Flock Dynamics, Linear Body Measurement and Body Weight Variation of Gumuz Sheep in Assosa District, Benishangul Gumuz Regional State, Western Ethiopia

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Abstract: The study aimed to estimate flock structure, body length, heart girth and height at wizard and body weight variation of Gumuz Sheep in Assosa district. Flocks of 30 households with a total of 171 sheep were monitored for 8 months. The results revealed that the highest flock sizes were recorded in the wet season (July and August). The number of sheep that entered flocks through birth was significantly ($p<0.05$) higher in July (0.55 ± 0.11) and August (1.11 ± 0.11). The majority of sales of sheep took place in April (0.45 ± 0.09) and May (0.25 ± 0.09) which coincides with Ethiopian Easter celebrations and Muslim holidays. High numbers of all age classes of sheep mortalities were documented during the dry (February, March and April) and cool (January) seasons. The sheep production potential (SPP) was significantly ($p<0.05$) higher in large flocks (1.13 ± 0.04) than in small flocks (0.90 ± 0.05) and it was higher ($p<0.05$) in May, June and July. The high sheep production efficiency (SPE) and off-take were recorded during April and May. Greater sheep production efficiency in the months of April and May indicate that a large number of mature and growing sheep were sold by farmers. The overall least squares mean body weight (BW) of sheep was 26.06 ± 0.33kg. A strong correlation between height at wizard (HW) and body weight was observed, for males ($r=0.79$) and females ($r=0.81$). Month had a significant ($p<0.05$) effect on body weight and all other body parameters. The higher body weight was recorded in June, July and August, because the potential of feed supplies, both in quantity and quality during these months. Mortality in lambs was higher in the dry season which might be associated with nutritional stress coupled with disease problems. From the study it was concluded that limited feed resources in dry season and disease problem were the main constraints that retard live weight and economic performance of sheep production in the study areas. Based on the conclusion strengthening the practice of feed resource conservation for dry season and design appropriate disease prevention strategy are recommended to improve live weight performance and reduce mortality of sheep.

Keywords: *Age category, Flock size, Mortality rate, Off-take rate, Production efficiency, Production potential*

Introduction

Ethiopia is a country that has a significant contribution to the global livestock gene pool. About 42.9 million sheep are estimated to be found in the country, out of which about 70 percent are females and about 30 percent are males (CSA, 2021). According to estimates indigenous breeds account for 99.9% of Ethiopia's total sheep populations. The majority of the country's sheep population is kept by smallholder farmers and sheep production is still done traditionally. Sheep can be found in a wide range of agro-ecological zones, from the cool alpine climate of the country's highlands to the arid pastoral plains of the lowlands (DAGRIS, 2003).

Small ruminants are an important part of livestock keeping in Ethiopia (Kosgey *et al.,* 2008), as they provide a wide range of products and multipurpose services to their owners, including immediate cash income, meat, milk and manure and provide regular income in both tangible and intangible ways to a large human population through the sale of live animals and skins (Abebe *et al.,* 2010; Shigdaf *et al*., 2013). They are also seen as a living bank against a range of natural disasters (crop failure, drought and flooding), as well as having socio-cultural significance for many traditional civilizations (Edea *et al*., 2010). Sheep farming in Ethiopia has great potential to help low-input smallholder farmers and pastoralists better their livelihoods by using traditional and extensive production systems. Sheep production has unique properties, such as their small size, which requires low initial investment to begin and expand as a business, efficient use of marginal and small areas of land and foreign money sources (Berhanu *et al*., 2006). Sheep contribute significantly to Ethiopia's household and national economies, but their output falls short of expectations when compared to their numbers. Lack of feed, high mortality, low commercial off-take rates, disease prevalence, poor genotype and a lack of marketing and infrastructure are all contributing factors (Gizaw *et al*., 2008; Solomon *et al*., 2014; Talore *et al*., 2018). As a result, several measures to improve production and productivity have been tried, but the success is limited. With a long history of focusing on

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exotic breeds, crossbreeding is one of the most important activities. On-farm performance study provides information about specific production conditions in a given place that could lead to system-specific improvement options (Getahun, 2008).

Performance recording is a significant tool for determining a certain area's production policy. In Ethiopia in particular and developing regions in general, populations of livestock of the same species are typically recognized as unique eco-types or breeds, especially if they are geographically isolated and recognized by ethnic owners as being distinct from others around them. Sheep breeds in Ethiopia are strongly associated with ethnic groups. Several traditional breeds are raised in specific communities and are named after them. Some communities are attached to their sheep culturally and refuse to receive breeding stock from other populations, creating a cultural barrier to gene flow (Gizaw *et al.*, 2008).

The Assosa sheep type (Gumuz sheep) is widely spread in the relatively low altitude areas of the northwestern parts of the Benishangul Gumz Regional state (400-1600 m.a.s.l) (Solomon, 2007). The Gumuz sheep, named after of the ethnic group keeping them, is the only thin-tailed sheep breed in Ethiopia that is kept by both small and large-scale farmers based predominantly on extensive grazing of native pasture. It has good prolificacy, lambing frequency, and good quality of meat. Gumuz sheep also possess adaptive characteristics as far as endurance to nutritional fluctuations and tolerances to extreme temperatures are concerned.

Despite its importance and abundance of resources, the region continues to deteriorate due to poverty and malnutrition. This suggests that a detailed examination of periodic monitoring and identification of factors affecting sheep flock dynamics is required for more focused targeting interventions. Furthermore, the driving forces for changes in sheep production systems operate at different aggregation levels because of the impact of agro-ecological conditions on the availability of feed and the prevalence of diseases/parasites. However, because of inadequate information, on the effect of seasonal variations in flock dynamics and management in smallholder production is limited, making it impossible to measure the efficiency of smallholder sheep production's contribution to its keepers. Under smallholder conditions, it is also difficult to estimate production, sales and consumption patterns due to a lack of information. Therefore, it requires assessing flock dynamics and linear body measurements of sheep in the area with the following objectives: (i) to determine the contribution of Gumuz sheep to the livelihood of resource-poor farmers through a continuous monitoring study; (ii) to identify factors affecting Gumuz sheep flock dynamics; and (iii) to evaluate linear body measurements and body weight variation of Gumuz sheep.

