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# HUSBANDRY PRACTICE AND MORPHOLOGICAL CHARACTERIZATION OF INDIGENOUS GOATS

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## ABSTRACT

This study aimed at characterizing the husbandry practice and morphology of the goat population in the study area. The data were collected through face-to-face personal interviews, focus group discussions and measurements of the morphological characteristics of goats. Data on 17 morphological traits were collected from 510 goats (411 females and 99 males) and about 180 households participated in the survey. Data were analysed using different procedures of the Statistical Analysis System. Crop production, goat rearing, cattle rearing, sheep rearing and apiculture were the major farming activities with index values of 0.41, 0.27, 0.23, 0.08 and 0.003, respectively. The source of immediate cash income, household meat consumption and a means of saving were the main reasons for keeping goats. The average flock size of goats per household is 6.72 ± 3.71. In the lowland areas, most of the kidding occurred in January, September and July. However, in midland and highland areas, September, October and January were ranked 1st, 2nd and 3rd. Most (75.0 to 93.0 %) of farmers culled female goats due to various reasons. The overall mean (± SE) market age for male and female goats were 8.88 ± 0.17 and 9.28 ± 0.16 months, respectively. Most of the goat keepers in the highland (93.3 % and 40.0 %), midland (91.7 % and 38.3 %) and lowland (96.7 % and 95.0 %) agro-ecologies have reported the practice of free grazing during the dry and wet seasons, respectively. Pasteurellosis, Goat pox and Anthrax were the possible economically important diseases in the study areas with index values of 0.298, 0.172 and 0.168, respectively. Feed shortage, disease prevalence, drought and labour shortage were the most limiting factors for goat production, although their importance was not similar across agro-ecologies. Sex, age and agroecology had a significant influence on the body weight and morphological characteristics of goats. Promoting alternative forage development strategies, improved forages and efficient feed utilization and conservation options are important to alleviate feed shortage and enhance drought resilience capacity. In addition, designing and implementing of community-based genetic improvement program through within-breed selection could improve the productivity of indigenous goats.

**Key words:** body weight; farming practice; indigenous goats; morphological traits

## INTRODUCTION

Small ruminants contribute substantially to the livelihoods of smallholder households as a mean of risk mitigation during crop failures, savings and sources of food and raw materials (Haile *et al.*, 2019). Ethiopia is a home to 52.5 million goats (CSA, 2021) and is categorized into eight genetically distinct groups (Alemu, 2004). Regardless of the availability of a diverse goat genetic pool, the country's vast goat population and the sector's significant economic benefit to rural households, the sector's contribution to the national economy is relatively modest (Haile *et al.*, 2019). The lower contribution can be explained by low productivity per unit of animal and low flock off-take.



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Now, a community-based breeding program is considered a promising approach for goat genetic improvement under smallholder tropical conditions (Mueller *et al.*, 2015; Jembere *et al.*, 2019) and for the utilization of indigenous goats. For planning the rational use of indigenous goat genetic resources and developing a community-based genetic improvement program, characterization of the production system, defining goat management in their environment, description of the breed/population characteristics, marketing, identification of major constraints, as well as production potentials in those environments are the prerequisites and the first step. Once the production system and breed characteristics are described, the next step is the identification of farmers' goat breeding objectives or a trait would like to improve (Haile *et al.*, 2018).

Research work on goat production system characterizations, morphological characterization and identification of goat breeding objectives has been executed in different parts of the country by different organizations and individuals (Alemu, 2004; Hassen *et al.*, 2012; Sheriff *et al.*, 2020). Even though the studies were conducted in many parts of the country, data on the morphological and production system characteristics of indigenous goat breed/population in the study area remain scarce. According to Wuletaw (2008), the absence of adequate information on the characteristics of breeds potentially leads to wrong decisions and genetic erosion through crossbreeding, substitution and dilution. Therefore, the identification of livestock breeds, documentation of their common uses and description of the management systems, in which they are maintained, are immensely important information to be addressed (FAO, 2011; Haile *et al.*, 2018). Thus, this study aimed at characterizing the husbandry practice and the morphology of goat population in the study area. The obtained results enable us to know the specific merit of indigenous goats, provide information to conserve the indigenous goat types in their natural production environment, plan sustainable utilization options and develop an effective breeding program that fits with the low input production system.

## MATERIALS AND METHODS

### Description of the study area

The study was conducted in Raya Kobo district of the north Wollo zone, Amhara National Regional State of Ethiopia. Geographically it is located in 12°50" 0" N to 13°20" 0" N latitude and 36°50" 0" E to 37°30" 0" E longitude. Raya Kobo district had a wet lowland, a wet highland and lowland agroecological zone. The altitude of Kobo ranges from 1100 meters on the plains to slightly more than 3000 meters above sea level along the border with Gidan (https://en.wikipedia.org/wiki/Kobo woreda). The most extensive soils of the study area are Vertisols followed by Fluvisols. The main crops grown in the area from July through November are Teff, Sorghum, Maize and other cereals. Mean annual rainfall, maximum and minimum temperature of the study area are 630 mm, 29 °C and 15 °C, respectively (Tesema, 2019).

### Sampling techniques and sample size

Raya Kobo district was selected purposively based on the potential of the goat population and the relative importance of goats.

Group discussions were held with experts and with elders representing the study areas and other key informants. These discussions are used to obtain appropriate information about goat distribution before the commencement of the actual survey. Purposively three rural *kebele* administrations from this district were selected based on the distribution of goat population and agroecology (one *kebele* from each highland, midland and lowland). Then, a total of 180 households (60 households from each agroecology) were randomly selected from the list of goat owners in study sites. The total households included in the study were determined by the formula given by Cochran (1977):

$$n = \frac{z^2 * (p)(q)}{e^2}$$

Where:

n = the minimum required number of sample size within the range of acceptable error margin,

$z^2$ = standard normal deviation (1.96 for 95 % confidence level),

$e^2$ = the margin of error (± 0.05, margin of error for confidence level of 95 %),

p = 0.136 is the degree of variability in the attributes being measured refers to the distribution of attributes in the population, and

q = (1-p) (estimate of the proportion of the population to be sampled, 0.864).

### Methods of data collection

*Household questionnaire survey:* Formal interviews with semi-structured questionnaires were employed

to gather information from the selected households. The main information collected in the interview includes general household characteristics, livestock composition, goat flock structure, feed source, management of goats, breeding practices, off-take rate, marketing and constraints for goat production. Before collecting the actual data, the questionnaire was pre-tested using 15 % (n = 27) of the households (n = 180) and corrected based on the feedback of the pre-test.

*Focus group discussion:* Both male and female household heads participated in focus group discussions (3 FGDs). The discussion had three groups consisting of eight individuals and it was used to complement the data obtained through the household survey. Members of the focus groups were people believed to be knowledgeable about past and present social and economic status of the area, community elders and storytellers.

*Morphological trait measurement:* Morphological data were collected based on the breed morphological characteristics descriptor list of FAO (2012) for the morphological characterization of goats. For phenotypic characterization, both qualitative and quantitative data were collected from 510 goats (411 female and 99 male goats). Quantitative morphological traits such as body weight, body length, wither height, chest girth, chest width, chest depth, rump height, rump length, rump width, punch girth, neck girth, head length, head width, ear length, muzzle circumference, scrotum circumference and horn length were measured using a textile measuring tape. Height and length were measured using 1.5-meter-long tape, and live weight was measured using a weighing balance with a 50 kg capacity. All measurements were taken early in the morning to avoid the effect of feeding and watering on the animal's size and conformation. Pregnant and unhealthy ones were excluded from the data or not measured.

