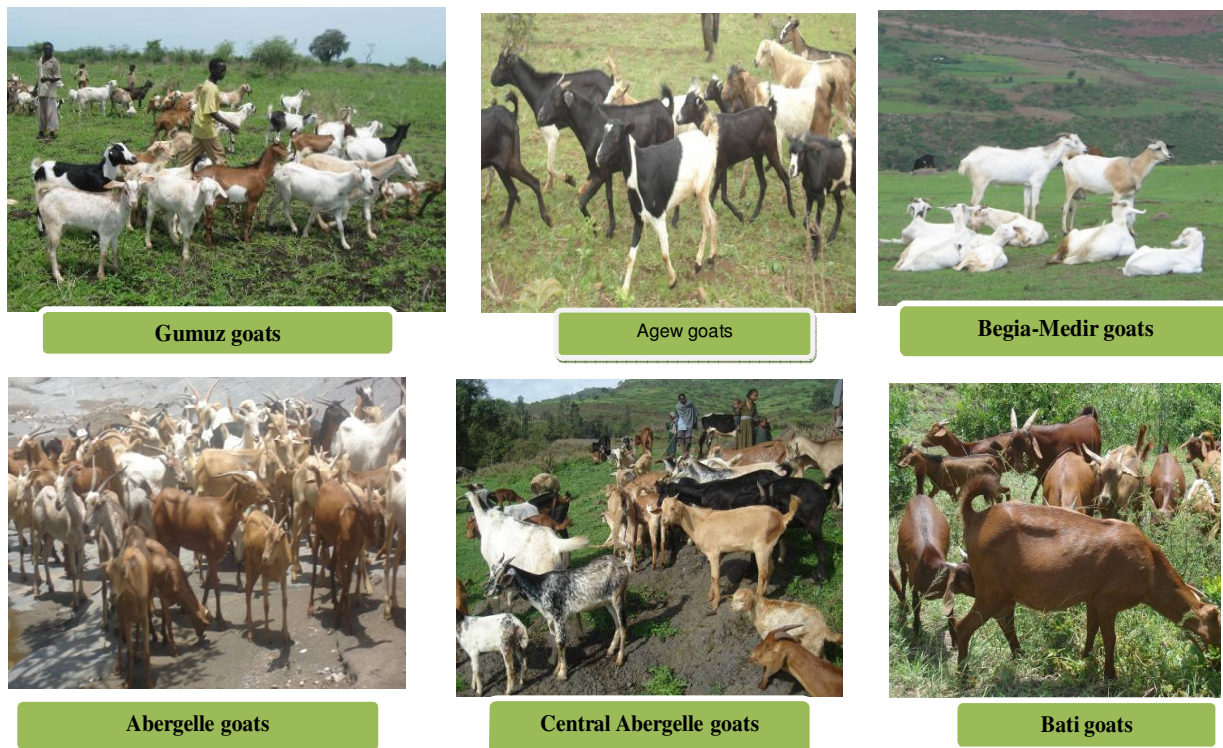
Coat color	Goat ecotype						Overall mean
	Gumuz	Agew	Begia-Medir	Bati	Central Abergelle	Abergelle	
Black	-	6.60	-	-	10.00	-	8.30
Brown	3.33	6.67	10.00	33.33	26.67	12.50	15.42
White	16.67	10.00	16.67	13.33	6.67	-	12.67
White with spot	23.33	26.67	40.00	6.67	6.67	-	20.67
White with patch	10.00	16.67	10.00	20.00	13.33	12.50	13.75
Brown with patch	13.33	20.00	10.00	16.67	20.00	25.00	17.50
Brown with spot	6.67	6.67	13.33	6.67	6.67	25.00	10.83
Black with spot	26.67	3.33	-	3.33	3.33	25.00	12.33
Black with patch	-	3.33	-	-	6.67	-	5.00

