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Original Research

Phenotypic Characterization of Indigenous Sheep Types in Eastern Arsi Zone of Oromia Regional State, Ethiopia

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Abstract

The study was conducted in Lode Hetosa, Lemmu Bilbilo, and Diksiis districts of the East Arsi zone of Oromia Regional State to undertake phenotypic characterization of indigenous sheep types. Multistage purposive and random sampling was employed as sampling techniques. Body weight, linear body measurements, and qualitative data were taken and observed on 576 mature sheep (500 females and 76 male sheep). In all districts, sheep were primarily kept for income generation. The major available feeds for the wet and dry seasons were natural pasture and crop residues, respectively. Disease was ranked as the first pertinent constraint for sheep production in all study districts. Most East Arsi sheep populations were characterised by a plain coat colour pattern accompanied by various coat colour types (plain brown, light red, and red, and brown + white coat colour) and medium-length hair. Body weight and heart girth were found to be positively correlated in both sexes. The regression analysis showed that body weight, in most of the cases, could be predicted with a higher level of accuracy from more than one independent variable or in combination with various variables. Generally, no significant differences were observed among the sheep types found in the study districts, indicating that they are the same breed.

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INTRODUCTION

Ethiopia is endowed with huge livestock resources and varied and diversified genetic pools with specific adaptations to a wide range of agro-ecologies (Tassew et al., 2014). The livestock sector has been contributing to the economy of the country and has the potential to contribute more to the economic development of the country. It is eminent that livestock products and by-products in the form of meat, milk, honey, eggs, cheese, and butter, etc., provide the needed animal protein that contributes to the improvement of the nutritional status of people (CSA, 2016). Poor people in major parts of Ethiopia and other underdeveloped nations utilise livestock as sources of cash income and food (milk, meat, and eggs). Therefore, utilising the farm animal genetic resources efficiently and optimally is crucial for both food security and the sustainable development of the country (Zelealem and Anil, 2013).

Sheep is the second most important livestock species in Ethiopia, estimated at 28.89 million heads (CSA, 2016). There are diverse breeds and sheep types distributed from the cool alpine climate of the mountains to the arid pastoral areas of the lowlands (Gizaw, 2008). The indigenous sheep are owned and managed by smallholder farmers as an integral part of the livestock sub-sector (Duguma, 2010). Sheep contribute substantial amounts of income, food (meat and milk), and non-food products such as manure, skins, and coarse wool. They also serve as a means of risk mitigation during crop failures, property security, monetary saving, and investment, in addition to many other socio-economic and cultural functions (Tibbo, 2006; Zewdu, 2008). Indigenous sheep breeds are highly adapted to low-input systems or are naturally selected for survival in suboptimal and disease-ridden environments (Tibbo et al., 2006).

Genetic improvement is one way to increase the productivity of the sheep resources in Ethiopia. The essential procedure for genetic improvement of livestock involves the identification of available breeds or strains and the characterization of existing production systems or production environments in which they are kept. Moreover, descriptions of breed characteristics and their adaptation, as well as production potential in those environments, are crucial for designing genetic improvement programmes (Workneh and Rowlands, 2004). Phenotypic characterization of animal genetic resources is the process of identifying distinct breed populations and describing their external and production characteristics in a given environment and under given management, taking into account the social and economic factors that affect them (FAO, 2012). There are limited studies on the characterization activities of sheep types found in the Arsi zone. Thus, to fill this gap, the present study was executed in Lode Hetosa, Lemmu Bilbilo, and Diksiis districts of the East Arsi zone to undertake phenotypic characterization of indigenous sheep types found in the districts.

MATERIALS AND METHODS

Description of the Study Area

The present study was carried out in Lode Hetosa, Lemmu Bilbilo, and Diksis districts of the East Arsi zone, which is located in south-eastern Ethiopia at latitude and longitude of 7°44’ N and 39°29’ E, respectively. The elevation of the East Arsi zone ranges from 1500 to 4245 m.a.s.l. The administrative town of the zone is Asella. The total livestock population in the East Arsi Zone was estimated at 7.9 million. Out of this, about 2.5 million are cattle, 1.6 million are sheep, 1.1 million are goats, 0.24 million are horses, 0.024 million are mules, 0.46 million are donkeys, 0.062 million are camels, 1.8 million are chickens, and 0.095 million are beehives (CSA, 2016). The East Arsi zone was selected for morphological characterization of sheep types and their production systems because it is mainly dominated by sheep production next to cattle and poultry production. The map of the study area is shown in Figure 1.

The altitude and temperature of Lode Hetosa district was ranging from 1800 to 3200 m.a.s.l. and 10 °CC, respectively. The area receives an annual rainfall of 800-1400mm. Lode Hetosa district has three major agro-ecologies: lowland (5%), midland (41%), and highland (51%). The main rainy season of the district occurs between March and September, and the dry season lasts from October to February.

The altitude of Lemmu Bilbilo district ranged from 1500 to 4180 m.a.s.l. The district receives an average annual rainfall of about 1100mm and has an average annual temperature ranging from 60 °C to 26°C. About 3%, 17%, and 80% of Lemmo Bilbilo district are categorised as lowland, midland, and highland, respectively. The main rainy season in all districts occurs between March and September, and the dry season lasts from October to February. The altitude of Diksiis district ranged from 2550 to 3600 m.a.s.l. The area receives an average annual rainfall range of 700mm to 1200mm and has an average annual temperature ranging from 100°C to 26°C. The main rainy season of the district occurs between March and September, and the dry season lasts from October to February. The district has only highland agro-ecology.

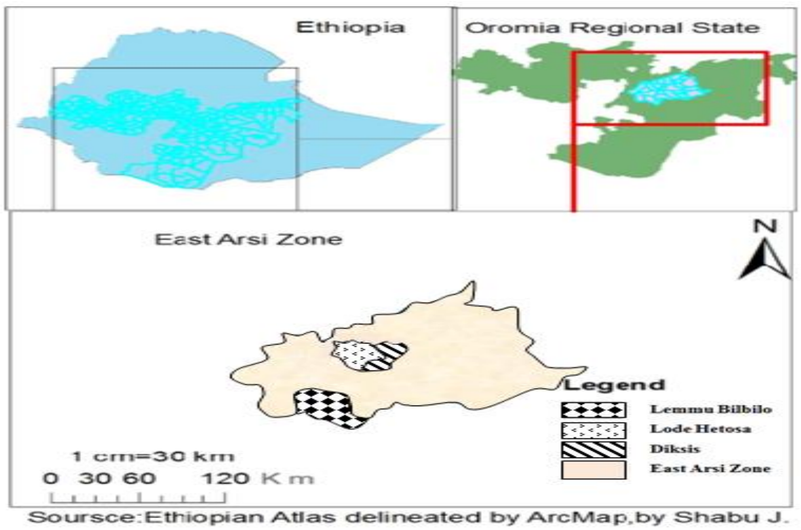

Figure 1: *Map of the study area*

Sampling Techniques and Sample Size

Multistage purposive sampling techniques were employed in the current study. In the first stage, districts known for having the highest sheep population were selected. Accordingly, out of 24 districts in East Arsi Zone, three were selected purposefully based on their sheep population, ranked one up to three. In the second stage, three gandas from each district were selected. At the third stage, households were selected purposefully, based on ownership of a minimum of two sheep, together with the respective district staff of livestock and fishery resources development offices and kebele administrators for characterization of the production practises. The total sample size was determined using the probability proportional to size sampling technique (Cochran, 1977).