Materials and Methods

Description of the Study Area

The study was conducted in Assosa district, located 663 kilometers to west of Addis Ababa, at 10°02.922'N latitude and 34°33.868'E longitude. The annual rainfall averages 950 1000 mm and the average annual temperature is 30°C, with the hottest months being March and May (Assefa *et al.*, 2015). The rainy season spreads from May until October. The study area is characterized by diverse topography with an altitude range of 580-1544 m.a.s.l. The area has a lengthy rainy season (June-September accounting for 75% of total rainfall), a short rainy season (February/March to April/May) and a dry season (October to January) (Assosa Agriculture Research Center, 2011).

Sampling Techniques and Sample Size

Before the actual data collection, discussions were held with zonal and district livestock experts and development agents (DAs) to get actual information on the distribution of the targeted sheep populations, and identify study district and *kebeles*. Based on the outcome of the discussion, Assosa district was purposively selected for this study to address the baseline data collection on flock dynamics and on-farm performance monitoring. Based on the rapid field survey and secondary information gathered from the key informants such as farmers' representatives/elders and livestock experts in the Bureau of Agriculture and Rural Development of the districts, two peasant associations (PAs) were selected purposively. Sheep population size, availability of communal grazing land, suitability for sheep production, the relative significance of sheep to the livelihood of the farmers, accessibility to markets and roads, and willingness of the farmers to participate in the program were the criteria used in selecting the PAs. For focus group discussions that were undertaken in the two districts (two per district), 10 household heads were selected in each *kebele*.

Probability proportional to size (PPS) technique was used to make the sample size taken from each PA proportional to the number of households in that PA after the total sample size was determined by using the formula by Yamane (1967). The following probability proportional to size (PPS) sampling technique formula was calculated as:

$$W=[A/B]xN$$

Where: W=number of households to be calculated from the selected PA; A=total number of households in the selected PA; and B=total number of households in all eight selected PAs and N=the calculated sample size.

Finally, for the flock dynamics study, the selection of farmers was based on owning at least four adult sheep with a minimum of one year experience in sheep husbandry and the presence of a literate member in the household to record entry and exit into and out of the flocks in the record booklets. The list of farmers was prepared in each selected PA with the help of development agents. Then, sample households were selected by using a simple random sampling technique until the calculated sample size of each PA was maintained. The following formula was used to determine the sample size for this study:

$$n=\frac{N}{1+Ne^2}$$

Where, n = minimum returned sample size, N = the population size, and e = the degree of accuracy expressed as a proportion = 0.05.

Based on the above sample size formula, 80 households (each 40 from Bambasi 01, Bambasi 02 *kebeles* in Bambasi districts) were selected for the monitoring study. Therefore, based on owning at least four adult sheep, the total sample size was reduced to thirty participants. From these 30 house households, 171 animals were monitored on a continuous basis. In each sampling site, the selected experimental animals were identified by color, size and the information on previous productivity performance and health conditions of the animals.

Data Types and Methods of Data Collection

On-farm monitoring of flock sizes and body weight: Assessment of flock dynamics and productivity was accomplished through monthly visits for eight months. Flocks were classified into small (<13 adult sheep) and large (>=13 adult sheep) as described by Rumosa *et al.* (2009) and Befikadu *et al.* (2019). Household heads were categorized into two age groups (<40 years) old and (≥40 years) as described by Mapiliyao *et al.* (2012). The sheep in a flock were classified into five categories; adult females (female sheep older than one year), rams (entire male older than one year), castrates, female lambs (female lambs less than one year) and male lambs (male lambs less than one year). Estimation of age using dentition was developed as 0PPI, 1PPI, 2PPI, 3PPI and 4PPI which are equivalent with the age categories of ≤ 1, 1-2, 2-3, 3-4, >4 years, respectively (Solomon and Kassahun, 2009).

The live weight of an animal was measured using a spring balance having a 50 kg capacity with 0.2 kg precision. Other linear body measurements such as body length (BL), which is the horizontal length measured from the point of shoulder to the pin bone, height at wither (HW) the highest point measured as the vertical distance from the top of the shoulder to the ground (bottom of forelegs) was measured, as was heart girth (HG). On-farm data recording formats were developed on different sheets accordingly, number and types of sheep owned by farmers at the beginning of flock inventory (base flock), flock dynamics (in-flows and out-flows) and linear body measurements were recorded in the data recording formats. The linear body measurements were taken using a tap meter.

Sheep off-take, production potential and production efficiency: Three measures of production efficiency were considered, namely off-take rate, sheep production potential (SPP) and sheep production efficiency (SPE). Off-take was defined as the total number of sheep that was sold and/or slaughtered plus animals gifted-out permanently as a proportion of the total flock size. The SPP and SPE for the flock were calculated every month, as described by Chiduwa *et al.* (2008). The sheep production efficiency (SPP) was computed as the proportion of mature and growing goats to the total flock size (SPP= $^{N}/_{H}$); Where, N = the number of mature and growing sheep; H = the number of total flocks. The SPE was defined as the proportion of mature sheep sold and/or slaughtered for consumption as a proportion of SPP (SPE= (M/SPP) 100); where: M=number of mature sheep sold and/or slaughtered for consumption.

Statistical Analysis

Basic statistics (mean, frequency and percentage) was used for base flock, final flock, flock size, flock structure. Analysis of the parameters and the effects of month, gender and age of head of household and flock size on entries, exits, SPP, SPE, off-take were expressed as Least Square Means (LSM) ± SE and quantitative traits (body weight and other body measurements: body length (BL), heart girth (HG) and wither height (WH) were determined using the general linear model procedure of SAS (2012). A two-way interaction effects were also fitted in to the models and retained in the final model when found significant (p<0.05) in the preliminary analysis. The following statistical model was used.

$$Y_{ijkl} = \mu+M_i+S_j+A_k+F_l+\varepsilon_{ijkl};$$

where: Y_{ijkl} = response variable (lamb mortality, adult mortality, sales, slaughters, sheep entrusted out (sheep given out from the flock given to someone's (delegates to care), births, purchases, exchanges, sheep entrusted in, gifts in, gift out, number of sheep missing (stolen, eaten by predator, died) SPE, SPP, off-take rate, quantitative traits (body weight and other body measurements); μ = constant mean common to all observations; M_i= effect of month; S_j= effect of gender of farmer (j = male, female); A_k= effect of age group (k = young, old); F_l= effect of flock size (l = small flocks, large flocks) and $\sum_{ijkl}$= random residual error, assumed to be normally distributed.