**Table 3.** Mean observed (%) values for qualitative traits in Ethiopian indigenous goats.

Morphology	Trait	Goat ecotype						Overall Mean
		Gumuz	Agew	Begia-Medir	Bati	Abergelle	Central Abergelle	
Coat pattern	Plain	23.33	23.33	33.33	46.67	12.50	43.33	30.42
	Patchy	16.67	40.00	23.33	36.67	37.50	40.00	32.36
	Spot	53.33	36.67	43.33	16.67	50.00	16.67	36.11
Head profile	Straight	66.67	13.33	46.67	26.67	12.50	16.67	30.42
	Slight convex	-	-	-	3.33	-	-	3.33
	Slight concave	33.33	86.67	53.33	36.67	87.50	60.00	59.58
	Concave	-	-	-	33.33	-	23.33	9.44
Ear form	Erect	-	-	-	-	87.50	3.33	15.14
	Horizontal	96.67	96.67	86.67	100.00	12.50	96.67	81.53
	Pendulous	-	3.33	13.33	-	-	-	2.78
Horn shape	Polled	3.33	23.33	6.67	-	-	-	5.56
	Straight	30.00	20.00	16.67	80.00	-	13.33	26.67
	Curved	46.67	10.00	46.67	-	25.00	36.67	27.50
Horn orientation	Spiral	20.00	46.67	30.00	20.00	75.00	50.00	40.28
	Upward	36.67	56.67	36.67	93.33	37.50	33.33	49.03
	Backward	60.00	20.00	56.67	6.67	62.50	66.67	45.42
	Polled	3.33	23.33	6.67	-	-	-	5.56
Hair type	Short	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Hair on thigh		13.33	-	13.33	-	-	-	4.44
Hair on abdomen		100.00	100.00	100.00	100.00	100.00	100.00	100.00
Presence of wattle/toggles		20.00	26.67	13.33	-	37.50	3.33	16.81
Presence of beard		56.67	53.33	23.33	33.33	12.50	16.67	32.64

consistent with their geographical origins. The first group included goat populations from west Amhara Region, that

is, Gumuz, Agew and Begia-Medir, while the second group comprised goats from east Amhara Region, that is,



**Figure 1.** Physical variations in Ethiopian indigenous goat ecotypes.

Bati, Abergelle and Central Abergelle goats. Further subdivisions in each of the main clusters showed that Agew and Begia-Medir were more closer to each other than to Gumuz goats and the same was true for Bati and Abergelle as compared to Central Abergelle goats (Figure 2).

The clustering of the goat populations using morphological data did not match with the phylogenetic tree constructed based on the molecular data which was obtained from the same goat individuals and populations (Halima et al., 2012). Molecular data clustered the six goat populations into two groups: the Abergelle goats in one main group and the Agew, Gumuz, Bati, Begia-Medir and Central Abergelle goats in the second group. Such differences might have occurred due to the fact that indigenous animal genetic resources characterization using morphological data is more sensitive to environmental factors together with human errors, while molecular characterization using microsatellite markers have the ability to detect species-specific bands and are more informative for establishing the detailed relationships between goat ecotypes and potentially powerful enough for distinguishing between closely related sheep breeds (Buduram, 2004; Gizaw, 2008). Furthermore, there is an extensive and random distribution of indigenous livestock populations including goats from one administrative zone to another by both

governmental and non-governmental organizations that could lead to the reduction of the existing goat genetic resources. These propose that the classifications of animal genetic resources based on historical, anthropological and morphological evidences (Ali, 2003) as well as their geographical origin are not satisfactory and enough for the purpose of conservation and utilization of these resources.