The formula for sample size determination is:

$n = ((z^2 pq)/d^2)/(1+1/N ((z^2 pq)/d^2 -1))$

Where:

n = the number of sample sizes when the population is less than 10,000.

z = z value (1.96 for 95% confidence level),

p = estimated value for the variability of the population,

q = 1-p,

N = denotes the total population, and

d = margin of error or degree of accuracy desired

Using the above formula with the assumption of a 5% standard of error (d), a 95% confidence level (z = 1.96), and 10% variability assumed (p) for the population size (N) of 7439 households in the sampling frame provided a sample size of 136 households.

Methods of Data Collection

Sampled sheep for body weight, linear body measurements, and qualitative traits were taken from a random sample of 500 mature female sheep and 76 mature male sheep following FAO (2012). The age of the animal was estimated using dentition. Measurements were made on individual sheep from randomly selected flocks until the target number of sample animals was reached. Linear body measurements were made using measuring tape, while live body weights were taken using a suspended spring balance with a 50 kg capacity. For qualitative traits, visual observations were made following the breed morphological characteristics descriptor list of FAO (2012), and qualitative traits were recorded from a total of 576 mature sheep.

Visual observations were made, and morphological features were recorded based on breed morphological characteristics following the descriptor list of FAO (2012) for phenotypic characterization. A total of 14 discrete or qualitative traits were examined for both female and male sheep. Coat colour pattern, coat colour type, hair length, horn nature, horn shape, horn orientation, ear orientation, head profile, rump profile, tail type, tail form, wattle, ruff, and temperament were qualitative traits considered. Regarding quantitative attributes, sixteen traits were measured and recorded for both male and female sheep. The traits included were body weight, body length, height at withers, canon bone length, canon bone circumference, heart girth, rump length, rump width, pelvic width, tail length, head length, head width, horn length, and ear length (Figure 2). In addition, scrotal circumference was also considered for male sheep.

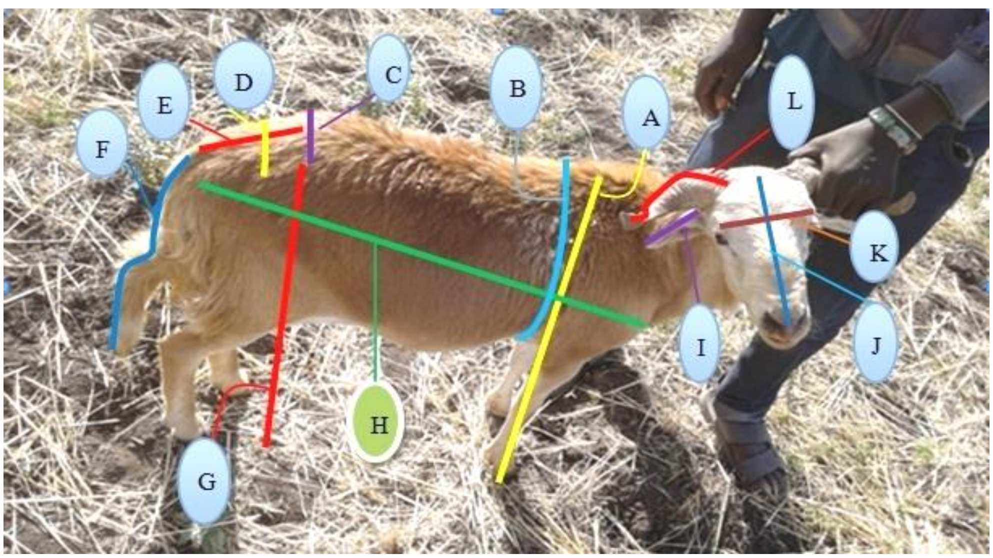

Figure 2 *Map of the study area*

Note:

A=height at wither	B=heart girth	C= pelvic width
D=rump width	E= rump length	F=tail length
G=height at rump	H=body length	I=ear length
J=head length	K=head width	L=horn length

Each animal was identified by its sex, age (based on dentition), and sampling site. According to FAO (2012), sheep were classified into lambs (under 1 year) with 8 sharp milk incisors, yearlings (1–2 years) with a central pair of permanent incisors, young adults (2–3 years) with 2 pairs of permanent incisors, adults (3–4 years) with 3 pairs of permanent incisors, and mature (4–5 years) with 4 pairs of permanent incisors.

The physical description was analysed using SPSS version 23. The data on quantitative traits was analysed according to general linear model procedures (PROC GLM) of the Statistical Analysis System (SAS, 2004 version 9.3). The location (districts), age, and sex of the sheep were fitted as fixed variables in the mathematical model for all quantitative traits except scrotal circumference, wherein the effect of sex was not included as a variable in the model. The model for analysis of all quantitative traits except scrotal circumference was:

+ Ai + Bj + Sk + (BxS)jk + eijkl = Yijkl

Where: Yijkl = observed body weight or linear measurements for the animal in the k^{th} sex, j^{th} age group, and i^{th} district;

μ = overall mean

A_i = fixed effect of ith district (i = 1,..., 3);

B_j = fixed effect of j^{th} age classes (j = 1,...,4);

S_k = fixed effects of k^{th} sex (k = 1, 2),

$(BxS)_{jk}$ = interaction effect between age and sex of animal;

e_{ijkl} = random residual error

The model analysis of scrotal circumference in males was:

$Y_{ijk} = \mu + A_i + B_j + e_{ijk}$

Where: Y_{ijk} = observed scrotal circumference of the animal in the age group and district;

μ = overall mean;

A_i = fixed effect of ith district (i = 1,...,3);

B_j = fixed effect of j^{th} age classes (j = 1,...,4)

e_{ijk} = random residual error

Correlations of live body weight with different body measurements studied were computed for each sex separately using the Pearson correlation coefficient. The stepwise regression procedure of SAS was used to estimate the regression coefficient of body weight on various linear body measurements in both sexes across all age groups separately in order to develop the best-fit regression equation for the prediction of live body weight.

The best-fitting models were selected based on a higher coefficient of determination (R^2) and a smaller mean square error. The following models were fitted for the estimation of male and female sheep body weight from linear body measurements.

- For Male:

$Y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_{17} X_{17} + e_j$

Where:

Y= Response (dependent) variable (body weight);

β_o = the intercept;

$\beta_1, \ldots, \beta_{17}$ = regression coefficients of independent variables ($X_1, \ldots, X_{17}$);

$X_1, \ldots, X_{17}$ = body measurement (independent variables) including scrotum Circumference;

e_j= random error

- For female:

$Y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_{16} X_{16} + e_j$

Where:

Y = Response (dependent) variable (body weight);

β_o = the intercept;

$\beta_1, \ldots, \beta_{16}$ = regression coefficients of independent variables ($X_1, \ldots, X_{16}$);

$X_1, \ldots, X_{16}$ = body measurement (independent variables); and ej= random error

RESULTS AND DISCUSSION

General Household Characteristics

The results of the current study showed that about 87% of respondents were male household heads, whereas 13% of the respondents were female household heads. This was in agreement with results reported by Mesfin (2015) in the Wolaita zone and Tesfaye (2008) in the Menz area of the Amhara regional state. With regard to the age structure of the respondents, about 38.3%, 35.8%, 15.4%, and 10.5% of the respondents were between the age groups of 36–50, 20–35, 51–60, and >60 years. These results showed that about 74.1% (38.3 + 35.8%) of respondents fell in the age group of 20–50 years, indicating that the three districts under study had a higher proportion of households of productive age.