**Statistical data analysis**

The questionnaire survey data were entered into Microsoft Office Excel, coded and organized. Descriptive statistics and chi-square test were implemented for qualitative traits of goats and categorical variables using SAS (2002). In addition, indices were calculated for all ranking data according to the formula: Index = sum of (3 for rank 1 + 2 for rank 2 + 1 for rank 3) given for an individual attribute divided by the sum of (3 for rank 1 + 2 for rank 2 + 1 for rank 3) for overall attributes (Zergaw *et al.*, 2016). The general linear model procedure of SAS was used to analyse the quantitative data of goats. Pearson's correlation was used to estimate the correlation coefficient among investigated traits, and the stepwise multiple regression procedure of SAS was used to obtain models for estimation of body weight from morphological traits. The higher values of the coefficient of determination ($R^2$) were used to determine the traits which contribute much to the response variable.

The model for body weight and morphological traits was as follows:

$$Y_{ijkl} = \mu + A_i + B_j + D_k + e_{ijkl}$$

Where:

$Y_{ijkl}$ = the live weight and morphological traits measurements

$\mu$ = overall mean,

$A_i$ = the effect of $i^{th}$ age group (i = 0, 1, 2, 3 and 4 pairs of permanent incisors ((PPI))

$B_j$ = the effect of $j^{th}$ sex (j = female and male)

$D_k$ = the effect of $k^{th}$ agro-ecology (k = lowland, midland and highland),

$e_{ijkl}$ = random residual error.

## RESULTS AND DISCUSSION

**Socio-economic characteristics of the respondents**

**Household characteristics**

The characteristics (age, sex, educational background, marital status, family size and landholdings) of the respondents are presented in Table 1. Based on the present findings, all household heads in the highland (100 %) and midland (100 %) agro-ecologies and most (91.7 %) of household heads in the lowland agro-ecology were males, implying that the proportion of male household heads in all the studied agro-ecologies was significantly ($P < 0.005$) higher than the female-headed household. This result agrees with the reports of Gatew (2014), Tesema (2019) and Getaneh (2020), who reported that male-headed households had a higher proportion than female-headed households in their respective study sites. The majority of the interviewed household heads from the midland (36.7 %) and the lowland (31.7 %) areas were found in an age category of 41 – 50 years, followed by 31 – 40 years (28.3 %) in the midland and 51 – 60 years (23.3 %) in the lowland agro-ecology. However, most goat keepers in the highland agroecology were grouped under the age category of 51 – 60 years (35.0 %), followed by an age category of 41 – 50 years (30.0 %).

**Table 1. Characteristics of households in the study areas**

| Items | Highland | Lowland | Midland | $\chi^2$-value | P-value |
|---|---|---|---|---|---|
| | N (%) | N (%) | N (%) | | |
| Sex | | | | | |
| Female | 0 (0.00) | 5 (8.30) | 0 (0.00) | 10.3 | 0.006 |
| Male | 60 (100) | 55 (91.7) | 60 (100) | | |
| Age | | | | | |
| >60 | 9 (15.0) | 11 (18.3) | 4 (6.70) | 8.96 | 0.346 |
| <30 | 1 (1.70) | 4 (6.70) | 2 (3.30) | | |
| 31-40 | 11 (18.3) | 12 (20.0) | 17 (28.3) | | |
| 41-50 | 18 (30.0) | 19 (31.7) | 22 (36.7) | | |
| 51-60 | 21 (35.0) | 14 (23.3) | 15 (25.0) | | |
| Education | | | | | |
| Illiterate | 35 (58.3) | 38 (63.3) | 24 (40.7) | 26.6 | 0.0001 |
| Read and write | 15 (25.0) | 13 (21.7) | 5 (8.50) | | |
| Primary | 7 (11.7) | 5 (8.30) | 22 (37.3) | | |
| Secondary | 3 (5.00) | 4 (6.70) | 8 (13.6) | | |
| Marital status | | | | | |
| Married | 57 (95.0) | 54 (90.0) | 58 (96.7) | 6.82 | 0.338 |
| Single | 3 (5.00) | 5 (8.30) | 1 (1.70) | | |
| Divorced | 0 (0.00) | 0 (0.00) | 1 (1.70) | | |
| Widow | 0 (0.00) | 1 (1.70) | 0 (0.00) | | |
| Family size | 6.46 ± 0.26 | 6.57 ± 0.26 | 6.47 ± 0.20 | - | 0.937 |
| Total land size (ha) | 1.05 ± 0.04$^a$ | 1.09 ± 0.06$^a$ | 0.71 ± 0.04$^b$ | - | <0.0001 |
| Grazing land | 0.42 ± 0.02$^a$ | 0.20 ± 0.03$^b$ | 0.25 ± 0.02$^b$ | - | <0.0001 |

N = number of households; $\chi^2$ = chi-square

The educational status of interviewed households was significantly different (P = 0.001) across agro-ecologies. Most of the respondents in highland (58.3 %) and lowland (63.3 %) agroecology were illiterate. This result is in line with the previous studies (Gatew, 2014; Getaneh, 2020). The proportion of illiterate respondents in the midland was lower than in highland and lowland agro-ecology. This result indicates the presence of a better education level in midland agro-ecology relatively to other agro-ecologies. The educational level may affect the acceptance of farmers for new technologies and most of the time the educated one is believed to have a high acceptance rate.

The average family size (mean ± SE) of the visited households in the highland, lowland and midland agro-ecologies were 6.46 ± 0.2, 6.57 ± 0.26 and 6.47 ± 0.20 persons, respectively (Table 1). There was no statistical difference (P > 0.05) among the studied areas in the average family size of the visited households. The average family sizes of the interviewed households of all agro-ecologies in the present study were higher than the report of Getaneh (2020), who reported an average family size of 5.85 ± 1.74 persons per household in selected districts of the East Gojjam Zone, Amhara Region, Ethiopia. However, the average family sizes in the present study (6.46 – 6.57) were almost similar to the average family size of 6.844 ± 0.234 in the Mandura district, Metekel Zone, Ethiopia (Getnet *et al.*, 2020). The average household size in the present study is higher, as compared with the average household size in Ethiopia, which is 4.6 persons (3.5 persons in urban and 4.9 people in rural areas; CSA, 2016). The difference in family size between households at a different location may be due to the differences in educational levels and use of family planning.

The total landholding in the midland area (0.71 ± 0.04) was significantly lower (P < 0.001) than the total landholding in the highland (1.05 ± 0.04) and lowland

(1.09 ± 0.06) areas. In this study, the landholding was positively associated with the goat population, i.e. the goat population in the midland was lower than goats in the highland and lowland (Table 1). However, grazing land holding in the highland area (0.42 ± 0.02) was significantly higher ($P < 0.001$) than in the midland (0.25 ± 0.02) and the lowland (0.20 ± 0.03) areas. The presence of fallow land due to poor fertility in the highland area could be the reason for higher grazing land in this agroecology.

**Farming activities and ecosystem service of goats**

The contributions of different farming activities to generating household income are presented in Table 2. Based on the interviewed households' ranking in the study areas, crop production, goat rearing, cattle rearing, sheep rearing and apiculture were rated from 1 to 5 as income priorities with overall index values of 0.41, 0.27, 0.23, 0.08 and 0.003, respectively. In the lowland and midland agroecology, crop production, goat production and cattle production had a higher contribution to households' income. However, in the highland areas, crop production followed by cattle and sheep production were the most important sources of household income. In general, the contribution of goat production to household income was ranked as 2$^{nd}$ in both lowland and midland agro-ecology.