#### **Relationship between body weight and other body measurements**

The correlation coefficient analyses were carried out in the present study to figure out and establish the relationship between live body weights with other body measurement traits of two goat populations found in Amhara Region of Ethiopia (Table 5). Accordingly, correlation coefficients ( $r$ ) between live weight and other body measurement traits were found positive with the presence of highly significant ( $P < 0.01$ ) associations of body weight with heart girth ( $r = 0.899$ ) and body weight with body length ( $r = 0.729$ ) for west Amhara Region goat populations' (Gumuz, Begia-Medir and Agew goat ecotypes). Moreover, a highly significant  $r$ -values were also obtained for the east Amhara Region goat populations (Bati, Abergelle and

**Table 4.** Descriptive statistics for live body weight and other body measurements for Ethiopian indigenous goats.

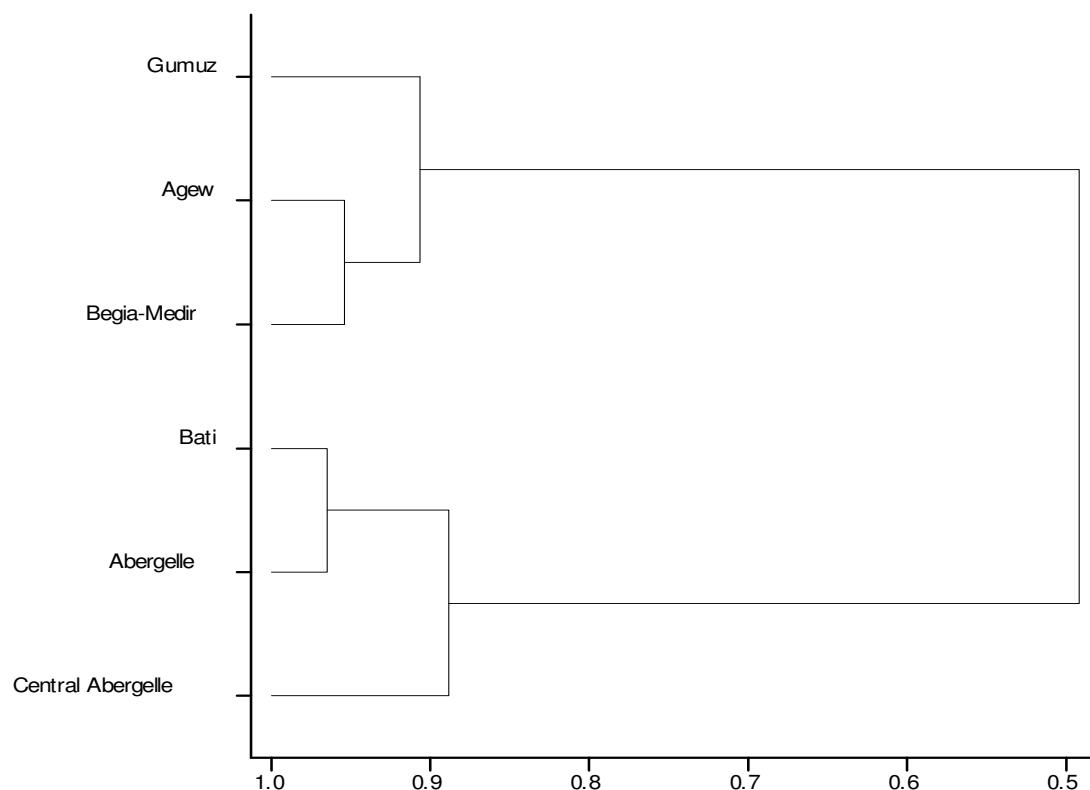
Variables		Goat ecotypes						Overall Mean
		Gumuz	Agew	Begia-Medir	Bati	Abergelle	Central Abergelle	
Body weight (kg)	Mean	34.65 <sup>a</sup>	31.47 <sup>ab</sup>	32.54 <sup>ab</sup>	29.87 <sup>bc</sup>	28.07 <sup>c</sup>	27.88 <sup>c</sup>	31.14
	Min	25	22	23	23	25	21	21
	Max	47	41	50	38	31	34	50
	SE	0.95	0.83	1.14	0.77	0.79	0.63	0.41
Height at wither (cm)	Mean	65.09 <sup>c</sup>	67.4 <sup>b</sup>	71.35 <sup>a</sup>	66.36 <sup>bc</sup>	67.19 <sup>bc</sup>	68.07 <sup>b</sup>	67.63
	Min	61	60	66	59	63	63	59
	Max	69	73	79	71	76	77	79
	SE	0.47	0.60	0.63	0.49	1.47	0.52	0.29
Body length (cm)	Mean	63.69 <sup>ab</sup>	63.52 <sup>ab</sup>	64.35 <sup>a</sup>	61.78 <sup>b</sup>	61.38 <sup>b</sup>	63.15 <sup>ab</sup>	63.20
	Min	57	56	57	55	59	57	55
	Max	70	74	72	69	63	70	74
	SE	0.65	0.74	0.70	0.63	0.51	0.59	0.29
Heart girth (cm)	Mean	75.03 <sup>a</sup>	73.00 <sup>a</sup>	73.93 <sup>a</sup>	70.02 <sup>b</sup>	70.56 <sup>b</sup>	70.53 <sup>b</sup>	72.4
	Min	67	67	66	64	67	66	64
	Max	87	80	84	76	75	80	87
	SE	0.77	0.58	0.74	0.56	0.93	0.66	0.32
Rump width (cm)	Mean	14.23 <sup>a</sup>	13.93 <sup>ab</sup>	14.25 <sup>a</sup>	13.57 <sup>bc</sup>	13.13 <sup>cd</sup>	12.79 <sup>d</sup>	13.65
	Min	12.5	12.5	13	12	12.5	11.5	11.5
	Max	16.5	16	16	15	14	14	16.5
	SE	0.15	0.15	0.17	0.16	0.18	0.14	0.08
Sacral pelvic width (cm)	Mean	9.66 <sup>a</sup>	9.79 <sup>a</sup>	9.54 <sup>a</sup>	7.70 <sup>c</sup>	8.4 <sup>b</sup>	7.99 <sup>bc</sup>	8.85
	Min	8	9	8	7	8	7	7
	Max	13	12	16	9	10	11	16
	SE	0.16	0.16	0.28	0.10	0.32	0.20	0.12
Ear length (cm)	Mean	13.23 <sup>a</sup>	13.79 <sup>a</sup>	14.44 <sup>a</sup>	13.72 <sup>a</sup>	11.19 <sup>b</sup>	13.86 <sup>a</sup>	13.67
	Min	12	11	13	10	9	13	9
	Max	16	16	16	16	14	16	16
	SE	0.54	0.44	0.16	0.31	0.62	0.14	0.16