The educational status of the respondents revealed that about 41.3% had attended primary (1–8 grades) education. This was in agreement with earlier reports by Michael (2013) in Gozamen, Sinan, and Huleteju districts of the east Gojjam zone of the Amhara regional state. The study also showed that about 27.8% of the respondents were able to read and write. Similarly, about 16% of respondents attended secondary (9–12 grades) education, whereas about 14.8% of respondents did not enroll in any formal education. The proportion of illiterates in the present study was lower than the report of Mesfin (2015) in the Wolaita zone. However, the proportion of primary and secondary education in the present study was lower than that reported by the same author. The current result also indicates that the higher proportion of farmers having either a primary or elementary educational background would be an opportunity to utilise modern technologies in sheep production.

Sheep Breeding Objectives in the Study Areas

The farmers' objectives for sheep rearing in the study area are presented in Table 1. As reported by the respondents, sheep are primarily kept for generating income in all the districts, with index values of 0.48, 0.47, and 0.47 in Lode Hetosa, Lemmu Bilbilo, and Diksiis, respectively. Similar results were reported by earlier workers (Tesfaye, 2008; Zewdu, 2008; Michael, 2013; Fsahatsion *et al*., 2013). The results further showed that the second and third reasons for sheep rearing in the study areas were saving (as a live bank for households) and social prestige, with index values of 0.21 and 0.19 for Lode Hetosa, 0.31 and 0.12 for Lemmu Bilbilo, and 0.27 and 0.20 for Diksiis districts, respectively.

Table 1

Sheep breeding objectives in the study areas

Breeding objectives	District											
	Lode Hetosa				Lemmu Bilbilo				Diksiis			
	1st	2nd	3rd	Index	1st	2nd	3rd	Index	1st	2nd	3rd	Index
Meat	1	3	19	0.09	0	2	15	0.06	0	4	6	0.04
Manure	0	0	11	0.03	0	3	8	0.04	0	0	5	0.02
Prestige	0	23	15	0.19	0	11	18	0.12	0	15	36	0.20
Saving	4	24	8	0.21	10	28	13	0.31	9	26	7	0.27
Income	49	4	1	0.48	44	10	0	0.47	45	9	0	0.47

Feed Resources

The feed resources available during both wet and dry seasons in the study areas are presented in Table 2. The availability and types of feed resources vary among seasons and locations. The different feed resources reported in the areas were natural pasture, improved forage, crop aftermath, crop residues, fallow land, and oats. A survey result by Alemayehu (2005) generalised that from the overall feed intake of animals in Ethiopia, natural pastures (including browse plants) and crop residues contributed 80–90% and 10-15%, respectively

Table 2

Feed resources during wet and dry seasons

Feed types	Districts											
	Lode Hetosa				Lemmu Bilbilo				Diksiis			
	1st	2nd	3rd	Index	1st	2nd	3rd	Index	1st	2nd	3rd	index
Wet season												
Natural pasture	24	16	5	0.35	45	8	0	0.47	54	0	0	0.57
Improved forage	0	0	0	0.00	0	0	2	0.01	0	0	0	0.00
Crop aftermath	0	8	5	0.07	0	2	4	0.03	0	4	7	0.05
Crop residues	12	6	12	0.19	0	6	20	0.10	0	19	3	0.14
Oat	17	19	12	0.33	0	24	11	0.19	0	22	6	0.18
Uncultivated land	1	2	10	0.06	9	14	11	0.21	0	4	7	0.05
Dry season												
Natural pasture	5	6	24	0.18	13	4	17	0.20	5	6	40	0.21
Improved forage	0	0	0	0.00	0	0	2	0.01	0	0	0	0.00
Crop aftermath	0	30	2	0.22	0	25	15	0.21	0	41	4	0.27
Crop residue	48	6	0	0.56	37	17	0	0.46	49	5	0	0.49
Uncultivated land	1	0	9	0.04	4	8	13	0.13	0	2	5	0.03

The main feed resources available during the wet season are natural pasture and oats, ranked number one and two with index values of 0.35, 0.47, and 0.57 for natural pasture and 0.33, 0.19, and 0.18 for oats in Lode Hetosa, Lemmu Bilbilo, and Diksiis districts, respectively. Crop residue ranked as the third source of feed in Lode Hetosa and Diksiis districts (0.19 and 0.14, respectively), whereas grazing on uncultivated lands ranked as the second feed source in Lemmu Bilbilo district (0.21). The present result with respect to natural pasture being the number one feed source during the wet season was in agreement with literature reports (Zewdu, 2008; Michael, 2013; Yenesew *et al.*, 2013).

During the dry season, crop residues ranked as the first source in all districts under study, with index values of 0.50, 0.39, and 0.44 in Lode Hetosa, Lemmu Bilbilo, and Diksiis districts, respectively. This was in agreement with the findings of Amelaml *et al.* (2015), who reported that the major feed resource commonly used in the dry season was crop residue in Tocha, Mareka, and Konta district in Dawuro Zone and Konta Special

Woreda of the South Region of Ethiopia. Crop residues, crop aftermath, and natural pasture were ranked as the 1st, 2nd, and 3rd feed sources in all districts (Table 5). Herding, tethering, and free grazing were the major feeding management strategies in the study areas.

Major Constraints on Sheep Production in the Study Areas

Identifying the constraints of sheep production is important to solve the problems facing sheep management and to improve sheep productivity. The major sheep production constraints reported by respondent sheep producers in study areas are presented in **Table 26**. The major constraints reported are diseases, feed shortages, predators, water shortages, and poor sheep types. Disease was ranked as the first important constraint in all study districts, with index values of 0.39, 0.40, and 0.40 in Lode Hetosa, Lemmu Bilbilo, and Diksiis districts, respectively. Similarly, feed shortage was ranked as the number two constraint in sheep production across all districts (index values of 0.30, 0.35, and 0.39 in Lode Hetosa, Lemmu Bilbilo, and Diksiis districts, respectively). According to Michael (2013), the severity of the problem was observed in cases of disease with high index values in Gozamen and Sinan districts in the east Gojjam zone of the Amhara region. Similarly, Zewdu (2008) reported that diseases, feed shortages, predators, and labour shortages were the most pertinent constraints that significantly influence sheep production in Horro and Bonga. Solomon (2007) also identified disease as the first and most important production constraint for Gumuz sheep in the North Western Lowland area of the Amhara Regional State.

Qualitative Traits of Indigenous Sheep

The results on qualitative traits of indigenous sheep studied in the present investigation in the study area are presented in Table 3. The chi-square test for these categorical variables showed that coat colour type, hair coat type, horn shape, horn orientation, ear orientation, head profile, rump profile, tail type, tail form, and temperament were found to be significantly ($p<0.05$) different among the districts, whereas coat colour pattern, horn nature, wattle, and ruff were found to be non-significant ($p>0.05$).

Coat Colour

The observed overall coat colour pattern for both sexes was plain (57.5%), patchy (29.9%), and spotted (12.7%). In contrast to the current study, Asefa *et al.* (2017) reported that the predominant coat colour pattern was patch (67.8%), followed by spotty (20.2%) of various colours for sheep types in the Bale zone of Oromia regional state.

The results of coat colour type showed that brown (22.6%) was the most frequently observed coat colour, followed by light red and red (20.7%), and brown with white (15.5%). In agreement with the current study, Gizaw *et al.* (2008) reported that the predominant coat colour for Arsi-Bale sheep types was brown. The results of hair length showed long hair length was predominant (69.3%) in the study area.

Horn

Results of the current study showed that about 62.3% of sampled sheep populations (both sexes) were horned, whereas about 37.7% were polled. However, males were 100% horned, whereas the proportion of horned females was 56.8% in the study areas. In agreement with the current finding, Gizaw (2008) reported that males and most females (52% of Arsi-bale sheep types) are horned. The shapes of the horns were curved, undeveloped, straight, and spiral, with proportions of 62.2, 22.4, 13.8, and 1.7% of sheep, respectively. The horn orientations observed in the sheep of the study areas were upward, backward, and lateral, out of which the backward orientation was predominant (49.2%), followed by upward (28.6%), and lateral (22.2%).