The Pearson's correlation coefficients between body weight and linear body measurements were computed separately for each sex (SAS, 2012 version 9.4). Furthermore, the best-fitted regression equations for the prediction of body weight from linear body measurements for male and female animals were determined by regressing body weight on body measurements (BL, HG and WH) using multiple regression procedures (SAS version 9.4). The R^2 adjusted was used to determine the best-fitted regression model. For the multiple linear regression analysis, the following model was used.

$$Y= \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \varepsilon j$$

where: Y = the dependent variable (body weight); β_o = the intercept; X_1, X_2 and X_3 are the explanatory variables (height at whither, heart girth and body length);

$\beta 1$, $\beta 2$ and $\beta 3$ are regression coefficients of the variables $X1$, $X2$ and $X3$ and εj = random error.

Results and Discussion

Demographic Characteristics

Thirty smallholder farmers with 171 sheep were interviewed for the household survey. Sex, age structure and flock size of the respondents are presented in Table 1. The survey revealed that the majority of the households were headed by males which accounted for 83.33%. The remaining proportion of the households was headed by females. Belete (2014) also reported among the respondents males were higher than female respondents. The majority of the respondents were from the older age groups (>=40 years old) of farmers. Small flock owners made up the majority of the respondents compared to large flock owners during the survey study.

Flock Sizes and Structure

Regardless of flock size, the number of sheep per household varied from month to month (Figure 1). Throughout the study period, the flock dynamic varied with either an increasing or decreasing trend. In general, the highest flock sizes were recorded in the wet season (July and August). The flock inflow affected by seasons is attributed to variations in the availability of sufficient quantity and quality forage. The current study is similar to earlier observations Mapiliyao (2010), who reported the highest peak period was recorded in June in communal farming systems of South Africa. Similarly, studies of Kom (2016) and Befikadu *et al.* (2019) also stated that sheep and goat flocks inflow was affected by month in South Africa and western Ethiopia in communal farming system, respectively.

Table 1. Gender, flock size and age structure of the household heads in the study area.

Parameters	N	Percent (%)
Gender of farmer:		
Male	25	83.33
Female	5	16.67
Age of farmer:		
<40	3	10.00
≥40	27	90.00
Flock Size:		
Small	20	66.67
Large	10	33.33

N= Number of observations.

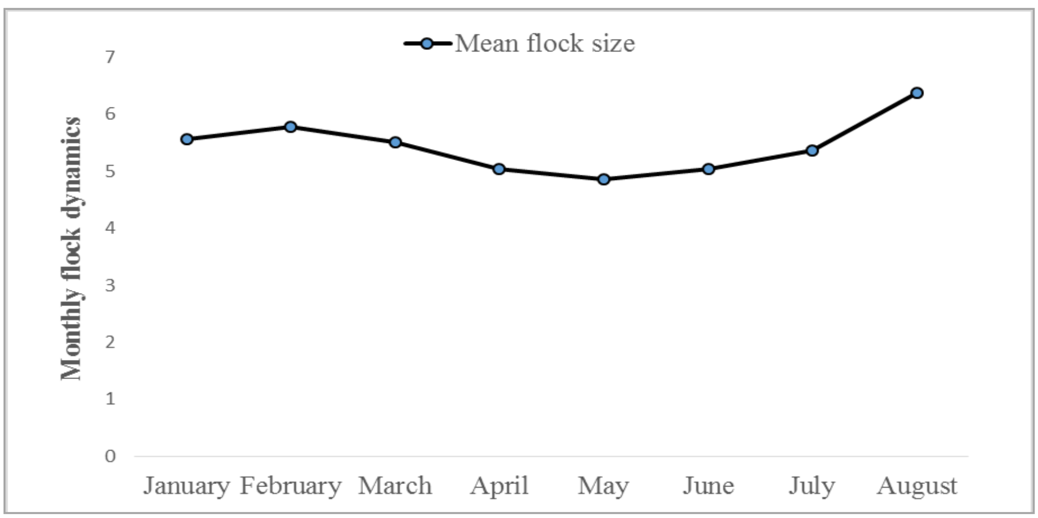

Figure 1. Monthly mean flock structure of sheep per household (January to August successive months).

Inflow of Sheep

Entries are the number of sheep that were added or the act or an instance of entering the flock through purchases and births (Table 2). Purchases were almost not recorded during the study period even though it rarely occurred during April and June. The study of Kom (2016) reported that purchase outcomes across areas of the Eastern Cape Province, South Africa were higher during June, though the average mean was statistically insignificant ($p>0.05$).

The number of sheep born was significantly affected ($p<0.05$) by month. The pattern of birth inflows was higher in August (1.11 ±0.11) and July (0.55 ±0.11) (Table 2), indicating that the wet season was a good time for flock growth through birth. However, there was a general decline in the number of sheep born between March and May; this might be due to the impact of unfavorable weather conditions on the availability of abundant feed during the dry season. Similarly, Talore *et al.* (2015) reported that flock dynamics were affected by land and feed scarcity, family, and farm size in southern Ethiopia. Mapiliyao (2010) also stated that sheep flock inflow was affected by month in South Africa's communal farming system.

The higher number of entries through birth obtained in the current study was also consistent with reports of Kom (2016) and Befikadu *et al.* (2019), who noted that the incidence of lambing and kidding were higher throughout the summer months; which implied the importance of feeding for timely conception and sustainable reproduction in the flock. Different studies (CSA, 2012; Assen and Aklilu, 2015; Talore *et al.*, 2018) indicated a positive relationship between the breeding season and feed availability for goats in Ethiopia.

Moreover, the lower flock entries through birth are due to irregular distribution (presence or absence) of rams in the flocks. Most of the farmers in the study area kept fewer numbers of intact males compared to female sheep (Figure 2) for breeding purposes. Higher numbers of female animals (57%) in flocks were also reported by (Befikadu *et al.,* 2020) in the western lowlands of Ethiopia. The higher female number in a flock is related to the need of owners to ensure sustainable household income and milk for family consumption by maintaining a high number of ewes and keeping fewer numbers of intact males for breeding and castrates for finishing. This result was in agreement with previous studies (Getahun, 2008; Rumosa *et al.,* 2009; Mapiliyao, 2010).