Values with different superscript letters differ significant at  $p < 0.001$ , SD, standard deviation; SE, standard error; Min, minimum; Max, maximum.

Central Abregelle goats) as indicated in Table 5. The present high correlations between heart girth and live body weight show that the body weight of goats can be predicted from heart girth measurements of goats, which is in agreement with other finds (Slippers et al., 2000; Fajemilehin and Salako, 2008; Sowande et al., 2010; Cam et al., 2010).

Results of the linear regression analyses of body weight with heart girth showed a moderately high relationship between these variables with a coefficient of determination values of  $R^2 = 0.807$ ;  $y = 1.273x - 61.329$  and  $R^2 = 0.095$ ;  $y = 0.486x - 5.799$  for the west (Table 5

Figure 3) and east (Figure 4) Amhara Region goat ecotypes, respectively. The regression between body weight and body length was also significant ( $R^2 = 0.532$ ;  $y = 1.041x - 33.644$ ) (Figure 3). These findings indicate that an increase of one cm of heart girth or body length resulted in an increase of 1.273 and 1.041 kg of live weight, respectively, which is in line with findings on goats elsewhere (Oztork et al., 1994; Nsoso et al., 2003; Atta and El Khidir, 2004). The high and significant correlation coefficient between body weight with heart girth and body length suggest that either of these variables or their combination would provide a good estimator for



**Figure 2.** Dendrogram based on average linkage distance between adult goats using quantitative body traits measurement

**Table 5.** Pearson's correlation coefficient values among body morphological traits measured in west Amhara (Gumuz, Agew and Begja-Medir: below diagonal) and east Amhara Region goat populations (Bati, Abergelle and Central Abergelle: above diagonal).