Ear Orientation and Head Profile

The ear orientations of sheep found in the study areas were erect, semi-pendulous, and carried horizontally. The horizontal ear orientation was most frequently observed in the districts (65.5%), whereas about 26.2, 6.6, and 1.7% of sheep had semi-pendulous, erect, and pendulous ear orientations, respectively. In contrast to this, Abera et al. (2014) reported that the most frequently observed ear orientation in sheep in the Selale area (Debre Libanos and Wuchale districts) of central Ethiopia was semi-pendulous. The most observed head profile was the straight head profile in 84.4% of the sheep population, followed by slightly convex (10.9%), concave (4.5%), and convex (0.2%) head profiles.

Rump Profile and Tail

The current study results revealed that sheep in the study areas had three types of rump profiles (flat, sloppy, and roofy). The proportions of sheep with sloppy, roofy, and flat feet were 87.7, 8.9, and 3.5%, respectively. The overall result showed that the predominant (51.7%) tail type observed in sample sheep populations was a thin tail. The overall proportion of fat-tailed sheep was higher in males (73%) as compared to females (28.9%). Contrary to this, the overall figures showed that a thin tail was more prevalent among females (56.4%) than males (20.3%). Contrary to current findings, Gizaw *et al*. (2008) reported that the predominant tail type for Arsi-Bale sheep types was a long, fat tail. The tail forms observed in the present study were curved, straight, and straight with a twisted end. The overall figures for both sexes showed that tails ending with a straight tip were more numerous (71.2%), followed by straight and twisted ends (23.4%), and a small proportion of curved ends (5.4%).

Wattle, Ruff, and Temperament

The presence of wattle in the study areas was less pronounced for both male and female populations. A total of only about 10.4% of both male and female sheep populations possessed wattles, whereas the majority (89.69%) was devoid of wattles. Ruff was grossly absent in most female sheep, whereas the majority (87.8%) of male sheep in the study areas have ruff. The present study showed that the majority of sheep in the study areas were docile (66.7%) in temperament, whereas 31.9 and 1.4% of sheep were moderately tractable and aggressive, respectively, in temperament(Table 3).

Table 3. *Qualitative traits of Sheep population in the study area*

Qualitative Character	District						Over all mean for both sex
	Lode Hetosa		Lemmu Bilbilo		Diksiis		
	Male N (%)	Female N (%)	Male N (%)	Female N (%)	Male N (%)	Female N (%)	N (%)
Coat color Pattern							
Plain	12(48)	98(58.7)	14(56)	96(57.5)	17(70.8)	94(56)	331(57.5)
Patchy	12(48)	47(28.1)	9(36)	49(29.3)	4(16.7)	51(30.4)	172(29.9)
Spotted	1(4)	22(13.2)	2(8)	22(13.2)	3(12.5)	23(13.7)	73(12.7)
							X^2value=0.35 ns
Coat color type							
Brown	6(24)	49(29.2)	8(32)	23(13.8)	7(29.2)	37(22)	130(22.6)
White	2(8)	20(12)	1(4)	19(11.4)	0(00)	16(9.5)	58(10.1)
Black	0(0)	5(3)	1(4)	27(16.2)	0(00)	5(3)	38(6.6)
Light Red and red	4(16)	22(13.2)	7(28)	39(23.4)	10(41.7)	37(22)	119(20.7)
Grey	1(4)	3(1.8)	1(4)	3(1.8)	0(00)	0(00)	8(1.4)
Roan	0(0)	1(0.6)	0(00)	0(00)	0(00)	0(00)	1(0.2)
Brown +white	8(32)	28(16.8)	3(12)	16(9.6)	4(16.7)	30(17.9)	89(15.5)
Light Red +white	4(16)	13(12)	2(8)	24(14.4)	2(8.3)	29(17.3)	84(14.6)
Black +white	0(00)	19(11.4)	2(8)	15(9.4)	1(4.2)	14(8.4)	49(8.5)
							X^2value=53.87*
Hair Length							
Medium	8(32)	61(36.5)	6(24)	48(28.7)	4(16.7)	50(29.8)	177(30.7)
Long	17(68)	106(63.5)	19(76)	119(71.3)	20(83.3)	118(70.2)	399(69.3)
							X^2value=3.67ns
Horn nature							
Present	25(100)	90(53.9)	25(100)	98(58.7)	24(100)	99(58.9)	359(62.3)
Absent	0(00)	77(46.1)	0(00)	69(41.3)	0(00)	69(41.1)	217(37.7)
							X^2value= 0.769ns
Horn shape							
Un developed	1(4)	26(28.6)	1(4)	27(27.6)	0(00)	26(26.3)	81(22.4)
Straight	0(00)	6(6.6)	1(4)	23(23.5)	0(00)	20(20.2)	50(13.8)
Curved	24(96)	56(61.5)	23(92)	47(48)	24(100)	51(51.5)	225(62.2)
Spiral	0(00)	3(3.3)	0(00)	1(1)	0(00)	2(2)	6(1.7)
							X^2value= 12.402*
Horn orientation							
Upward	1(4)	28(31.5)	1(4)	38(38.8)	0(00)	35(35.4)	103(28.6)
Back ward	21(84)	52(59.6)	18(72)	29 (29.6)	21(87.5)	35(35.4)	177(49.2)
Lateral	3(12)	8(9.0)	6(24)	31(31.6)	3(12.5)	29(29.3)	80(22.2)
							X^2value= 24.08*
Ear orientation							
Erect	3(12)	9(5.4)	0(00)	6(3.6)	5(20.8)	15(8.9)	38(6.6)
Semi-pendulous	2(8)	40(24)	6(24)	54(32.3)	5(20.8)	44(26.2)	151(26.2)
Pendulous	0(00)	6(3.6)	1(4)	3(1.8)	0(00)	0(00)	10(1.7)
Carried horizontal	20(80)	112(67.1)	18(72)	104(62.3)	14(58.3)	109(64.9)	377(65.5)
							X^2value=17.144*

Table 3 continued

Head profile							
Straight	18(72)	159(95.2)	18(72)	130(77.8)	14(58.3)	147(87.5)	486(84.4)
Concave	0(00)	5(3)	0(00)	21(12.6)	0(00)	0(00)	26(4.5)
Convex	0(00)	0(00)	0(00)	0(00)	0(00)	1(0.6)	1(0.2)
Slightly convex	7(28)	3(1.8)	7(28)	16(9.6)	10(41.3)	20(11.9)	63(10.9)
							X^2value= 42.184*
Ramp profile							
Flat	4(16)	2(1.2)	3(12)	8(4.8)	1(4.2)	2(1.2)	20(3.5)
Sloppy	21(84)	157(94)	22(88)	143(85.6)	22(91.7)	140(83.3)	505(87.7)
Roofy	0(00)	8(4.8)	0(00)	16(9.6)	1(4.2)	26(15.5)	51(8.9)
							X^2value= 16.465*
Tail type							
Thick at base	2(8)	42(25.1)	0(00)	16(9.6)	3(12.5)	16(9.5)	79(13.7)
Fat tailed	17(68)	43(25.7)	21(84)	57(34.1)	16(66.7)	45(26.8)	199(34.5)
Thin tailed	6(24)	82(49.1)	4(16)	94(56.3)	5(20.8)	107(63.7)	298(51.7)
							X^2value= 28.376*
Tail form							
Curved	3(12)	12(7.2)	0(00)	5(3)	2(8.3)	9(5.4)	31(5.4)
Straight	9(36)	102(61.1)	22(88)	137(82)	14(58.3)	126(75)	410(71.2)
Straight twisted end	13(52)	53(31.7)	3(12)	25(15)	8(33.3)	33(19.6)	135(23.4)
							X^2value= 30.032*
Wattle							
Present	0(00)	15(9)	3(12)	17(10.2)	0(00)	25(14.9)	60(10.4)
Absent	25(100)	152(91)	22(88)	150(89.8)	24(100)	143(85.1)	516(89.6)
							X^2value= 2.791ns
Ruff							
Present	18(72)	0(00)	23(92)	0(00)	24(100)	0(00)	67(11.7)
Absent	7(28)	167(100)	2(8)	166(100)	0(00)	168(100)	508(88.3)
							X^2value= 1.484*ns
Temperament							
Docile	18(72)	141(84.4)	14(56)	103(61.7)	11(45.8)	97(57.7)	384(66.7)
Moderately tractable	7(28)	26(15.4)	10(40)	58(34.7)	13(54.2)	70(41.7)	184(31.9)
Aggressive	0(00)	0(00)	1(4)	6(3.6)	0(00)	1(0.6)	8(1.4)
							X^2value= 43.796*