Goats provide a variety of ecosystem services that contribute to environmental sustainability, agricultural productivity and the livelihoods of people, especially in rural areas. Goats support the livelihood and food security of producers, have socio-cultural service, fertilize soil, important for weed control and habitat management due to their grazing behaviours. Although goats are blamed for their contribution to environmental degradation, Rosa Garcia *et al.* (2012) noted that a moderate grazing pressures can be compatible with high levels of biodiversity and can provide externalities, which support population, whereas high grazing pressures can be valuable tools for weed control. Organic goat farming

**Table 2. Household income contribution of different farming activities**

| Income priority | Lowland | | | | Midland | | | | Highland | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R1 | R2 | R3 | Index | R1 | R2 | R3 | Index | R1 | R2 | R3 | Index | Overall |
| Crop production | 52 | 2 | 5 | 0.460 | 40 | 10 | 7 | 0.413 | 30 | 13 | 11 | 0.354 | 0.409 |
| Goat production | 6 | 35 | 19 | 0.298 | 11 | 36 | 13 | 0.331 | 7 | 13 | 19 | 0.184 | 0.271 |
| Cattle production | 2 | 22 | 35 | 0.237 | 7 | 13 | 30 | 0.216 | 15 | 14 | 16 | 0.248 | 0.234 |
| Sheep production | 0 | 1 | 0 | 0.006 | 1 | 1 | 5 | 0.028 | 8 | 20 | 13 | 0.214 | 0.080 |
| Apiculture | 0 | 0 | 0 | 0.000 | 1 | 0 | 1 | 0.011 | 0 | 0 | 0 | 0.000 | 0.003 |

R1, R2, and R3 = number of respondents gave first, second and third rank for attributes, respectively

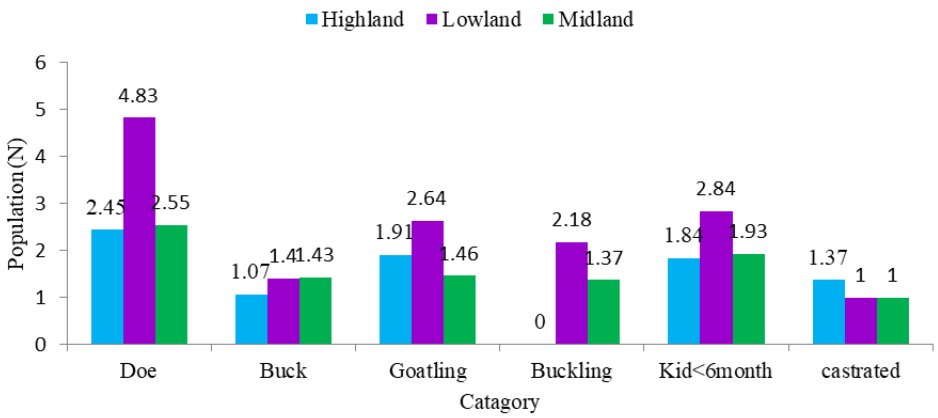


**Figure 1. Goat population by age category**

and low-input goat production systems that yield high-quality products are two of the greatest ways to create environmentally friendly and sustainable management solutions.

**Flock structure**

The number of goats per household by age category is presented in Figure 1. The average flock size of goats per household in the highland, lowland and midland agro-ecologies were 5.05 ± 2.18, 10.5 ± 6.79 and 4.61 ± 2.17 goats, respectively. Breeding female goats (does), followed by kids less than six months, had a higher proportion, than another age category in all agro-ecologies. This result was in agreement with the report of Alemu (2015). The number of males in lowland areas was higher than in other agro-ecologies. The presence of more than one male goat per flock could improve the conception rate of females and flock productivity.

**Purpose of goat keeping**

The main purposes of raising goats in the visited areas are presented in Figure 2. In all agro-ecologies, sources of immediate cash income, household meat consumption and a means of saving were the main reasons for keeping goats. The source of immediate cash income, rated as the first purpose of goat production in the studied agro-ecologies, could be due to the dominant application of the mixed crop-livestock farming system in the areas, in which farmers need immediate cash income for the purchase of agricultural inputs and other household needs i.e. purchase of clothes and pay children's school fee. Similar ranking for goat production purposes has been reported in the studies of Getaneh (2020) and Getaneh *et al.* (2021).

**Feed resources and feeding management of goats**

The major feed resources for goats during the dry and wet seasons of the year are presented in Table 3. Private grazing land was the first-ranked feed resource in the midland and highland agro-ecologies in both the dry and wet seasons of the year, followed by communal grazing. The index values for private grazing in the midland and highland agro-ecologies in the dry season were 0.43 and 0.45, while the corresponding index values during the wet seasons were 0.41 and 0.46, respectively. However, in the lowland agro-ecology, communal grazing land was the first rated feed resource for goats in both the dry (index = 0.49) and wet seasons (index = 0.50) of the year, which is in line with previous studies in Ethiopia (Alubel Alemu, 2014; Effa, 2015), who reported natural pasture as the main feed resource for goats during the dry and wet seasons of the year.

Goat keepers were mentioned fallow land, concentrate feeds, hay, *atela* and tree and bush as a feed source during the dry season, although their contribution was low. Crop aftermath, fallow lands, crop residue, cut grass, concentrate and trees and bush were also mentioned as the potential feed resources for goat production during the wet season. The present result is in agreement with the report of Befikadu and Kflom (2015), who mentioned that the feed resource base for goat production in Ethiopia is natural grazing land and crop residues, in which quality and supply of feed resources are seasonally variable.

**Supplementation**

The frequencies and percentages of interviewed households practiced the provision of supplementary feeds for goats, and seasons of supplementation are