Variable	Body weight	Body length	Heart girth	Sacral pelvic width	Rump width	Ear length
Body weight	xxx	0.538**	0.823**	0.292**	0.748**	0.214**
Body length	0.729**	xxx	0.607**	0.284**	0.366**	0.240
Heart girth	0.899**	0.627**	xxx	0.189**	0.567**	0.087**
Sacral pelvic width	0.298**	0.173**	0.281**	xxx	0.257**	0.251**
Rump width	0.684**	0.579**	0.659**	0.201**	xxx	0.125**
Ear length	0.017 <sup>ns</sup>	0.048 <sup>ns</sup>	0.045 <sup>ns</sup>	-0.002 <sup>ns</sup>	-0.052 <sup>ns</sup>	xxx

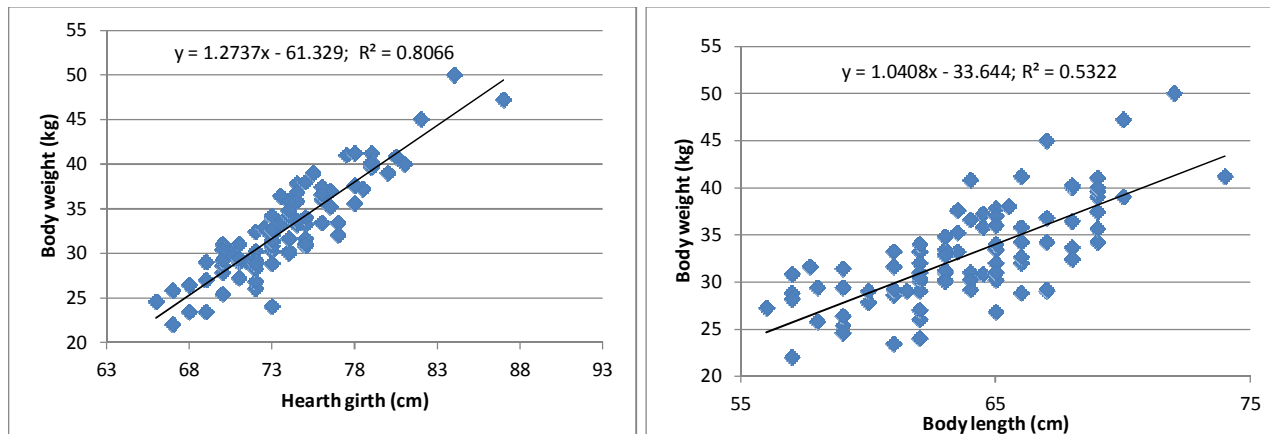
\*\* = P<0.01, ns non significant.

predicting live body weight in Ethiopian goat ecotypes, especially in areas where weighing scale is not available. Moreover, such relatively high relationship of heart girth with weight could be used as a proxy to estimate live body weight for indigenous goats for countries like Ethiopia where formal breed data recording schemes are not well established. In general, such assessment of body measurements in goats remains very important for avoiding the errors of visual determination of animal weights in areas where weighing balance cannot be