Quantitative Traits of Indigenous Sheep

Linear body measurements and body weight are important predictive factors to obtain better use of carcasses, in addition to being breed characteristics and important criteria that may be used in selection (Çilek and Petkova, 2016). Information on body weight with several body measurements is necessary not only to monitor the growth of sheep but also to estimate genetic correlations between body weight and body measurements (Asefa *et al.,* 2017). The use of easily obtainable measures, like the chest girth, which allows an accurate estimate of the weight to be made, could create the basis for the assignment of performance recording to the farmers, allow more efficient planning of the selection process, and also allow an adequate economic qualification of the studied breeds (Olatunji *et al.*, 2009). Both live weight and linear body measurement play crucial roles in genetic improvement and the selection of a specific breed. Nevertheless, under smallholder farmers' conditions, where weighing scales and records are not available, it may be difficult to know the weight of sheep and goats (Abegaz and Awgichew, 2009). Looking for other options, for instance, such as chest girth measurement using chest girth measuring tapes, may be viable options to estimate live weight. This could create the basis for the assignment of performance recording under farmers' management conditions, and it may also allow more efficient planning of the selection process.

The least squares means, along with standard errors of live body weight (BW) and linear body measurements, viz., BL (body length), HW (height at withers), CBL (cannon bone length), CBC (cannon bone circumference), HG (heart girth), RH (rump height), RL (rump length), RW (rump width), PW (pelvic width), TL (tail length), TC (tail circumference), HdL (head length), HdW (head width), HL (horn length), EL (ear length), and SC (scrotal circumference for male), are presented in Table 4.

District Effect

The influence of districts on body weight and all other linear body measurements was either significant ($p<0.05$) or highly significant ($p<0.01$), except in SC, where it was non-significant. Similarly, Mesfin (2016) reported that the effect of locations on quantitative traits was significant, except for chest depth, which did not differ across locations. The significant effects of locations on live weight and linear body measurements were also reported by Asefa et al. (2017). The body weight and all linear body measurements were lowest in the sheep of Diksiis district, except head length (HdL), head width (HdW), and horn length (HL). However, body weight (BW), cannon bone length (CBL), cannon bone circumference (CBC), heart girth (HG), and scrotal circumference (SC) were highest in the sheep of Lode Hetosa district, whereas body length (BL), height at wither (HW), rump height (RH), rump length (RL), rump width (RW), pelvic width (PW), tail length (TL), tail circumference (TC), and ear length (EL) were highest in the sheep of Lemmu Bilbilo district. Similarly, the sheep of Diksiis district had the highest head length (HdL), head width (HdW), and horn length (HL). This might be due to the difference in management conditions among farmers across the district.

Age effect

The influence of age on body weight and all body measurements were either significant ($p<0.05$) or highly significant ($p<0.01$), except cannon bone length (CBL), tail length (TL), tail circumference (TC), ear length (EL), and scrotal circumference (SC). The size and shape of the animal increase until it reaches maturity, and the effect of age on body weight and other body measurements was also reported in different sheep breeds in Ethiopia (Tesfaye, 2008). The study results showed that there was a steadily increasing trend in body weight and linear body measurements with advancing age, which was estimated using dentition. A similar finding was reported by Asefa *et al*. (2017).

Sex effect

The effect of sex was either significant ($p<0.05$) or highly significant ($P<0.01$) on body weight and linear body measurements, except tail length (TL) and ear length (EL), where it was non-significant. The male sheep had consistently higher values for all quantitative traits measured, except ear length (EL), which was higher in females. This result was in disagreement with the results of Abera *et al.* (2014) and Asefa *et al.* *(*2017). These authors reported that females had larger linear body measurements than their male counterparts in the Selale area and Bale zone, respectively. The body weight of rams (33.06kg) in the current study was higher than the 30.8kg body weight of rams reported by Michael (2013) in Gojjam Zone and the 25.64kg reported for Bale male sheep by Asefa *et al*. (2017). Tesfaye (2008) and Kefale *et al*. (2017) also reported a lower body weight of 22.0kg for Menz rams and 22.2kg for Holla rams, respectively. The weight of ewes reported in the present study (26.44 kg) was similar to the 26.36kg body weight reported by Asefa *et al*. (2017) for the Bale sheep breed and the 26.5 kg reported by Wossenie (2013) for the Hararghe Highland sheep breed. But it is higher than the 19.3kg body weight reported by Tesfaye (2008) for Menz ewes but lower than the 28.6 kg body weight reported by Gizaw *et al*. (2008) for ewes of Arsi-Bale sheep.

Sex-by-age interaction

The interaction of sex and age group was highly significant ($p<0.01$) for body weight and significant ($p < 0.05$) for cannon bone circumference, rump height, rump length, rump width, head width, and horn length, indicating that these measurements were affected by the sex-age interaction effect. In other words, it means that there is a difference in body weight and these linear body measurements between the two sexes of the same age class. Tassew *et al*. (2014) reported a significant ($p<0.05$) interaction of sex and age group for all quantitative traits analysed, except ear length, for both Habru and Gubalafto sheep of the North Wollo Zone. Similarly, Abera *et al*. (2014) reported that ear length was not significantly affected by the interaction between sex and age group in indigenous sheep types in the Selale area. The results further showed that there was an increasing trend in body weight and measurements with advancing age.

This study indicated that in body weight and all body measurements showing a significant difference, the male sheep were higher than the female sheep of the same age group. This result was in agreement with Tassew *et al.* (2014), who reported that in all age groups in Habru and Guba Lafto districts of North Wollo Zone, sheep males were higher ($p<0.05$) than females. Similarly, Michael (2013) reported that male sheep had a heavier body weight ($p<0.05$) than female sheep in all age groups in a study conducted in the East Gojjam zone. The overall mean body weight (BW) of sheep observed in the current study areas was 28.84 ± 0.21 kg. The current result was higher than the 26kg reported by Asefa *et al.* (2017) for Bale sheep.