Table 2. Least squares means (±SE) for effects of gender, age of household head, flock size, and month on birth and purchase of sheep.

Effects	Birth	Purchase
Gender of farmer:		
Male	0.32 ±0.04	0.01±0.02
Female	0.31 ±0.09	0.00±0.03
	ns	ns
Age of farmer:		
<40	0.32 ±0.12	0.00±0.04
≥40	0.32 ±0.04	0.01±0.02
	ns	ns
Flock size:		
Small	0.26 ±0.06	0.02±0.03
Large	0.37 ±0.07	0.00±0.02
	ns	ns
Month:		
January	0.08 ±0.11^{cd}	0.00±0.04
February	0.38 ±0.11^{bc}	0.00±0.04
March	0.08 ±0.11^{cd}	0.00±0.04
April	0.01 ±0.11^{d}	0.06±0.04
May	0.15 ±0.11^{cd}	0.00±0.04
June	0.18 ±0.11^{cd}	0.06±0.04
July	0.55 ±0.11^{b}	0.00±0.04
August	1.11 ±0.11^{a}	0.00±0.04
	*	ns

^{a,b,c,d}*Means values within a column with different superscripts are significantly different; *=Significant at p<0.05; ns = Non-significant.*

Figure 2. Gumuz ewe (left) and Gumuz ram (right).

Outflow of Sheep

The outflow of sheep is the total number of sheep that left the flock permanently through sales, mortalities and slaughter.

Sales and slaughter of sheep: Sales of sheep were significantly (p<0.05) affected by month (Table 3). The majority of the sheep sales took place in April (0.45 ±0.09) and May (0.25 ±0.09) due to high sheep demand during these months, which coincides with Ethiopian Easter celebrations and Muslim holidays. During this time of the year, demand for small ruminant meat is high, and the price is reasonably acceptable to the producers.

Table 3. Least squares means (±SE) for effects of sex, age of household head, flock size and month on total sales and slaughter of sheep.

Effects	Sales	Slaughter
Gender of farmer:		
Male	0.09 ±0.05[b]	0.02±0.02
Female	0.31±0.07[a]	0.00±0.03
	*	ns
Age of farmer:		
<40	0.19 ±0.09	0.00±0.03
≥40	0.21±0.04	0.02±0.01
	ns	ns
Flock size:		
Small	0.16±0.06	0.00±0.02
Large	0.24±0.06	0.01±0.01
	ns	ns
Month:		
January	0.08 ±0.09[b]	0.00±0.05
February	0.08 ±0.09[b]	0.00±0.05
March	0.15 ±0.09[b]	0.02±0.03
April	0.45 ±0.09[a]	0.02±0.03
May	0.25 ±0.09[ab]	0.02±0.03
June	0.12 ±0.09[b]	0.02±0.03
July	0.25 ±0.09[ab]	0.02±0.03
August	0.22 ±0.09[b]	0.00±0.03
	*	ns

[a,b]*Means values within a column with different superscripts are significantly different; *=Significant at p<0.05; ns = Non-significant.*

Farmers sold sheep in July to buy agricultural supplies and food in addition to the peak selling months of April and May. Farmers, on the other hand, sell their sheep at any time when they need money urgently. The higher sales of sheep during holidays in the current study were consistent with previous reports of Mapiliyao (2010), who reported that the largest sales were in April during Easter celebrations, followed by June during the period of food shortages. In general, earlier studies (Kocho *et al*., 2011; Talore *et al.,* 2018; Befikadu *et al*., 2020) noted a high number of exits of small ruminants through sale for the purchase of agricultural inputs, miscellaneous expenses for school children, and to buy commodities for home consumption. Higher exits through sales (69.4%) were also reported by (Belete, 2009) from the flocks monitored for about six months, which is due to a huge number of local sheep breed and a large number of mean flock sizes of local sheep breed.

The peak period of selling was observed in April and July for female sheep and March, April and August for male sheep (Figure 3). Despite the fact that there were more female flocks sold during the study period, it was found that males were removed from the flock at an early age (less than a year) whenever cash is needed in the household, as confirmed by the sampled farmers during the continuous monitoring period, resulting in a lower proportion of males and the absence of males in some flocks at various times. Because of lack of males in a flock due to early removal (since they reach market age within 6-10 months), conception rates were lower and the flock's entry rate through birth was lower as well which implies the disturbance of effective population size in the flocks and as a consequence rate of inbreeding may be increased (Belete, 2014). Hence, farmers should be advised to have at least a ram available in the flock.

Sheep slaughtering was rarely practiced during the holidays of March, April, May and June but it was unconvincing in this study location (Table 3). Slaughtering, on the other hand, was at its peak during January, April and June for sheep sold and consumed (Kom, 2016).