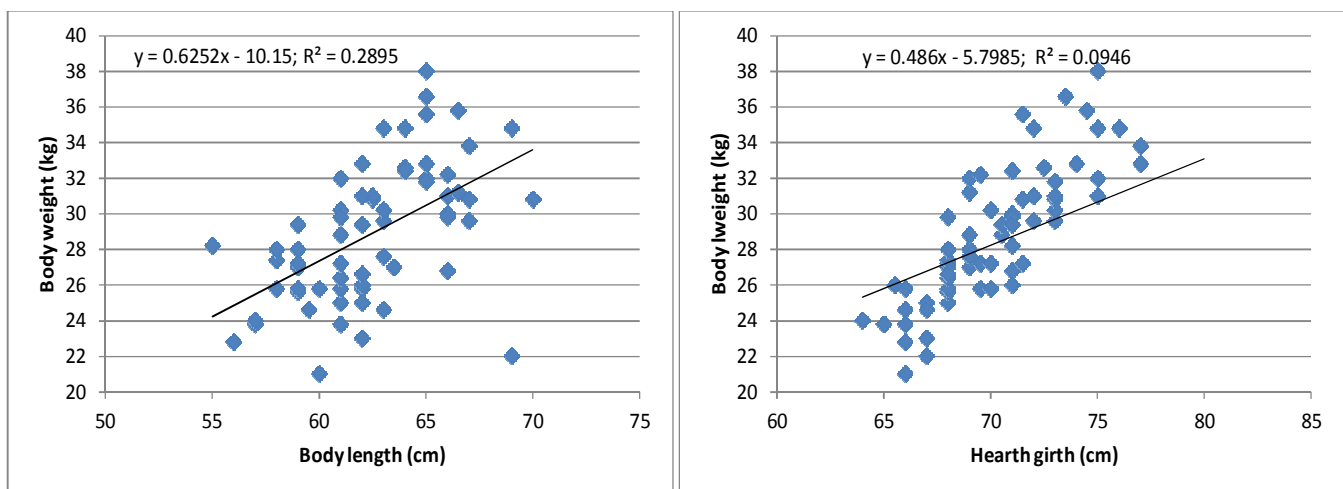
assessed.

In conclusion, both morphological and molecular markers show a high degree of variation among and within the Ethiopian goat populations analyzed. Dendrograms constructed from morphological and molecular data separated the six Ethiopian goat populations into two main groups with differences in each cluster group. The contrast in the clusters derived from morphological and molecular data clearly shows that genetic relatedness cannot be easily derived from





**Figure 3.** Prediction of west Amhara Region goat populations (Gumuz, Agew and Begia-Medir) live body weight using heart girth and body length measurements.



**Figure 4.** Prediction of east Amhara Region goat populations (Bati, Abergelle and Central Abergelle) live body weight using heart girth and body length measurements.

phenotypic similarity. However, a small genetic distance between genotypes may still be linked to an important productive or adaptive trait. Thus, it would be useful to include performance data into characterization studies to understand which genotypes have comparative advantages within an agro-ecological zone.

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## REFERENCES

- Adedeji TA, Ojedapa LO, Adedeji SO, Aderogba TA, Abdullah A (2006). Characterization of traditionally reared West African Dwarf goats (WAD) in the derived Savannah zone of Nigeria. *J. Anim. Vet. Adv.* 5(8):686-688.
- Alemayehu N (1994). Characterization of indigenous goat types of Eritrea, Northern and Western Ethiopia. M.Sc. Thesis, Alemaya University of Agriculture, Ethiopia.
- Alemu T (2004). Genetic characterization of indigenous goat populations of Ethiopia using Microsatellite markers (<http://hdl.handle.net/10568/3929>). Ph.D. Thesis, Karmal National Dairy Research Institute (Deemed University, India).
- Al-Ghalban AM, Tabbaa MJ, Kridli RT (2004). Factors affecting semen characteristics and scrotal circumference of Damascus bucks. *Small Rumin. Res.* 53:141-149.
- Ali BA (2003). Genetics similarity among four breeds of sheep in Egypt detected by random amplified polymorphic DNA markers. *Afr. J. Biotechnol.* 2:194-197.