Table 4

Least squares mean (LSM±SE) and significance levels of Body weight (kg) and linear body measurements (cm) of sheep in the study area

Effect and level	BW	BL	HW	CBL	CBC	HG
Over all	28.84±0.21	62.48±0.16	65.65±0.16	12.81±0.04	7.12±0.02	73.11±0.2
CV	13.34	5.25	5.16	7.04	6.96	5.39
R^2	0.4	0.26	0.25	0.25	0.28	0.36
District	**	**	**	**	**	**
Lode Hetosa	30.67±0.34^{a}	63.05±0.29^{a}	66.85±0.30^{b}	13.43±0.08^{a}	7.42±0.04^{a}	75.85±0.35^{a}
Lemmu Bilbilo	29.75±0.34^{b}	63.62±0.29^{a}	67.79±0.30^{a}	12.93±0.08^{b}	7.36±0.04^{a}	73.19±0.35^{b}
Diksiis	28.84±0.34^{c}	60.55±0.29^{b}	65.47±0.30^{c}	12.30±0.08^{c}	7.01±0.04^{b}	72.50±0.35^{b}
Age	**	**	**	**NS**	**	**
1PPI	25.69±0.47^{c}	60.16±0.40^{c}	64.66±0.42^{c}	12.73±0.11	6.99±0.06^{b}	70.16±0.49^{c}
2PPI	29.30±0.46^{b}	61.99±0.39^{b}	66.68±0.41^{b}	12.96±0.11	7.27±0.06^{a}	72.99±0.47^{b}
3PPI	32.20±0.59^{a}	63.84±0.51^{a}	67.35±0.52^{ab}	12.98±0.14	7.43±0.08^{a}	76.10±0.61^{a}
4PPI	31.82±0.49^{a}	63.64±0.42^{a}	68.13±0.44^{a}	12.87±0.12	7.36±0.06^{a}	76.13±0.51^{a}
Sex	**	*	**	*	**	**
Male	33.06±0.46^{a}	63.23±0.39^{a}	68.92±0.41^{a}	13.11±0.11^{a}	7.59±0.06^{a}	76.52±0.47^{a}
Female	26.44±0.21^{b}	61.59±0.18^{b}	64.48±0.19^{b}	12.66±0.05^{b}	6.94±0.03^{b}	71.18±0.22^{b}
Sex*Age	**	**NS**	**NS**	**NS**	*	**NS**
Male 1PPI	28.77±1.13^{bc}	60.92±0.74	66.38±0.84	13±0.17	7.22±0.10^{b}	72.214±1.2
Male 2PPI	33.64±1.13^{a}	63.25±0.74	69.66±0.84	13.38±0.17	7.70±0.10^{a}	76.15±1.2
Male 3PPI	36.26±1.58^{a}	64.57±1.04	69.22±0.18	13.20±0.24	7.89±0.15^{a}	79.69±1.69
Male 4PPI	33.57±1.37^{a}	64.18±0.90	70.43±0.03	12.87±0.21	7.54±0.13^{a}	78.08±1.46
Female 1PPI	22.60±0.5^{e}	59.40±0.45	62.94±0.45	12.46±0.12	6.76±0.07^{d}	68.16±0.5
Female 2PPI	24.97±0.45^{d}	60.73±0.41	63.69±0.41	12.54±0.11	6.84±0.06^{cd}	69.84±0.45
Female 3PPI	28.15±0.38^{c}	63.1±0.35	65.47±0.35	12.76±0.1	6.98±0.05^{c}	72.53±0.38
Female 4PPI	30.07±0.21^{b}	63.11±0.19	65.83±0.19	12.87±0.05	7.17±0.03^{b}	74.19±0.21

NS= not significant; *=significant at $p<0.05$; **=Significant at $p<0.01$; ***=Significant at $p<0.001$; BW= Body weight; BL= Body length; HW= Height at wither; CBL= Cannon bone length; CBC = Cannon bone circumference; HG = Heart girth

Table 4 continued

	RH	RL	RW	PW	TL	TC
Over all	66.41±0.15	18.47±0.07	21.61±0.06	15.8±0.06	30.03±0.19	19.1±0.13
CV (%)	4.66	7.52	6.5	7.66	13.98	15.67
R^2	0.26	0.25	0.13	0.29	0.15	0.11
District	**	**	*	**	*	*
Lode Hetosa	67.95±0.27[a]	17.57±0.12[c]	21.43±0.12[b]	15.23±0.1[b]	31.58±0.37[b]	20.23±0.26[a]
Lemmu Bilbilo	68.27±0.27[a]	19.20±0.12[a]	21.84±0.12[a]	16.49±0.1[a]	32.66±0.37[a]	20.24±0.27[a]
Diksiis	66.17±0.28[b]	18.61±0.12[b]	21.74±0.12[a]	15.31±0.1[b]	31.22±0.37[b]	19.53±0.27[b]
Age	**	**	**	**	**NS**	**NS**
1PPI	65.43±0.38[c]	17.77±0.17[b]	20.72±0.17[c]	14.83±0.15[c]	30.97±0.52	19.56±0.37
2PPI	67.53±0.37[b]	18.48±0.17[a]	21.33±0.17[b]	15.57±0.15[b]	31.71±0.54	19.72±0.36
3PPI	68.07±0.48[ab]	18.79±0.21[a]	22.41±0.22[a]	16.16±0.18[a]	31.80±0.50	20.48±0.46
4PPI	68.82±0.40[a]	18.81±0.18[a]	22.21±0.18[a]	16.14±0.16[a]	32.80±0.65	20.23±0.38
Sex	**	*	*	*	**	**
Male	69.48±0.37[a]	18.79±0.17[a]	22.01±0.17[a]	15.88±0.14[a]	34.37±0.5[a]	21.53±0.36[a]
Female	65.45±0.17[b]	18.13±0.08[b]	21.33±0.08[b]	15.47±0.07[b]	29.26±0.23[b]	18.46±0.17[b]
Sex*Age	*	**	*	**NS**	**NS**	**NS**
Male 1PPI	66.44±0.74[b]	17.81±0.29[c]	20.60±0.29[d]	14.85±0.28	33.01±0.87	20.96±0.69
Male 2PPI	70.39±0.74[a]	19.06±0.29[a]	21.77±0.29[bc]	16.02±0.28	34.45±0.87	21.12±0.69
Male 3PPI	69.91±1.04[a]	19.45±0.41[a]	23.08±0.41[a]	16.49±0.4	36.13±1.22	22.69±0.97
Male 4PPI	71.18±0.9[a]	18.84±0.36[ab]	22.60±0.35[a]	16.17±0.35	33.90±1.06	21.36±0.84
Female 1PPI	64.42±0.42[c]	17.72±0.19[c]	20.85±0.19[c]	14.79±0.16	28.92±0.58	18.15±0.39
Female 2PPI	64.66±0.38[c]	17.91±0.17[c]	20.89±0.18[d]	15.15±0.15	29.14±0.53	18.33±0.36
Female 3PPI	66.23±0.32[b]	18.13±0.15[bc]	21.74±0.15[c]	15.83±0.13	29.45±0.45	18.27±0.31
Female 4PPI	66.48±0.18[b]	18.78±0.08[a]	21.82±0.08[c]	16.12±0.07	29.52±0.25	19.09±0.17

NS = not significant; NA= Not applicable; *=significant at $p<0.05$; **=Significant at $p<0.01$; ***=Significant at $p<0.001$; RH= Rump height; RL = Rump length; WW= Rump width; PW = Pelvic width; TL = Tail length; TC = Tail circumference