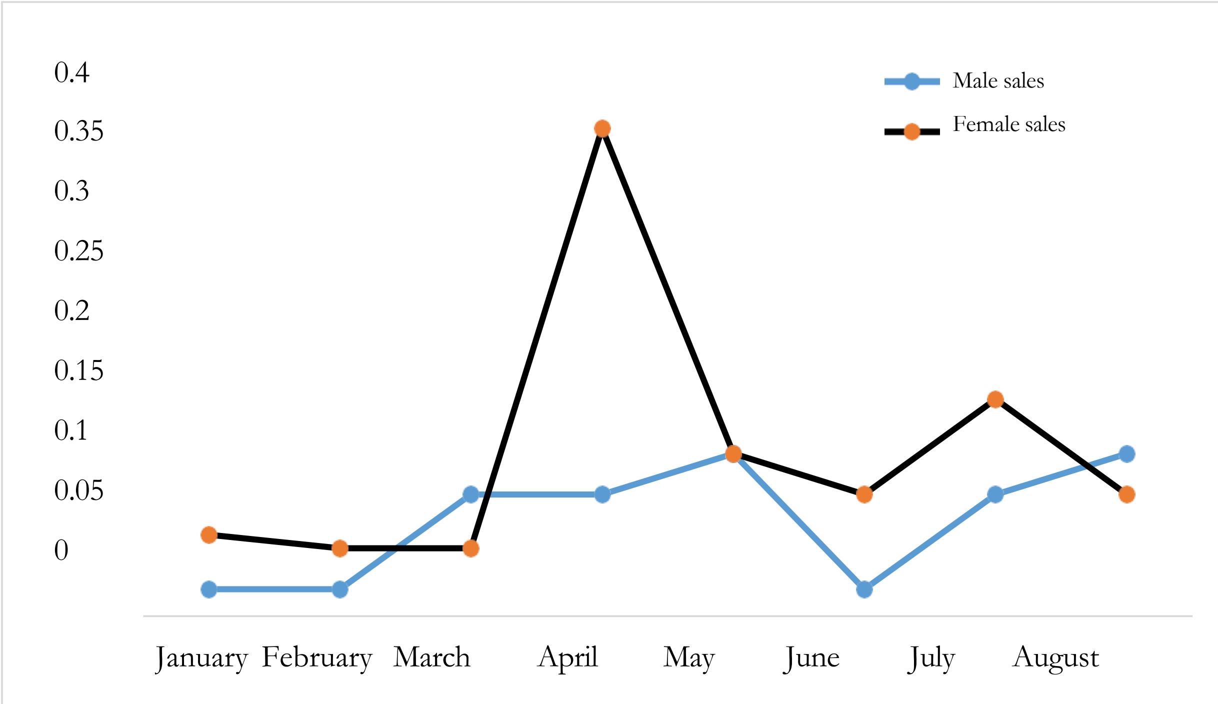

Figure 3. Monthly sales of male and female sheep classes in the study area.

Mortality of sheep: High numbers of all age classes of sheep mortalities were documented in the dry (February, March and April) and cool (January) seasons (Figure 4). In the current study, sheep mortality was the major exit of the flock. The high disease outbreaks and parasite infestations at end of dry season and the beginning of short rain in the spring season (March) were common which could be due to the presence of aggregation and movement of sheep, the occurrence of such parasite infestation diseases and farmers unwillingness to take appropriate preventive measures were the possible cofactors to the increase in the number of deaths. Additionally, farmers in the study area cannot easily get information on animal diseases and inputs that might have been used in disease prevention and treatment. This is in line with Marufu *et al.* (2010), who reported that the high mortality observed in the hot and wet seasons could be attributed to warm and moist conditions which promote vector survival and multiplication. According to Belete (2014) findings, death due to diseases was and the highest followed by concentrate and forage bloats and other digestive disorders.

In the current study, lamb mortality was higher than adult mortality (Figure 5). Adult mortality peaked in March followed by January which is known for prolonged dearth periods in terms of feed and water. However, across the period (except in January and May) of the study, the number of adult sheep was almost constant. This might be due to the susceptibility lambs to diseases and parasite infestations compared to adult sheep. High lamb mortality was documented in the dry (February and April) and cool (January) seasons. The high kid mortalities during dry season as compared to wet season could be inability of does to provide enough milk due to insufficient feed availability to does during dry seasons and does were affected by disease. Besides, the way sheep are managed, very limited access for private and public veterinary services result in higher mortality rates of sheep. Therefore, this result suggests the need critical intervention policy to develop health interventions and feeding during the dry season to reduce mortality of sheep and optimize their productivity could be an appropriate intervention. According to Mapiliyao (2010), in the Eastern Cape Province that the peak contribution of lambs' mortality to total exits in upland and lowland was observed in January confirms the drastic influence of rain on mortality. Sheep sells as well as adult mortality were mostly occurred during January to February and March to April and August could be attributed the decreasing sheep number between May to June and July to August, which concurs very well with earlier work (Befikadu *et al.*, 2019) that reported similar trend decreasing number in goat flock.

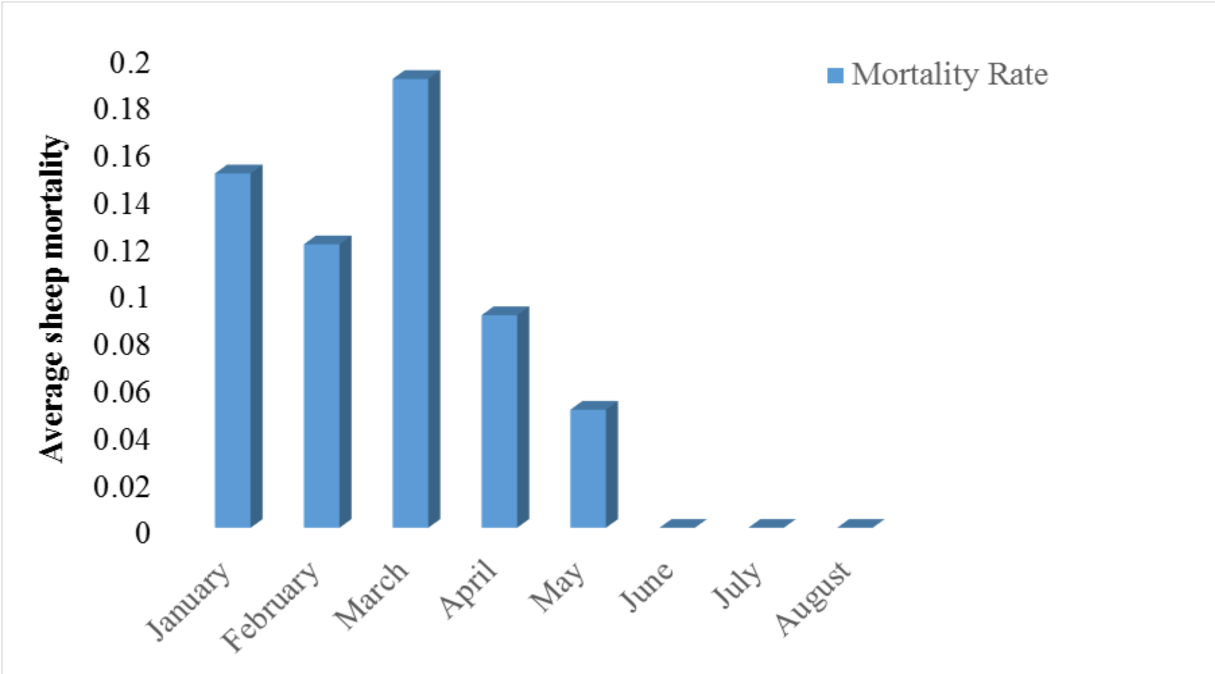

Figure 4. Monthly total sheep cumulative mortality rate during the study period (January to August).