- Ameha G (2001). On-farm characterization of types and evaluation of productivity of goats in northern, western part of Ethiopia. M.Sc. Thesis, Alemaya University of Agriculture, Ethiopia.
- Atta M, El-Khidir OA (2004). Use of heart girth withers height and scapulaischial length for prediction of live weight of Nilotic sheep. *Small Rumin. Res.* 55(1-3):233-237.
- Ayalew W, Rowlands J (2004). Design, execution and analysis of the livestock breed survey in Oromia regional state, Ethiopia and ILRI, Kenya.
- Banerjee AK, Anmut G, Ermias E (2000). Selection and breeding strategies for increased productivity of goats in Ethiopia. In: R.C. Merkel, G. Abebe and A.L. Goetsch (eds.). Proceedings of a conference on opportunities and challenges of enhancing goat production in East Africa, Institute for goat research, Langston University pp.70-79.
- Buduram P (2004). Genetic characterization of South African sheep breeds using DNA markers (etd.uovs.ac.za/etd-db/theses). M.Sc. Thesis, University of Free State, South Africa.
- Cam MA, Olfaz M, Soydan E (2010). Possibilities of using morphometrics characteristics as a tool for body weight prediction in Turkish hair goats (Kilkeci). *Asia. J. Anim. Vet. Adv.* 5(1):52-59.
- Delgado JV, Barba C, Camacho ME, Sereno FTPS, Martinez A, Vega-Pla JL (2001). Livestock characterization in Spain. *AGRI.* 29:7-18.
- Derebe B (2008). Growth, reproductive performance and carcass characteristics of Abergelle and central highland goat types under traditional and slightly improved management in Sekota district. M.Sc. Thesis, Haramaya University, Ethiopia.
- Devendra C, Burns M (1983). Goat production in the tropics. Common Wealth Agricultural Bureaux, Farnham Royal, London, UK.
- Fajemilehin OKS, Salako AE (2008). Body measurement characteristics of the West African Dwarf goat in deciduous forest zone of southwestern Nigeria. *Afr. J. Biotechnol.* 7(14):2521-2526.
- FAO (1986). Animal genetic resource data banks- 2. Descriptor lists for cattle, buffalo, pigs, sheep and goats. Animal production and health paper No. 59/2, Rome, Italy.
- Farm-Africa (1996). Goat types of Ethiopia and Eritrea: Physical description and management systems. Farm-Africa, UK and ILRI, Kenya.
- Food and Agriculture Organization of the United Nations (FAO) (1999). *AGRI.* Paper No. 25, Rome, Italy.
- Gizaw S (2008). Sheep genetic resources of Ethiopia: Genetic diversity and breeding strategy (www.eap.gov.et/sites/default/files/sheepresources\_eth.pdf). Ph.D. Thesis, Wageningen University, Netherlands.
- Halima H, Lababidi S, Rischkowsky B, Baum M, Tibbo M (2012). Molecular characterization of Ethiopian indigenous goat populations. *Trop. Anim. Health Prod.* 44(6):1239-1246.
- Hasan NA, Shaker B (1990). Goat resources in Arab States. The Arab center for the studies of arid zones and dry lands, Damascus, Syria.
- Indetie D, Karimi S, Wandera F, Lebbie S, Mwai O (1998). Phenotypic characteristics of east African goats in Kajiado districts of Kenya. Sixth Biennial KARI Scientific Conference.
- Institute of Biodiversity Conservation (IBC). (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, Addis Ababa, Ethiopia.
- Kosgey IS, Okeyo AM (2007). Genetic improvement of small ruminants in low-input smallholder production systems: Technical and infrastructural issues. *Small Rumin. Res.* 70(1):76-88.
- Kridli RT, Tabbaa MT, Sawalha RM, Amashe MG (2005). Comparative study of scrotal circumference and semen characteristics of mountain black goat and its crossbred with Damascus goat as affected by different factors. *Jordan J. Agri. Sc.* 1(1):18-25.
- Lanari MR, Taddeo H, Domingo E, Centeno MP, Gallo L (2003). Phenotypic differentiation of exterior traits in local Criollo goat population in Patagonia (Argentina). *Archiv Tierzucht Dummerstorf.* 46:347-356.