Table 4 Continued

Effect and level	HdL	HdW	EL	HL	SC
Over all	19.07±0.05	11.35±0.04	10.82±0.06	9.45±0.4	25.13±0.26
CV	5.58	6.74	12.81	38.17	8.69
R^2	0.31	0.32	0.08	0.78	0.11
District	**	**	**	*	**NS**
Lode Hetosa	18.54±0.09[c]	11.16±0.07[b]	10.13±0.12[b]	13.89±0.37[b]	25.43±0.43
Lemmu Bilbilo	19.48±0.09[b]	11.10±0.07[b]	10.83±0.12[a]	14.18±0.37[ab]	24.97±0.44
Diksiis	19.85±0.09[a]	12.06±0.07[a]	10.75±0.12[a]	15.00±0.37[a]	25±0.46
Age	**	*	**NS**	*	**NS**
1PPI	18.81±0.13[c]	11.28±0.09[b]	10.42±0.17	12.79±0.5[b]	24.12±0.44
2PPI	19.19±0.13[b]	11.52±0.09[ab]	10.64±0.17	14.29±0.47[a]	24.88±0.45
3PPI	19.39±0.16[ab]	11.23±0.11[b]	10.82±0.21	14.93±0.59[a]	26.09±0.63
4PPI	19.76±0.14[a]	11.73±0.10[a]	10.42±0.18	15.43±0.47[a]	25.45±0.55
Sex	**	**	*	**	**NA**
Male	19.90±0.13[a]	11.76±0.09[a]	10.28±0.17	22.79±0.43[a]	25.13±0.26
Female	18.69±0.06[b]	11.12±0.04[b]	10.86±0.08	5.93±0.27[b]	NA
Sex*Age	**NS**	*	**NS**	*	**NA**
Male 1PPI	19.37±0.24	11.76±0.19[ab]	10.10±0.31	19.66±1.16[b]	24.12±0.45
Male 2PPI	19.87±0.24	12.03±0.19[a]	10.4±0.31	22.71±1.16[a]	24.88±0.45
Male 3PPI	20.03±0.33	11.25±0.26[bcde]	10.71±0.44	24.07±1.63[a]	26.09±0.63
Male 4PPI	20.29±0.29	12.01±0.23[a]	9.91±0.38	24.73±1.41[a]	25.45±0.55
Female 1PPI	18.23±0.14	10.81±0.1[e]	10.75±0.19	5.92±0.55[c]	NA
Female 2PPI	18.75±0.13	11.01±0.09[de]	10.85±0.17	5.86±0.46[c]	NA
Female 3PPI	18.51±0.11	11.21±0.08[d]	10.89±0.15	5.78±0.44[c]	NA
Female 4PPI	19.24±0.06	11.44±0.04[c]	10.95±0.08	6.13±0.22[c]	NA

NS = not significant; NA = Not applicable; *=significant at $p<0.05$; **=Significant at $p<0.01$; ***=Significant at $p<0.001$; HdL = Head length; HdW = Head width; EL = Ear length; HL = Horn length; SC = Scrotal circumference

Correlation between Body Weight and Linear Body Measurements

The association between body weight and linear body measurements for all age groups of the sampled male and female sheep population is presented in Table 5. The results showed that most of the correlations in male sheep were positive, except between BL-TC, HW-TC, CBL-TC, CBL-HdL, CBL-HdW, CBL-HL, RH-TC, and HdW-TL.

Table 5.

Correlation between Body Weight and Linear Body Measurements

Traits	BW	BL	HW	CBL	CBC	HG	RH	RL	RW	PW	TL	TC	HdL	HdW	EL	HL
BW		0.45*	0.43*	0.30*	0.48*	0.76*	0.40*	0.17*	0.39*	0.43*	0.13*	0.23*	0.17*	0.25*	-.01^{ns}	0.08^{ns}
BL	0.66*		0.68*	0.34*	0.43*	0.41*	0.62*	0.23*	0.40*	0.49*	0.17*	0.15*	0.10*	0.03*	0.10*	0.03^{ns}
HW	0.57*	0.84*		0.42*	0.42*	0.39*	0.82*	0.28*	0.35*	0.40*	0.20*	0.14*	0.18*	0.06^{ns}	0.08^{ns}	0.10^{ns}
CBL	0.43*	0.39*	0.39*		0.35*	0.39*	0.40*	0.02^{ns}	0.18*	0.15*	0.03^{ns}	0.16*	-.06^{ns}	-.06^{ns}	-.01^{ns}	0.04^{ns}
CBC	0.55*	0.45*	0.33*	0.41*		0.53*	0.38*	0.16*	0.27*	0.31*	0.16*	0.26*	0.08^{ns}	0.01^{ns}	-.05^{ns}	.001^{ns}
HG	0.84*	0.70*	0.63*	0.43*	0.49*		0.38*	0.08^{ns}	0.39*	0.35*	0.11*	0.22*	0.10*	0.14*	-.04^{ns}	0.05^{ns}
RH	0.58*	0.80*	0.91*	0.47*	0.42*	0.67*		0.24*	0.28*	0.33*	0.21*	0.13*	0.14*	0.04^{ns}	0.08 ns	0.04^{ns}
RL	0.38*	0.48*	0.32*	0.03^{ns}	0.25*	0.37*	0.35*		0.38*	0.42*	0.13*	0.07^{ns}	0.44*	0.12*	0.11*	0.05^{ns}
RW	0.51*	0.53*	0.37*	0.07^{ns}	0.37*	0.49*	0.39*	0.52*		0.56*	0.07^{ns}	0.15*	0.29*	0.10*	0.18*	0.07^{ns}
PW	0.68*	0.66*	0.50*	0.03^{ns}	0.44*	0.66*	0.46*	0.50*	0.66*		0.10*	0.17*	0.33*	0.05^{ns}	0.13*	-.11^{ns}
TL	0.27*	0.17^{ns}	0.15^{ns}	0.18^{ns}	0.30*	0.33*	0.22^{ns}	0.05^{ns}	0.09^{ns}	0.18^{ns}		0.17*	0.02^{ns}	-.02^{ns}	0.09^{ns}	0.02^{ns}
TC	0.13^{ns}	-.13^{ns}	-.21^{ns}	-.17^{ns}	0.05^{ns}	0.12^{ns}	-.06^{ns}	0.21^{ns}	0.29*	0.19^{ns}	0.09^{ns}		0.01^{ns}	-.07^{ns}	0.06^{ns}	0.06^{ns}
HdL	0.31*	0.36*	0.22^{ns}	-.11^{ns}	0.09^{ns}	0.27*	0.22^{ns}	0.49*	0.52*	0.37*	0.05^{ns}	0.25*		0.25*	0.17*	0.14*
HdW	0.15*	0.05^{ns}	0.06^{ns}	-.11^{ns}	0.01^{ns}	0.14^{ns}	0.09^{ns}	0.14^{ns}	0.07^{ns}	0.02^{ns}	-.08^{ns}	0.25*	0.38*		0.03^{ns}	0.12*
EL	0.14^{ns}	0.16^{ns}	0.18^{ns}	0.06^{ns}	0.17^{ns}	0.13^{ns}	0.19^{ns}	0.13^{ns}	0.03^{ns}	0.16^{ns}	0.24*	0.13^{ns}	0.14^{ns}	0.10^{ns}		0.12^{ns}
HL	0.37*	0.35*	0.32*	-.09^{ns}	0.20^{ns}	0.41*	0.31*	0.20^{ns}	0.36*	0.33*	0.22^{ns}	0.08^{ns}	0.35*	0.29*	0.04^{ns}	
SC	0.46*	0.45*	0.33*	0.24*	0.30*	0.36*	0.28*	0.17^{ns}	0.41*	0.36*	0.15^{ns}	0.09^{ns}	0.26^{ns}	0.13^{ns}	0.26*	0.16^{ns}

NS= non-significant; *=p<0.05; **=p<0.01; ***=p<0.001

In males, positive and strong associations were found between BW and HG (r = 0.84), PW (0.68), BL (0.66), RW (0.58), HW (0.57), CBC (0.55), and RW (0.51). This indicates that these variables are more appropriate for predicting the live weight of male sheep, which is important for sheep producers in rural areas where other instruments like spring balances are not available to know the exact live body weight of sheep. Moderate and positive correlations were observed between BW and SC (0.46), CBL (0.43), RL (0.38), HL (0.37), and HdL (0.31). However, TL (0.27) and HW (0.15) showed a mild and positive correlation, while EL and TC did not show a significant correlation. In the Horro sheep breed, the highest correlation coefficient between BW and HG was established in females from pooled data (77%) and in males (85%) in the study of Zewdu (2008).