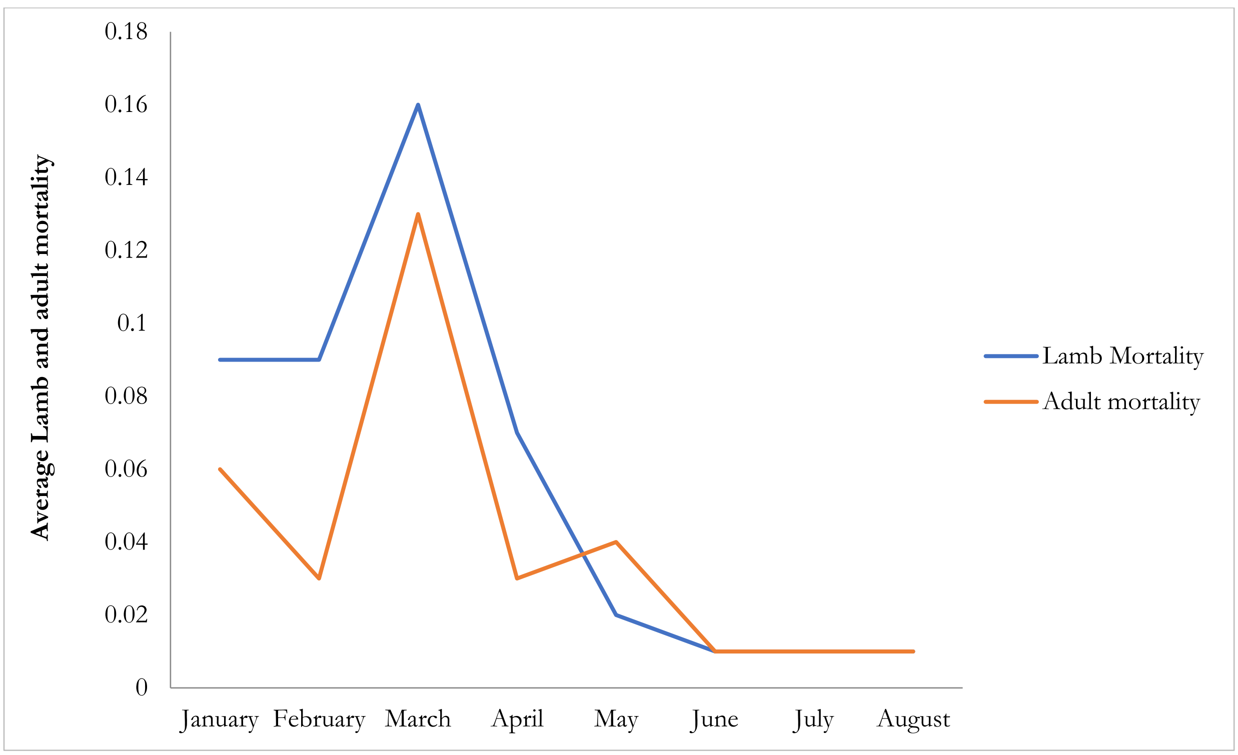

Figure 5. Monthly lamb and adult mortality rates of sheep in the study area.

Off-take rate: In this study, the off-take rate was significantly affected by month (Table 4). The high off-take was observed in the month of April (0.06 ±0.02) and May (0.05 ±0.02) which indicated the number of sheep sold and/or slaughtered from the flocks. The most probable reason for the high number of sheep sold and/or slaughtered at the month of April and May in the study areas associated with high demand for small ruminant meat with Ethiopian Easter and Muslim holidays. Besides, farmers were also ready to sell their flocks during these months in order to buy agricultural in puts. As a result, the majority were being removed from the flock before a year to set up agricultural products and overcome feed shortage problems. The result of off take obtained in the current study, however, was lower as compared to with the study of Talore *et al.*

(2018), who noted that the higher off take (41.8%) rate of sheep in their study was due to the area's emerging market and the presence of other national and international market channels.

Production Potential and Efficiency of Sheep

The sheep production potential (SPP) was significantly ($p<0.05$) affected by age of the sheep owner, in that young age owners had higher SPP value than old age farmers. The sheep production potential was significantly ($p<0.05$) affected by the flock size, in that large flock size owners had higher SPP value than small flock owners. Month also significantly ($p<0.05$) affected SPP (Table 4). The highest SPP was recorded in successive months of May, June and July. Similarly, the significant effect of month on SPP was also reported by the study of (Mapiliyao *et al.,* 2012). Small flocks had a lower output potential than large flocks. The lower sheep production potential results obtained in small flocks size in the current study implied that high death rates prevent small flock owners from obtaining greater benefits from their sheep. The results of this study was supported by Rumosa *et al.* (2009), who reported that a continuous need of cash to solve immediate problems make farmers of small flock holder not to build up flocks to sustainable size and remain with low goat production in Gaga areas of South Africa.

The result of this study indicated that, sheep production efficiency was significantly ($p<0.05$) affected by months. The highest SPE was recorded in the month of April (32.73 ±6.74) and May (21.33±6.74) (Table 4). Greater SPE in the month of April and May indicate that a greater number of mature and growing sheep were sold by owners for those months coincide with Ethiopian Easter festivities, followed by the start of agricultural activities. Similarly, the peak period of sheep production efficiency for Sompondo areas of South Africa was experienced in April, May and June indicating that a high number of growers and mature sheep were sold (Mapiliyao, 2010).

Table 4. Least squares means (±SE) for effects of sex, age of household head, flock size and record month on sheep production potential, off-take and sheep production efficiency.