- Manzi M, Rutagwenda T, Kanuya N, Chatikobo P (2011). Phenotypic characterization of goats raised under traditional husbandry systems in Bugesera and Nyagatare districts of Rwanda. *J. Anim. Vet. Adv.* 10(24):3297-3302.
- Martins GEN, Quadros SAF, Trindade JPP, Quadros FFL, Costa JHC, Raduenz G (2009). Shape and function in Braford cows: The body shape as an indicative of performance and temperament. *Archivos de Zootecnia* 58:425-433.
- Molefe DS (1986). Sheep and goat production in Botswana. In: K.O. Adeniji and J.A. Kategile (eds.). Proceedings of a workshop on the improvement of small ruminants in Eastern and Southern Africa, Nairobi p. 235-243.
- Mwacharo JM, Okeyo AM, Kamande GK, Rege JEO (2006). The small east African shorthorn zebu cows in Kenya: Linear body measurements. *Trop. Anim. Health Prod. J.* 38:65-76.
- Nesamvuni AE, Mulaudzi J, Ramanyimi ND, Taylor GJ (2000). Estimation of body weight in Nguni-type cattle under communal management conditions. *South Afr. Anim. Sci. J.* 30(Supplement 1):97-98.
- Nsoso SJ, Aganga AA, Moganetsi BP, Tshwenyane SO (2003). Body weight, body condition score and hearth girth in indigenous Tswana goats during the dry and wet seasons in Southeast Botswana. *Livest. Res. Rur. Dev.* 15(4):25-31.
- Odubote K (1994). Characterization of West African dwarf goats for certain qualitative traits. *Nigerian J. Anim. Prod.* 21:37-41.
- Oseni S, Soniya A, Omitogun G, Ajayi A, Muritala I (2006). West African dwarf goat production under village conditions: I- Characterization and the establishment of breed standards. Conference on International Agricultural Research for Development, University of Bonn, Germany.
- Oztorik A, Kayis SA, Parlat SS, Gurkan M (1994). The possibilities of estimating live weight using somebody measurements in Konya Merino. *J. Anim. Res.* 4(1):23-25.
- Pace JE, Wakeman DL (2003). Determining the age of Cattle by their teeth (<http://edis.ifas.ufl.edu/AN046>). University of Florida, Institute of Food and Agricultural Sciences, USA.
- Payne RW, Harding SA, Murray DA, Soutar DM, Baird DB, Glaser AI, Channing IC, Welham SJ, Gilmour AR, Thompson R, Webster R (2010). The guide to GenStat release 13. VSN International, Hemel Hempstead.
- Peters KJ, Horst P (1981). Development potential of goat breeding in the tropics and sub-tropics. *Anim. Res. Rev.* 14:54-71.
- Philipsson J, Rege JEO, Okeyo AM (2006). Sustainable breeding programmes for tropical farming systems. In: J. M. Ojango, B. Malmfors and A.M. Okeyo (eds.). *AGTR - version 2*, International Livestock Research Institute, Nairobi and Swedish University of Agricultural Sciences, Uppsala, Sweden.
- Robertshaw D (2006). Mechanisms for the control of respiratory evaporative heat loss in panting animals. *J. Appl. Physiol.* 101:664-668.
- Rodero E, de la Haba MR, Rodero A, Herrera M (1996). Genetic and phenotypic profiles of endangered Andalusian sheep and goat breeds *AGRI.* FAO publication No. 19.
- Sebsibe A (2006). Meat quality of selected Ethiopian goat genotypes under varying nutritional Conditions (upetd.up.ac.za/thesis/available/etd-07092008-081206/). Ph.D. Thesis, University of Pretoria, South Africa.
- Slippers SC, Letty B A, de Villiers J F (2000). Prediction of the body weight of Nguni goats. *South Afr. J. Anim. Sci.* 30(Supplement 1):127-128.
- Sowande O, Oyewale B, Iyasere O (2010). Age- and sex dependent regression models for predicting the live weight of West African Dwarf goat from body measurements. *Trop. Anim. Health Prod.* 42(5):969-975.
- Yakubu A (2010a). Path coefficient and path analysis of body weight and biometric traits in Yankasa lambs. *Slovak J. Anim. Sci.* 43:17-25.
- Yakubu A, Salako AE, Imumorin IG (2010b). Multivariate analysis of spatial patterns of morphological traits in West African dwarf goats in three agro-ecological zones of Nigeria. *J. Appl. Anim. Res.* 38:257-260.