The results of Table 5 showed that most of the correlations in female sheep were positive. In females, HG (r = 0.76) showed a strong positive correlation with BW. Moderate and positive correlations were observed between BW and CBC (0.48), BL (0.45), HW (0.43), PW (0.43), RH (0.40), RW (0.39), and CBL (0.30). However, HdW (0.25), TC (0.23), HdL (0.17), RL (0.17), and TL (0.13) showed a mild and positive correlation, whereas HL and EL did not show a significant correlation with BW. A higher coefficient was obtained for males (r = 0.84) as compared to females (r = 0.76). This implies that a better prediction of body weight could be obtained in male sheep than female sheep in the study area.

Multiple Regression Analysis

Multiple regression equations were developed to predict live weight from seventeen different linear body measurements for males and thirteen body measurements for females. In order to predict body weight from linear measurements, stepwise multiple regressions were carried out. The coefficient of determination (R^2) and mean square error (MSE) were used in fitting the best model. One may define the "best model" as that which has the highest R^2 value and the lowest MSE.

The small sample size of rams in the current study may decrease the accuracy of the result if separate age groups are used. Thus, instead of using separate equations for different age groups, it seemed logical to pool age groups for the prediction of the body weight of males. However, in the case of females, the live weight prediction equations for different age groups and pooled overall age groups were estimated. The regression analysis of live body weight on different body measurements for males and females is presented in Tables 6 and 7, respectively.

Based on pooled overall age groups in both sexes, the heart rate was selected as the first regressor. Similarly, across the four age groups of females, heart girth has been selected as the first regressor. This implies a higher contribution of heart girth in terms of the R^2 value. The regression equation for male sheep was estimated as Y = **(-27.02) + 0.78X** (where X stands for HG) with an R^2 value of **0.70.** Similarly, the regression equation for female sheep was estimated as Y = **(-27.15) + 0.76X** (where X stands for HG) with an R^2 value of **0.58** in the study area. This finding showed that an increase of one cm of HG resulted in an increase of 0.78 and 0.76 kg of live weight in male and female sheep, respectively.

The role of other body measurements in predicting body weight differed in different age groups of females. Thus, it seems that body measurements other than HG may not possibly be used in general prediction equations. However, the parameter estimates in the multiple linear regression models showed that subsequent inclusion of other body measurements with heart girth increased the R^2 value. This suggested that body weight could be predicted with a higher level of accuracy from more than one linear body measurement.

Table 6

Multiple Regression Analysis of Body Weight on Different Body Measurements for Female

Age	Model	Intercept	B1	B2	B3	B4	B5	B6	R^2	MSE
1PPI	HG	-15.12	0.55						0.61	2.48
	HG +HdW	-21.64	0.54	0.66					0.67	2.11
	HG +HdW +RW	-25.60	0.48	0.72	0.37				0.70	1.94
2PPI	HG	-15.20	0.58						0.50	4.22
3PPI	HG	-12.23	0.56						0.42	6.32
	HG +RW	-22.58	0.55	0.50					0.45	6.02
	HG +RW +RH	-27.59	0.52	0.46	0.12				0.47	5.85
	HG +RW +RH +RL	-24.10	0.50	0.56	0.13	0.25			0.48	5.77
	HG +RW +RH +RL + PW	-25.57	0.49	0.41	0.13	0.32	0.41		0.50	5.63
4PPI	HG	-18.80	0.66						0.44	9.05
	HG +HW	-31.48	0.59	0.27					0.48	8.46
	HG +HW +HdW	-38.46	0.59	0.27	0.63				0.50	8.18
	HG +HW +HdW +PW	-39.09	0.56	0.20	0.65	0.46			0.51	7.90
	HG +HW +HdW +PW +CBC	-39.00	0.52	0.15	0.67	0.45	0.74		0.52	7.80
	HG +HW +HdW +PW +CBC +TC	-39.26	0.51	0.15	0.68	0.44	0.68	0.10	0.52	7.75
Pooled age	HG	-27.15	0.76						0.58	8.46
	HG +PW	-31.99	0.70	0.61					0.61	7.83
	HG +PW +HdW	-39.01	0.67	0.61	0.76				0.63	7.40
	HG +PW +HdW +HW	-43.89	0.64	0.51	0.76	0.13			0.64	7.24
	HG +PW +HdW +HW +CBC	-44.47	0.61	0.49	0.79	0.11	0.59		0.64	7.19
	HG +PW +HdW +HW +CBC +TC	-45.08	0.61	0.48	0.81	0.11	0.51	0.08	0.64	7.15

Table 7

Multiple Regression Analysis of Body Weight on Different Body Measurements for Male

	Model	Intercept	B1	B2	B3	B4	B5	B6	R^2	MSE
Pooled Age	HG	-27.02	0.78						0.70	11.23
	HG +SC	-34.91	0.72	0.50					0.73	10.31
	HG +SC +PW	-36.34	0.61	0.43	0.73				0.75	9.67
	HG +SC +PW +CBC	-41.33	0.57	0.39	0.63	1.44			0.77	9.24
	HG +SC +PW +CBC +CBL	-44.33	0.51	0.35	0.86	1.08	0.58		0.77	9.09

CONCLUSIONS

The study of phenotypic characterization of sheep types and their production systems was carried out in the east Arsi zone in three districts (Lode Hetosa, Lemmu Bilbilo, and Diksiis). The study area was characterised by a mixed-crop-livestock farming system. Crop production was the major farming activity of households (74.1%) across the study area, while the contribution of livestock (25.9%) was the least as compared to crop production.

The main objectives of keeping sheep were for income, followed by saving (as a live bank for households) and social prestige across all the districts studied. The main feed resources available during the wet season were natural pasture and oats, ranked numbers one and two. However, during the dry season, crop residues ranked first in all districts under the study. The major constraints on sheep production in the study areas were disease, feed shortages, predators, water shortages, and poor genotype.

Most East Arsi sheep populations were characterised by a plain coat colour pattern with a plain brown coat colour, long hair length, thin tailed tail ending with a straight tip, a horned, curved horn shape, and a straight head profile. The variation between the different age classes for most linear body measurements and body weight was found to be significant ($p<0.05$). Male sheep had consistently higher values of body weight and most linear body measurements than females, except for ear length, which is higher in females. The influence of districts on body weight and all other linear body measurements was either significant ($p<0.05$) or highly significant ($p<0.01$), except in SC, where it was non-significant. The influence of age on body weight and all body measurements were either significant ($p<0.05$) or highly significant ($p<0.01$) except CBL, TL, TC, EL, and SC.

Generally, a positive and strong association were found between body weight and chest girth (r = 0.70 and r = 58) in males and females, respectively. Stepwise regression analysis showed that body weight, in most of the cases, could be predicted with a higher level of accuracy from more than one body measurement.

The high correlation coefficients between BW and linear body measurements suggest that either of these variables or their combination could provide a good estimate for predicting the live weight of sheep from body measurements. Heart girth alone or in combination with other body measurements can be used to predict body weight with reasonable accuracy. Generally, it was found that body weight could be predicted from body linear measurements with varying levels of accuracy. Based on their contribution to variation in body weight, parameters such as heart girth, scrotal circumference, pelvic width, cannon bone circumference, and cannon bone length are the most important body measurements required for the selection of male sheep. Similarly, for female sheep, heart girth, pelvic width, head width, height at weather, cannon bone circumference, and tail circumference are used for the same purpose.

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