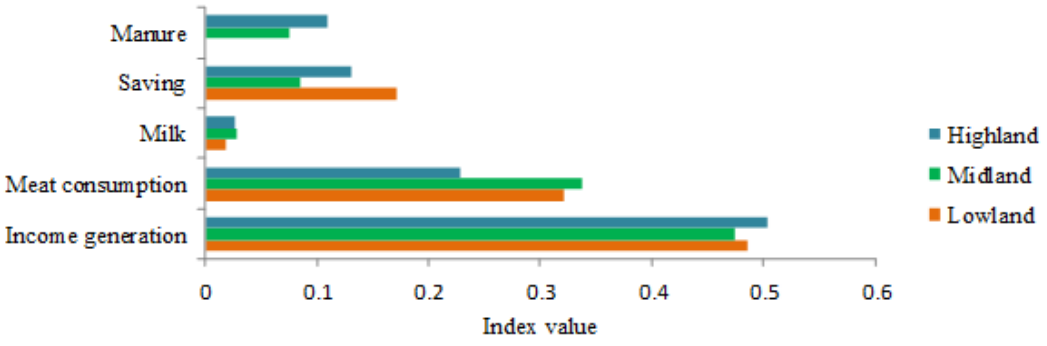


**Figure 2. Purpose of keeping goats in the study areas**

**Table 3. Major feed sources during dry and wet season**

| Feed sources | Lowland | | | | Midland | | | | Highland | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R1 | R2 | R3 | Index | R1 | R2 | R3 | Index | R1 | R2 | R3 | Index |
| Dry season | | | | | | | | | | | | |
| Communal grazing | 56 | 4 | 0 | 0.490 | 14 | 34 | 11 | 0.337 | 9 | 36 | 15 | 0.317 |
| Private grazing | 0 | 0 | 0 | 0.000 | 42 | 14 | 0 | 0.429 | 48 | 9 | 0 | 0.450 |
| Fallow land | 0 | 0 | 0 | 0.000 | 1 | 0 | 1 | 0.011 | 3 | 11 | 12 | 0.119 |
| Concentrate | 0 | 0 | 44 | 0.123 | 0 | 1 | 9 | 0.031 | 0 | 3 | 26 | 0.089 |
| Hay | 0 | 0 | 6 | 0.017 | 1 | 0 | 0 | 0.008 | 0 | 0 | 4 | 0.011 |
| *Atela* | 0 | 0 | 10 | 0.028 | 0 | 0 | 0 | 0.000 | 0 | 0 | 0 | 0.000 |
| Tree and bush | 3 | 57 | 0 | 0.343 | 1 | 11 | 41 | 0.184 | 0 | 0 | 5 | 0.014 |
| Wet season | | | | | | | | | | | | |
| Communal grazing | 60 | 0 | 0 | 0.500 | 11 | 32 | 16 | 0.315 | 1 | 33 | 24 | 0.259 |
| Private grazing | 0 | 0 | 0 | 0.000 | 42 | 11 | 0 | 0.412 | 51 | 5 | 1 | 0.457 |
| Crop aftermath | 0 | 1 | 8 | 0.028 | 1 | 0 | 0 | 0.008 | 0 | 0 | 0 | 0.000 |
| Fallow land | 0 | 0 | 0 | 0.000 | 1 | 0 | 1 | 0.011 | 8 | 20 | 7 | 0.198 |
| Crop residue | 0 | 14 | 24 | 0.144 | 0 | 0 | 0 | 0.000 | 0 | 0 | 0 | 0.000 |
| Cut grass | 0 | 42 | 10 | 0.261 | 5 | 10 | 29 | 0.178 | 0 | 0 | 4 | 0.011 |
| Concentrate | 0 | 3 | 18 | 0.067 | 0 | 2 | 11 | 0.042 | 0 | 1 | 25 | 0.075 |
| Tree and bush | 0 | 0 | 0 | 0.000 | 0 | 4 | 4 | 0.033 | 0 | 0 | 0 | 0.000 |

R1, R2, and R3 = number of respondents gave first, second and third rank for attributes, respectively

summarized in Table 4. There was a significant association between the studied agroecology and provisions of supplementary feed for goats. The proportion of goat keepers providing supplementary feeds for goats in the highland agroecology (100 %) was significantly ($P < 0.001$) higher than in the midland (85.0 %) and lowland (73.3 %) agro-ecologies. However, in all agro-ecologies, the majority of goat keepers have reported the provision of supplementary feeds for goats. From goat keepers, who supplement their goats, in the highland and midland agro-ecologies, the majority were provided the supplements during the dry seasons of the year, whereas in most of the goat keepers supplements were provided throughout the year. The season of supplementation might depend on the availability of feed resources, as the access to feed is different across agro-ecologies.

**Table 4. Supplementation practice and season of supplementation**

| Variables | Highland | Lowland | Midland | $\chi^2$- value | P-value |
|---|---|---|---|---|---|
| | N (%) | N (%) | N (%) | | |
| Do you supplement your goats? | | | | | |
| Yes | 60 (100) | 44 (73.3) | 51 (85.0) | 17.9 | 0.000 |
| No | 0 (0.00) | 16 (26.7) | 9 (15.0) | | |
| Season of supplementation | | | | | |
| Dry | 29 (48.3) | 11 (25.6) | 30 (60.0) | 14.5 | 0.006 |
| Wet | 10 (16.7) | 14 (32.6) | 4 (8.00) | | |
| Both | 21 (35.0) | 18 (41.9) | 16 (32.0) | | |

N = number of households; $\chi^2$ = chi-square

**Grazing and herding method**

The grazing management and herding practices of goats in the dry and wet seasons across the studied agro-ecologies are summarized in Table 5. Most of the goat keepers in the highland (93.3 %, 40.0 %), midland (91.7 %, 38.3) and lowland (96.7 %, 95.0 %) agro-ecologies have reported the practice of free grazing during the dry and wet seasons, respectively. In addition to free grazing, goat keepers have reported the application of tethering and herding in the dry seasons, as well as tethering, herded and cutting and carrying in the wet season as grazing management of goats. The higher percentage of free grazing as grazing management of goats may be related to the application of extensive goat production system in the studied agro-ecologies i.e. the primary feed resource for goats is communal grazing land and goats are allowed to graze freely. Most goat keepers in the highland (85 %), midland (71.7 %) and lowland (63.3 %) agro-ecologies herded goats with other livestock species together on the grazing/ browsing fields. However, some respondents from the highland (15 %), midland (28.3) and lowland (28.3 %) agro-ecologies reported separate goat herding practices. The majority of goat keepers from all agro--ecologies reported the absence of goat flock mixing with another flock. This may have an appositive influence on goat genetic improvement through a community-based approach.

**Water sources and distance of watering**

The frequency of watering, distance of water sources and major water sources for goats in the dry and wet seasons are presented in Table 6. There was a significant ($P < 0.001$) difference between the studied agro-ecologies regarding major water sources for goats in both the dry and wet seasons of the year. Most of the respondents in the highland (60.0 %, 60.0 %) and midland (58.3 %, 56.7 %) agro-ecologies used stream water in both the dry and wet seasons of the year to water goats, whilst in the lowland agro-ecology, most goat keepers used pipe water in both the dry (83.3 %) and wet (60.0 %) seasons of the year. The variation between the agro-ecologies in

**Table 5. Methods of grazing and herding of goats**

| Variables | Highland | Lowland | Midland | $\chi^2$-value | P-value |
|---|---|---|---|---|---|
| | N (%) | N (%) | N (%) | | |
| Dry season | | | | | |
| Free grazing | 56 (93.3) | 58 (96.7) | 55 (91.7) | 6.08 | 0.193 |
| Herded | 2 (3.30) | 2 (3.30) | 5 (8.30) | | |
| Tethering | 2 (3.30) | 0 (0.00) | 0 (0.00) | | |
| Wet season | | | | | |
| Cut and carry | 14 (23.3) | 2 (3.30) | 10 (16.7) | 54.60 | 0.000 |
| Free grazing | 24.0 (40.0) | 57 (95.0) | 23 (38.3) | | |
| Herded | 9 (15.0) | 1 (1.70) | 15 (25.0) | | |
| Tethering | 13 (21.7) | 0 (0.00) | 12 (20.0) | | |
| How your goats herded during grazing time? | | | | | |
| With other species | 51 (85.0) | 38 (63.3) | 43 (71.7) | 14.93 | 0.005 |
| Separately | 9 (15.0) | 17 (28.3) | 17 (28.3) | | |
| No control | 0 (0) | 5 (8.30) | 0 (0) | | |
| If goats graze together with another type of species? | | | | | |
| Cattle | 1 (2.00) | 0 (0) | 0 (0) | 13.53 | 0.009 |
| Sheep | 24 (47.1) | 7 (18.4) | 9 (20.5) | | |
| All species | 26 (51.0) | 31 (81.6) | 35 (79.5) | | |
| Do you practice mixing of your goat flock with other flocks? | | | | | |
| Yes | 19 (31.7) | 15 (25.4) | 20 (33.3) | 0.980 | 0.613 |
| No | 41 (68.3) | 44 (74.6) | 40 (66.7) | | |