Effects	SPP	SPE	Off-take
Gender of farmer:			
Male	1.03±0.04	10.83±3.78	0.02±0.01
Female	1.00±0.06	21.97±5.65	0.04±0.01
	ns	ns	ns
Age of farmer:			
<40	0.89±0.07^{b}	19.16±6.79	0.03±0.02
≥40	1.14±0.03^{a}	13.64±3.03	0.03±0.01
	*	ns	ns
Flock size:			
Small	0.90±0.05^{b}	15.15±4.61	0.03±0.01
Large	1.13±0.04^{a}	17.65±4.34	0.03±0.01
	*	ns	ns
Month:			
January	0.95±0.07^{bc}	6.33±6.74^{b}	0.01±0.02^{b}
February	0.94±0.07^{bc}	6.33±6.74^{b}	0.01 ±0.02^{b}
March	0.99 ±0.07^{abc}	13.64 ±6.74^{b}	0.02 ±0.02^{ab}
April	1.06 ±0.07^{ab}	32.73 ±6.74^{a}	0.06 ±0.02^{a}
May	1.16 ±0.07^{a}	21.33±6.74^{ab}	0.05 ±0.02^{a}
June	1.14±0.07^{a}	12.23 ±6.74^{b}	0.02 ±0.02^{ab}
July	1.08±0.07^{ab}	19.88±6.74^{ab}	0.05±0.02^{a}
August	0.83±0.07^{c}	18.73±6.74^{ab}	0.03±0.02^{ab}
	*	*	*

^{a,b,c}*Means values within a column with different superscripts are significantly different; *=Significant at p<0.05; ns = Non-significant; SPP= Sheep production potential; SPE= Sheep production efficiency.*

Live Body Weight and Linear Body Measurements

The overall mean (±SE) values for body weight, body measurements and dentition of sheep by sex, age groups, record month and interaction effect of sex and age group are presented in Table 5. The overall average body weight, body length, heart girth and wither height of sheep were 26.06±0.33 kg, 55.84±0.51 cm, 66.11±0.81 cm, and 61.14±0.48 cm, respectively. The overall least squares mean of sheep body weight obtained in this study (26.06±0.33) kg was lower than the (26.7±0.45) kg reported for Washera sheep in the western highlands of Amhara National Regional State (Mengistie *et al.*, 2010), but it was higher than (21.69±0.48) kg reported for the west African sheep in northern Ghana (Birteeb and Ozoje, 2012). This indicated the effects of breeds and location differences on the variations in the mean body weight of sheep.

Effect of age categories on sheep morphometric measurements: There was a significant ($p<0.05$) effect of dentition on mean live body weight and body measurements (Table 5). There was an increasing trend in body weight as the age group progressed from the youngest (0PPI) to the oldest (4PPI). This was due to the large size of adult sheep with greater gut capacity that changed the size and the shape of the animal as the age increased. A slower growth rate was observed at age groups of 0PPI but the rate of increase in body weight was higher from 0PPI and 1PPI and attributed to the fast growth of attainment at younger age. Besides, an increasing trend of BL, WH, and HG was observed as age increased from the lower dentition class to the higher ages. This was attributed to the attainment of mature weight, BL, HG and WH at a later age (4PPI). Information on the body size of specific sheep type at constant age has paramount importance in the selection of genetically superior animals for production and reproduction purposes. Body weight is mostly used to evaluate body development and carcass characteristics in animals. In Ghanaian sheep, it was observed that an animal large for one trait was generally large for all traits (Birteeb *et al.*, 2012). This indicates that animals that are big will have evenly long body lengths, wide heights and heart girths. Hence, this result indicated that body weight and morphological traits could be sufficient for decision-making by livestock farmers.

Table 5. Least square means (±SE) for body weight (kg) and other body measurements of sheep.

Effect	BW	BL	HG	WH
	LSM±SE	LSM±SE	LSM±SE	LSM±SE
Overall	26.06± 0.33	55.84±0.51	66.11±0.81	61.14±0.48
CV%	14.07	9.29	12.44	7.97
Age:	*	*	*	*
0PP	15.93±0.16[e]	48.94±0.25[c]	56.91±0.40[d]	52.54±0.23[e]
1PP	22.98±0.29[d]	54.22±0.44[b]	63.55±0.70[c]	58.75±0.42[d]
2PP	26.80±0.47[c]	55.41±0.72[b]	68.43±1.14[b]	62.06±0.68[c]
3PP	30.51±0.48[b]	59.18±0.74[a]	68.67±1.18[b]	64.91±0.70[b]
4PP	34.08±0.65[a]	61.45±0.99[a]	72.97±1.58[a]	67.42±0.93[a]
Month:	*	*	*	*
January	23.80± 0.30[f]	50.74±0.46[f]	64.58±0.74[d]	59.22±0.43[f]
February	24.43±0.30[ef]	51.16±0.47[f]	64.72±0.74[cd]	59.46±0.44[ef]
March	25.05±0.32[ed]	52.87±0.48[e]	65.35±0.77[bc]	60.29±0.45[de]
April	25.74±0.33[cd]	54.65±0.51[d]	66.05±0.81[abc]	60.99±0.48[cd]
May	26.40±0.34[bc]	56.88±0.52[c]	66.58±0.83[ab]	61.71±0.49[bc]
June	26.99±0.34[b]	58.78±0.52[b]	67.13±0.83[ab]	62.22±0.49[ab]
July	28.01±0.35[a]	60.73±0.54[a]	67.86±0.86[a]	62.89±0.51[a]
August	28.08±0.36[a]	60.91±0.55[a]	66.59±0.87[ab]	62.31±0.51[ab]
Sex by age:	*	ns	ns	*
Female,0PPI	16.22±0.21[f]	49.50±0.33	58.90±0.52	53.82±0.31[f]
Female,1PPI	21.73±0.31[e]	54.34±0.48	64.14±0.76	59.02±0.45[de]
Female,2PPI	26.99±0.24[c]	56.84±0.37	69.68±0.59	62.46±0.35[c]
Female,3PPI	30.96±0.21[b]	59.46±0.33	68.08±0.52	64.76±0.31[c]
Female,4PPI	31.77±0.41[b]	59.71±0.63	73.16±0.99	65.33±0.59[b]
Male,0PPI	15.64±0.24[f]	48.38±0.37	54.92±0.59	51.26±0.35[g]
Male,1PPI	24.25±0.48[d]	54.09±0.74	62.96±1.17	58.48±0.69[e]
Male,2PPI	26.61±0.90[c]	53.99±1.39	67.17±2.20	61.67±1.30[cd]
Male,3PPI	30.06±0.94[b]	58.90±1.45	69.26±2.30	65.06±1.36[bc]
Male,4PPI	36.39±1.24[a]	63.19±1.90	72.79±3.02	69.52±1.78[a]