N = number of households; $\chi^2$ = chi-square

**Table 6. Dry and wet season water sources**

| Variables | Highland | Lowland | Midland | $\chi^2$-value | P-value |
|---|---|---|---|---|---|
| | N (%) | N (%) | N (%) | | |
| Dry season water sources | | | | | |
| Pipe | 12 (20.0) | 50 (83.3) | 17 (28.3) | 0.011 | 0.000 |
| Spring | 12 (20.0) | 1 (1.70) | 8 (13.3) | | |
| Stream | 36 (60.0) | 8 (13.3) | 35 (58.3) | | |
| Water harvest | 0 (0.00) | 1 (1.70) | 0 (0.00) | | |
| Distance of water source | | | | | |
| 0.5 – 1.0 km | 39 (65.0) | 25 (41.7) | 48 (80.0) | 19.10 | 0.000 |
| < 0.5 km | 21 (35.0) | 35 (53.8) | 12 (20.0) | | |
| Wet-season water sources | | | | | |
| Pipe | 12 (20.0) | 36 (60.0) | 17 (28.3) | 0.012 | 0.000 |
| Pond | 0 (0.00) | 15 (25.0) | 0 (0.00) | 0.012 | 0.000 |
| Spring | 12 (20.0) | 2 (3.40) | 9 (15.0) | | |
| Stream | 36 (60.0) | 7 (11.7) | 34 (56.7) | | |
| Distance of water source | | | | | |
| 0.5 – 1.0 km | 39 (65.0) | 26 (43.4) | 48 (80.0) | 20.10 | 0.000 |
| < 0.5 km | 21 (35.0) | 34 (56.4) | 12 (20.0) | | |

N = number of households; $\chi^2$ = chi-square

terms of the major water sources may be correlated with the variation in the availability of water sources between agro-ecologies. During the dry and wet seasons, most of the respondents in lowland areas had access to water with less than five kilometres.

**Housing type**

Proper housing of animals is immensely important to enhance their productivity. Housing type was different in different agro-ecologies (Table 7). In the lowland areas, most of the producers (90.0 %) housed their goats in a separate house to protect them from predators and adverse climatic conditions. About 60 % of goat keepers in the highland and 78.3 % of households in the midland area housed their goat within the same roof with family, which may create a conducive environment for the transmission of zoonosis disease from humans to animals and *vice versa*. The difference in house type and housing systems could be due to environmental temperature, moisture, goat population and the type of goat production system practiced in the areas. In all study areas, most of the goat keepers housed kids separately from the adult

**Table 7. Goat house type in the study area**

| Parameters | Highland | Lowland | Midland | $\chi^2$-value | P-value |
|---|---|---|---|---|---|
| | N (%) | N (%) | N (%) | | |
| Type of shelter | | | | | |
| Separate house | 24 (40.0) | 54 (90.0) | 13 (21.7) | 60.05 | 0.000 |
| Shelter constructed inside family house | 36 (60.0) | 6 (10.0) | 47 (78.3) | | |
| Are kids housed with adult goats? | | | | | |
| Yes | 10 (16.7) | 1 (1.70) | 0 (0) | 17.62 | 0.000 |
| No | 50 (83.3) | 59 (98.3) | 60 (100) | | |

N = number of households; $\chi^2$ = chi-square

**Table 8. Ranks of diseases and parasites in the study areas**

| Local name | Common name | Lowland | | | | Midland | | | | Highland | | | | Overall index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | R1 | R2 | R3 | Index | R1 | R2 | R3 | Index | R1 | R2 | R3 | Index | |
| Fentata | Goat pox | 18 | 6 | 1 | 0.187 | 12 | 4 | 5 | 0.136 | 16 | 8 | 5 | 0.192 | 0.172 |
| Anfit | Pasteurellosis | 13 | 23 | 18 | 0.288 | 28 | 17 | 9 | 0.353 | 26 | 5 | 3 | 0.253 | 0.298 |
| Entutie | Anthrax | 16 | 18 | 15 | 0.277 | 8 | 9 | 10 | 0.144 | 6 | 6 | 0 | 0.083 | 0.168 |
| Kezen | Diarrhoea | 1 | 3 | 3 | 0.034 | 2 | 3 | 0 | 0.033 | 9 | 6 | 2 | 0.114 | 0.060 |
| Afemended | Orf | 0 | 4 | 19 | 0.075 | 0 | 4 | 6 | 0.039 | 0 | 11 | 4 | 0.072 | 0.062 |
| Anbeke | Fasciolosis | 0 | 0 | 0 | 0 | 1 | 10 | 15 | 0.106 | 0 | 3 | 25 | 0.086 | 0.064 |
| Kitegne | Mange mite | 4 | 1 | 1 | 0.042 | 3 | 5 | 5 | 0.067 | 2 | 7 | 18 | 0.106 | 0.072 |
| Dubdubie | LSD | 8 | 3 | 3 | 0.092 | 1 | 0 | 0 | 0.008 | 0 | 0 | 0 | 0 | 0.033 |
| Azurit | Coenurosis | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0.008 | 0 | 0 | 0 | 0 | 0.003 |
| Meziger | Tick | 0 | 1 | 0 | 0.006 | 5 | 7 | 9 | 0.106 | 1 | 14 | 3 | 0.094 | 0.069 |

R1, R2, and R3 = number of respondents gave first, second and third rank for attributes, respectively

goats. This result agrees with other studies in Ethiopia (Gatew, 2014; Alemu, 2015; Zergaw *et al.*, 2016; Getaneh, 2020).

**Diseases in the area**

Diseases and parasite prevalence cause reproductive and growth performance reduction, reduced output per animal and flock off-take rates. Farmers in the study areas were asked to identify the major goat diseases and parasites. The identified diseases are presented in Table 8. Pasteurellosis, Goat pox and Anthrax were economically important diseases in the study areas with index values of 0.298, 0.172 and 0.168, respectively. In addition, external parasites, such as mange mites and ticks, were also identified as a serious problem. In midland and highland areas, Fasciolosis was reported as an important disease. Once the most prevalent diseases are identified, intervention (prevention measures, vaccination and sanitation) is required to reduce the impact associated with diseases and parasites.

**Kidding pattern**

Knowledge of goat kidding patterns is important for the management of goats and for conducting selection. The kidding patterns of does are shown in Figure 3. Kidding occurred in all months, although the magnitude was not similar for all months. This could be due to uncontrolled mating in all agro-ecologies and the non-seasonality of oestrus. The kidding pattern seems to be affected by agroecology and in the lowland areas, most of the kidding occurred in January, followed by September and July. However, in midland and highland areas, September, October and January were ranked as 1st, 2nd, and 3rd. The variation of pick kidding season among agro-ecology

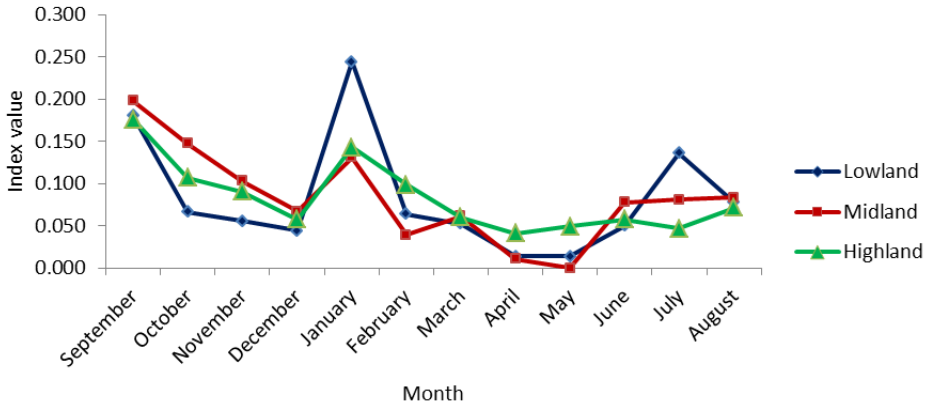


**Figure3. Kidding pattern of goats in the study area**

could be associated with the variation in feed availability and management of goats.

**Culling practice**

Culling unproductive animals with defects is very important in goat breeding to improve productivity and reduce production costs. The culling practices of goats in the study areas are summarized in Table 9. Most (75.0 to 93.0 %) of farmers in all study areas culled female goats due to various reasons. In the highland and midland areas, diseases, poor reproduction, poor mothering behaviour, low milk yield and poor physical condition were the major reasons for culling of female goats. Similarly, poor reproduction, poor mothering behaviour, diseases, poor physical condition, low milk yield, age and need for cash income were the reasons for the culling of female goats in the lowland area. In general, disease/health problems and poor reproduction performance were the major reasons for culling of does. In the study of Adem (2018), health problems and age were mentioned as major reasons for doe culling. In all study areas, most (72.9 to 73.7 %) of farmers culled male goats for need of cash, due to bad coat colour, poor physical condition, age, diseases and poor libido.

**Marketing and market age of goats**

Goat keepers in the study areas sold their goats at local markets throughout the year in times of feed scarcity and cash need. The overall mean (± SE) market age for male and female goats were 8.88 ± 0.17 and 9.28 ± 0.16 months, respectively (Table 10). A relatively earlier market age, than the current result, was reported in previous studies (Gatew, 2014; Tesema, 2019; Getaneh, 2020). In the lowland and midland areas, old does,

**Table 9. Culling practice of goats in Raya Kobo district**

| Parameters | Highland | Lowland | Midland | $\chi^2$-value | P-value |
|---|---|---|---|---|---|
| | N (%) | N (%) | N (%) | | |
| Do you practice culling of female goats? | | | | | |
| Yes | 45 (75.0) | 53 (93.0) | 54 (90.0) | 9.066 | 0.011 |
| No | 15 (25.0) | 4 (7.00) | 6 (10.0) | | |
| Reason for culling female goats | | | | | |
| Diseases/health problems | 15 (30.0) | 7 (14.3) | 5 (8.30) | 26.27 | 0.024 |
| Old age | 0 (0) | 1 (2.00) | 0 (0) | | |
| Poor reproduction | 14 (28.0) | 17 (34.7) | 13 (30.9) | | |
| Poor physical condition | 2 (4.0) | 4 (8.16) | 12 (28.6) | | |
| Low milk yield | 4 (8.00) | 2 (4.08) | 3 (7.14) | | |
| Poor mothering behaviour | 15 (30.0) | 17 (34.7) | 9 (21.4) | | |
| Need of cash | 0 (0) | 1 (2.00) | 0 (0) | | |
| Do you practice culling of male goats? | | | | | |
| Yes | 44 (73.3) | 42 (73.7) | 43 (72.9) | 0.010 | 0.995 |
| No | 16 (26.7) | 15 (26.3) | 16 (27.1) | | |
| The reason for culling male goats? | | | | | |
| Diseases | 0 (0) | 1 (2.32) | 0(0) | 23.99 | 0.020 |
| Old age | 0 (0) | 3 (6.97) | 1 (2.17) | | |
| Poor physical condition | 2 (4.44) | 3 (6.97) | 2 (4.34) | | |
| Bad coat colour | 12 (26.6) | 21 (48.8) | 26 (56.5) | | |
| Poor libido | 0 (0) | 2 (4.65) | 0(0) | | |
| Need of cash | 31 (68.8) | 13 (30.2) | 17 (36.9) | | |
| Age of doe culling (year) | 4.39 ± 0.17 | 3.90 ± 0.29 | 3.36 ± 0.29 | - | 0.067 |
| Age of buck culling (year) | 1.57 ± 0.11 | 1.59 ± 0.25 | 1.37 ± 0.12 | - | 0.605 |

N = number of households; $\chi^2$ = chi-square

males from 6 to 12 months of age and females from 6 to 12 months of age in the order of their importance were preferred for selling by goat keepers (Table 10). However, in the highland area, males from 6 to 12 months of age, castrated bucks and old doe were prioritized for selling with index values of 0.281, 0.214 and 0.197, respectively. Selling buckling and young breeding females may have its own impact on the genetic progress of the breeding program. Thus, selling old does, castrated and unproductive goats is preferable.

**Major constraints of goat production**

Identification of barriers to goat production is a primary step for intervention to enhance productivity. The major constraints for goat production in the study areas are shown in Table 11. The constraints were not similar across agroecology, for example, diseases/poor veterinary service, drought, labour shortage and feed shortage were the major constraints in the lowland area with index values of 0.398, 0.223, 0.162 and 0.109, respectively. However, in midland areas, feed and grazing land shortage, diseases, drought and labour shortage were mentioned as a limiting factor for goat production with index values of 0.303, 0.286, 0.186 and 0.122, respectively. Likewise, feed and grazing land shortages followed by predators, labour shortages and diseases were identified as serious problems in highlands. In general, feed shortage, disease prevalence, drought and labour shortage were the most limiting factors for goat production, although their importance was not similar across agro-ecologies. This result is in agreement with those of Abegaz (2014). Therefore, giving due attention to these constraints is very important to increase goat productivity. For example, promoting

**Table 10. Selling priority of different classes of goats in Raya Kobo district**

| Age category | Lowland | | | | Midland | | | | Highland | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R1 | R2 | R3 | Index | R1 | R2 | R3 | Index | R1 | R2 | R3 | Index |
| Male kid < 6 month | 0 | 0 | 0 | 0.000 | 0 | 0 | 0 | 0.000 | 0 | 1 | 0 | 0.006 |
| Female kid < 6 month | 0 | 1 | 3 | 0.014 | 1 | 3 | 8 | 0.047 | 0 | 3 | 9 | 0.042 |
| Male 6 to 12 months | 11 | 38 | 9 | 0.328 | 7 | 29 | 11 | 0.250 | 12 | 26 | 13 | 0.281 |
| Female 6 to 12 months | 2 | 7 | 40 | 0.167 | 13 | 12 | 26 | 0.247 | 9 | 8 | 7 | 0.139 |
| Breeding doe | 2 | 1 | 2 | 0.028 | 1 | 2 | 1 | 0.022 | 10 | 4 | 6 | 0.122 |
| Breeding buck | 0 | 0 | 1 | 0.003 | 0 | 0 | 0 | 0.000 | 0 | 0 | 0 | 0.000 |
| Old doe | 40 | 12 | 5 | 0.414 | 25 | 12 | 11 | 0.306 | 6 | 15 | 23 | 0.197 |
| Castrated | 5 | 1 | 0 | 0.047 | 13 | 2 | 3 | 0.128 | 23 | 3 | 2 | 0.214 |

R1, R2, and R3 = number of respondents gave first, second and third rank for attributes, respectively