[a,b,c,d,e,f,g]*Means on the same column with different superscripts are significantly different; BW= Live body weight; BL= Body length; HG= Heart girth; WH= Height at wither; 0PPI= Sheep with milk teeth (< a year); 1PPI = 1 pair of permanent incisor; 2PPI = 2 pairs of permanent incisors; 3PPI= 3 pair of permanent incisor; 4PPI = 4 pair of permanent incisor and above; *=Significant at p<0.05; ns = Non-significant.*

Effect of the month on sheep morphometric measurements: Month had a significant ($p<0.05$) effect on body weight and all other body parameters (Table 5). The results indicated that the overall BW, BL, HG and HW increased from January up to August. However, higher BW and other linear body measurements (BL, HG and HW) were recorded in June, July and August. This was because of the potential of feed supplies, both in quantity and quality during these months. The findings of the present study were in accordance with a study that reported the highest body weights in the post and rainy period for sheep in South Africa (Mapiliyao *et al.*, 2012). There was also a significant ($p<0.05$) interaction effect of age and sex on body weight (Table 5). Similarly, interactions were observed between sex and age groups for Habru and Gubalafto sheep in the North Wollo Zone of the Amhara Region (Tassew,

2012) and Dawro and Konta sheep of the southern region (Amelmal, 2011) of Ethiopia.

Correlation between Body Weight and Linear Body Measurements

The correlation coefficient between sheep's body weight and body measurements across all age groups is combined and presented in Table 6. The results of the study indicated that strong and highly significant ($p<0.05$) correlations were observed between body weight and linear body measurements. This suggested that these variables could be useful in predicting flock live weight. Besides, the strong correlation indicated that measurements can be used as indirect selection criteria to improve live weight or could be used to predict body weight (Afolayan *et al*., 2006; Solomon *et al*., 2008; Fasae *et al*., 2011). This strong correlation of body weight and body measurements in both sexes was in agreement with other results (Mengistie *et al*., 2010).

A strong correlation between WH and BW was observed during the study (r=0.79, 0.81) for male and female flocks, respectively. This strong correlation between WH and BW of female sheep in this study show that BW of female sheep can be predicted from these measurements. Similarly, strong correlations between BW and WH of male sheep were reported by Michael *et al.* (2016). According to Thiruvenkadan (2005), the better relationship of BW with HG was most likely due to a relatively larger influence to BW which consists of skeletons, muscles and viscera. Body weight is a very important characteristic in animal husbandry as a selection criterion and measure of economic profit. Body measurements are important data sources in terms of reflecting the breed standards (Riva *et al*., 2004) and can also be used as qualitative growth indicators that reflect the conformational changes occurring during the life span of animals. This study's results indicated that, functional trait preferences like body weight and linear body measurement descriptions could help as an input for efficient utilization and designing of improvement strategies for Gumuz sheep.

Table 6. Coefficient of correlations between body weight and linear body measurements (Above diagonal for female and below diagonal for male).

	BW	BL	HG	HW
BW		0.75*	0.56*	0.81*
BL	0.72*		0.52*	0.77*
HG	0.78*	0.75*		0.56*
HW	0.79*	0.81*	0.84*	

** Significant at 0.05 level; BW=Body weight, HG=Heart girth, HW= Height at whither; BL= Body length.*

Prediction of Body Weight from Linear Body Measurements

To predict body weight from linear measurements, multiple regressions were performed within each sex group based on independent variables that had a positive correlation with body weight for sheep flock. Body length (BL), heart girth (HG) and height at wither (HW). The variables entered in the model to predict body weight and their contribution in terms of adjusted coefficient of determination (R^2 adj.) is indicated in Table 7. When overall age groups within each sex of Gumuz sheep were observed, height at withers was constantly selected to be best fitted variable with other variables. Similarly, good prediction of body weight from HW in the case of males was also reported by (Michael *et al.,* 2016). Precisely, HW, HG and BL in combination were found to have significant association with BW when overall age groups were observed for male and female flocks which explained total variability of 67% and 70% respectively.

Table 7. Prediction equations of live body weight on different body measurements for each sex in combined age group.

		Parameters						
Sex	Model	Intercept	β1	β2	β3	R^2	R^2 adj.	Root MSE
Male	HW	-19.94	0.71			0.63	0.62	4.40
	HW+HG	-24.37	0.43	0.33		0.66	0.66	4.16
	HW+HG+BL	-24.23	0.34	0.30	0.13	0.67	0.67	4.12
Female	HW	-29.75	0.90			0.65	0.65	4.14
	HW+BL	-30.38	0.62	0.31		0.69	0.69	3.88
	HW+BL+HG	-31.38	0.57	0.28	0.08	0.70	0.70	3.83

β= Regression coefficient; R^2= Coefficient of determination; MSE= Mean standard error; HW= Height at wither; HG= Heart girth; BL= Body length.

The higher the value of the adjusted coefficient of determination, the more independent measurements are used at a time. Thus, live body weight could be fairly estimated from measurements in combinations rather than alone. This finding is in agreement with the report of Michael *et al.* (2016), who noted that body weight could be more accurately predicted by combinations of two or more measurements in the study conducted in East Gojam Zone sheep types: $\mathrm{Y} = -19.94 + 0.71\ \mathrm{HW}$, for male and $Y = -29.75 + 0.90\ \mathrm{HW}$, for females; where Y= response variable (body weight) and BL, HW and HG are explanatory variables.

Conclusion

The study demonstrated that the pattern of birth inflows was higher in August and July, indicating that the wet season was a good time for flock growth through birth. However, there was a general decline in the number of sheep born between March and May, due to the impact of unfavorable weather conditions on the availability feed during these months. The greater sheep production efficiency (SPE) in April and May implied that a larger number of mature and growing sheep were sold by owners in targeting holidays celebrated during these months. Nevertheless, they also faced relatively high mortality rates in comparison to production rates. The study of body weight changes at different periods of sheep revealed that the body weight was lower in dry seasons due to a reduced rate of feed intake resulted from limited feed resources and heat stress. Mortality in lambs was the highest during the dry season which might be associated with nutritional stress coupled with disease problems. Therefore, identifying the most pertinent constraints which can put impediment on sheep production should be the initial step for improving the growth and economic performance of sheep production potentials in the studied areas. The results of this study suggested the need to strengthen intervention through conservation of feed resource for dry season and design appropriate disease prevention strategy to improve live weight performance and reduce mortality of sheep.

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Conflict of Interests

The authors declare that they have no competing interests.

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