**Table 11. Major constraints of goat production in Raya Kobo district**

| Constraints | Lowland | | | | Midland | | | | Highland | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R1 | R2 | R3 | Index | R1 | R2 | R3 | Index | R1 | R2 | R3 | Index |
| Disease/ poor veterinary service | 36 | 12 | 11 | 0.398 | 17 | 20 | 12 | 0.286 | 10 | 8 | 8 | 0.150 |
| Feed and grazing land shortage | 4 | 6 | 15 | 0.109 | 22 | 14 | 15 | 0.303 | 34 | 7 | 12 | 0.355 |
| Water shortage | 2 | 1 | 2 | 0.028 | 1 | 2 | 1 | 0.022 | 0 | 0 | 0 | 0.000 |
| Labour shortage | 8 | 13 | 8 | 0.162 | 8 | 7 | 6 | 0.122 | 4 | 21 | 7 | 0.169 |
| Market problem | 2 | 0 | 1 | 0.019 | 0 | 0 | 0 | 0.000 | 0 | 0 | 0 | 0.000 |
| Predator | 1 | 4 | 9 | 0.056 | 3 | 4 | 11 | 0.078 | 9 | 14 | 10 | 0.180 |
| Genotype | 0 | 1 | 0 | 0.006 | 0 | 0 | 1 | 0.003 | 0 | 0 | 0 | 0.000 |
| Drought | 7 | 22 | 15 | 0.223 | 10 | 10 | 17 | 0.186 | 2 | 12 | 23 | 0.147 |

R1, R2, and R3 = number of respondents gave first, second and third rank for attributes, respectively

**Table 12. Live weight and morphological traits of goats in Raya Kobo district (LSM ± SE)**

| Sources of variation | N | BW | BL | WH | CG | CW | CD | RH | RL | RW |
|---|---|---|---|---|---|---|---|---|---|---|
| CV | 510 | 17.05 | 6.748 | 5.393 | 6.082 | 10.609 | 7.43 | 5.62 | 6.451 | 8.44 |
| Overall mean | 510 | 22.2 ± 0.29 | 60.9 ± 0.29 | 65.3 ± 0.25 | 68.4 ± 0.32 | 13.3 ± 0.08 | 33.8 ± 0.17 | 63.6 ± 0.23 | 18.56 ± 0.08 | 12.69 ± 0.08 |
| Sex | | *** | *** | *** | ** | ** | *** | *** | *** | ** |
| Female | 411 | 22.8 ± 0.31$^{a}$ | 61.8 ± 0.31$^{a}$ | 65.79 ± 0.26$^{a}$ | 69.4 ± 0.35$^{a}$ | 13.3 ± 0.09$^{a}$ | 34.0 ± 0.19$^{a}$ | 64.16 ± 0.24$^{a}$ | 18.7 ± 0.09$^{a}$ | 13 ± 0.08$^{a}$ |
| Male | 99 | 19.3 ± 0.64$^{b}$ | 57.59 ± 0.69$^{b}$ | 63.3 ± 0.61$^{b}$ | 64.45 ± 0.68$^{b}$ | 13.05 ± 0.18$^{b}$ | 32.67 ± 0.39$^{b}$ | 61.57 ± 0.58$^{b}$ | 17.9 ± 0.19$^{b}$ | 11.2 ± 0.16$^{b}$ |
| Age | | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| 0PPI | 163 | 15.9 ± 0.30$^{d}$ | 54.49 ± 0.39$^{d}$ | 59.86 ± 0.34$^{d}$ | 61.4 ± 0.41$^{e}$ | 12.38 ± 0.10$^{c}$ | 30.6 ± 0.24$^{d}$ | 58.7 ± 0.34$^{d}$ | 17.1 ± 0.12$^{d}$ | 10.85 ± 0.09$^{e}$ |
| 1PPI | 80 | 19.7 ± 0.38$^{c}$ | 59.00 ± 0.40$^{c}$ | 64.2 ± 0.38$^{c}$ | 66.3 ± 0.48$^{d}$ | 12.6 ± 0.16$^{c}$ | 32.7 ± 0.30$^{c}$ | 62.8 ± 0.37$^{c}$ | 18.08 ± 0.15$^{c}$ | 12.4 ± 0.13$^{d}$ |
| 2PPI | 75 | 24.5 ± 0.53$^{b}$ | 64.09 ± 0.43$^{b}$ | 67.7 ± 0.45$^{b}$ | 70.85 ± 0.52$^{c}$ | 13.49 ± 0.23$^{b}$ | 35.18 ± 0.37$^{b}$ | 66.18 ± 0.42$^{b}$ | 19.08 ± 0.17$^{b}$ | 13.36 ± 0.12$^{c}$ |
| 3PPI | 74 | 25.0 ± 0.44$^{b}$ | 64.45 ± 0.41$^{b}$ | 67.9 ± 0.35$^{b}$ | 72.06 ± 0.42$^{b}$ | 13.7 ± 0.17$^{b}$ | 35.48 ± 0.33$^{b}$ | 66.1 ± 0.38$^{b}$ | 19.3 ± 0.16$^{b}$ | 13.7 ± 0.10$^{b}$ |
| 4PPI | 118 | 29.2 ± 0.42$^{a}$ | 67.15 ± 0.37$^{a}$ | 70.35 ± 0.27$^{a}$ | 75.75 ± 0.44$^{a}$ | 14.5 ± 0.17$^{a}$ | 37.05 ± 0.28$^{a}$ | 67.86 ± 0.30$^{a}$ | 20.09 ± 0.13$^{a}$ | 14.3 ± 0.11$^{a}$ |
| Agro-ecology | | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| Highland | 111 | 20.8 ± 0.56$^{c}$ | 60.03 ± 0.53$^{b}$ | 64.48 ± 0.47$^{b}$ | 66.0 ± 0.59$^{c}$ | 12.25 ± 0.14$^{c}$ | 32.36 ± 0.31$^{c}$ | 62.79 ± 0.47$^{b}$ | 17.76 ± 0.15$^{c}$ | 12.09 ± 0.14$^{b}$ |
| Lowland | 205 | 23.1 ± 0.50$^{a}$ | 60.36 ± 0.50$^{b}$ | 65.6 ± 0.42$^{a}$ | 70.06 ± 0.56$^{a}$ | 14.09 ± 0.14$^{a}$ | 35.38 ± 0.28$^{a}$ | 64.1 ± 0.40$^{a}$ | 19.4 ± 0.13$^{a}$ | 12.8 ± 0.14$^{a}$ |
| Midland | 194 | 21.9 ± 0.44$^{b}$ | 62.18 ± 0.46$^{a}$ | 65.4 ± 0.38$^{a}$ | 68.1 ± 0.46$^{b}$ | 12.9 ± 0.09$^{b}$ | 32.97 ± 0.25$^{b}$ | 63.65 ± 0.34$^{a}$ | 18.08 ± 0.11$^{b}$ | 12.85 ± 0.12$^{a}$ |

BW = body weight, BL = body length, WH = wither height, CG = chest girth, CW = chest width, CD = chest depth, RH = rump height, RL = rump length, RW = rump width; ** = P < 0.01; *** = P < 0.001

**Table 12. Continued**

| Sources of variation | N | PG | HL | HW | MC | EL | NG | SC | HOL |
|---|---|---|---|---|---|---|---|---|---|
| CV | 510 | 12.5 | 7.48 | 9.03 | 8.01 | 8.18 | 10.2 | 12.0 | 8.22 |
| Overall mean | 510 | 70.4 ± 0.51 | 18.7 ± 0.08 | 15.3 ± 0.07 | 20.6 ± 0.11 | 13.4 ± 0.05 | 27.3 ± 0.18 | 20.45 ± 0.31 | 9.23 ± 0.17 |
| Sex | | *** | *** | * | ns | ns | *** | - | ns |
| Female | 411 | 72.8 ± 0.40$^{a}$ | 18.7 ± 0.08$^{a}$ | 15.3 ± 0.08$^{a}$ | 20.8 ± 0.12 | 13.5 ± 0.05 | 27.1 ± 0.19$^{b}$ | - | 9.29 ± 0.18 |
| Male | 99 | 60.5 ± 1.74$^{b}$ | 18.5 ± 0.24$^{b}$ | 14.9 ± 0.18$^{b}$ | 19.9 ± 0.25 | 12.8 ± 0.12 | 27.9 ± 0.48$^{a}$ | 20.4 ± 0.31 | 8.97 ± 0.46 |
| Age | | *** | *** | *** | *** | *** | *** | * | *** |
| 0PPI | 163 | 61.2 ± 0.94$^{e}$ | 17.1 ± 0.15$^{c}$ | 14.4 ± 0.12$^{d}$ | 19.1 ± 0.17$^{d}$ | 12.7 ± 0.08$^{c}$ | 25.6 ± 0.26$^{c}$ | 19.6 ± 0.35$^{c}$ | 5.9 ± 0.19$^{d}$ |
| 1PPI | 80 | 68.2 ± 0.94$^{d}$ | 18.3 ± 0.13$^{b}$ | 14.9 ± 0.18$^{c}$ | 19.8 ± 0.21$^{c}$ | 13.35 ± 0.09$^{b}$ | 26.26 ± 0.43$^{c}$ | 21.5 ± 0.91$^{b}$ | 7.85 ± 0.25$^{c}$ |
| 2PPI | 75 | 72.9 ± 1.05$^{c}$ | 19.6 ± 0.15$^{a}$ | 15.5 ± 0.19$^{b}$ | 21.2 ± 0.25$^{b}$ | 13.81 ± 0.12$^{a}$ | 28.09 ± 0.55$^{b}$ | 23.69 ± 0.49$^{a}$ | 10.8 ± 0.42$^{b}$ |
| 3PPI | 74 | 75.6 ± 0.60$^{b}$ | 19.6 ± 0.13$^{a}$ | 15.6 ± 0.17$^{b}$ | 21.3 ± 0.21$^{b}$ | 13.78 ± 0.18$^{a}$ | 27.78 ± 0.41$^{b}$ | 23.69 ± 0.49$^{a}$ | 10.98 ± 0.38$^{b}$ |
| 4PPI | 118 | 79.9 ± 0.56$^{a}$ | 19.8 ± 0.11$^{a}$ | 16.3 ± 0.15$^{a}$ | 22.6 ± 0.20$^{a}$ | 13.87 ± 0.08$^{a}$ | 29.5 ± 0.37$^{a}$ | - | 12.6 ± 0.29$^{a}$ |
| Agro-ecology | | *** | *** | *** | *** | *** | *** | ns | ** |
| Highland | 111 | 68.9 ± 0.68$^{b}$ | 18.7 ± 0.15$^{b}$ | 14.2 ± 0.11$^{c}$ | 19.36 ± 0.17$^{c}$ | 13.09 ± 0.11$^{b}$ | 24.4 ± 0.26$^{c}$ | 21.05 ± 0.64 | 8.40 ± 0.37$^{b}$ |
| Lowland | 205 | 70.5 ± 1.12$^{a}$ | 18.2 ± 0.14$^{c}$ | 16.0 ± 0.13$^{a}$ | 22.07 ± 0.18$^{a}$ | 13.56 ± 0.09$^{a}$ | 30.15 ± 0.29$^{a}$ | 20.4 ± 0.41 | 10.1 ± 0.28$^{a}$ |
| Midland | 194 | 71.3 ± 0.52$^{a}$ | 19.1 ± 0.11$^{a}$ | 15.1 ± 0.09$^{b}$ | 19.90 ± 0.13$^{b}$ | 13.41 ± 0.08$^{a}$ | 25.98 ± 0.19$^{b}$ | 20.11 ± 0.70 | 8.78 ± 0.27$^{ab}$ |

PG = paunch girth, HL = head length, HW = head width, EL = ear length, NG = neck girth, SC = scrotum circumference, HOL = horn length; Ns = non-significant; *= P < 0.05; ** = P < 0.01, *** = P < 0.001

alternative forage development strategies, developing improved forages and efficient feed utilization options are important to alleviate feed shortage.

**Morphological traits of goat**

The least square means and standard errors of quantitative morphological traits of goats are shown in Table 12. Goats are classified as large, when they weigh between 20 and 60 kg and with a height at withers above 65 cm, according to Devendra and Bums (1983). On this basis, goats in Raya Kobo could be classified as large-sized. Sex had a significant influence on body weight (BW), body length (BL), wither height (WH), chest girth (CG), chest width (CW), chest depth (CD), rump height (RH), rump length (RL), rump width (RW), paunch girth (PG), head length (HL), head width (HW) and neck girth (NG) except muzzle circumference (MC), ear length (EL) and horn length (HOL). The BW, BL, WH, CG, CW, CD, RH, RL, RW, PG, HL and HW values of females were higher than in males except NG. On the contrary, the superiority of male over female goats was reported by previous studies (Abegaz, 2014; Alemu, 2015). The lower performance of males in this study could be due to the physiology of females, a small sample size of males, and most of the male goats were kids and buckling (young) than females.

The age of the goat had a significant influence on all quantitative morphological traits. A similar observation has been made by several authors (Abegaz, 2014; Getaneh, 2020). The values for most of the morphological traits were increased with the age of goats except for HL and EL. The HL and EL were not increased with age after 2PPI. Similarly, the BW, BL, WH, CW, CD, RH, RL and HW of 2PPI and 3PPI goats were not statistically different.

Agroecology exerted a significant influence on the body weight and morphological traits of goats. The influence of agroecology on morphological traits was also reported by Tsegaye *et al.* (2013). In this study, goats in the lowland area had significantly higher BW, CW, CG, CW, RL, MC and NG, than goats in the highland and midland areas. However, the WH, RH, RW, PG, EL and HOL of goats in the midland and lowland areas were found to be similar. In general, goats in the highland area had lower values of morphological traits. This result agrees with the reports of Zeleke *et al.* (2017). However, Tsegaye *et al.* (2013) reported that goats in the lowlands had lower BW, BL and HG. The observed performance difference across agro-ecologies could be associated with feed availability, the type of grazing they were exposed to and the number of goats sampled in each age group and sex.

## CONCLUSION

Goat rearing was the major farming activity next to crop production. Goats provide a variety of ecosystem services that contribute to environmental sustainability, agricultural productivity and the livelihoods of people. Indigenous goats in the study area could be classified as large-sized based on their body weight and morphological features. The goat production system in the study area is categorized under an extensive production system, based on different indicators. Feed shortage, disease prevalence, drought and labour shortage were the most limiting factors for goat production. Pasteurellosis, Goat pox and Anthrax were economically important diseases in the study areas. In addition, external parasites such as mange mites and ticks were also identified as a serious problem. Once the most prevalent diseases are identified, intervention (prevention measures, vaccination and sanitation) is required to reduce the impact associated with diseases and parasites. Promoting alternative forage development strategies, improved forages and efficient feed utilization and conservation options are important to alleviate feed shortage and enhance drought resilience capacity. In addition, designing and implementing a community-based genetic improvement program through within-breed selection could improve the productivity of indigenous goats.

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## *DATA AVAILABILITY STATEMENT*

The data presented in this study are available on request from the corresponding author.

## *CONFLICT OF INTEREST*

The authors declare no conflict of interest.

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