On-Farm Comparative Evaluation of Growth and Reproductive Performance Traits of Washera and Gumuz Sheep Populations in Northwestern Ethiopia

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Abstract
Growth and reproductive performance traits are traits of economic importance for sheep selection and productivity improvement. This study aimed at comparative evaluation of growth and reproductive performance traits of Washera and Gumuz indigenous sheep in the highland and lowland agro-ecologies of northwestern Ethiopia. Data on growth performance traits were collected from 412 Washera (162 male and 250 female) lambs and 208 Gumuz (72 male and 136 female) lambs. Concurrently, data on reproductive performance traits were collected from 406 Washera (130 rams and 276 ewes) sheep and 213 Gumuz (75 rams and 138 ewes) sheep. General linear model (GLM) univariate procedure was employed to analyze the collected data. Mean±SD values of adjusted yearling weight of Washera and Gumuz sheep was 21.80±1.91 and 20.37±1.85 kg, respectively. Breed type affect live weight significantly (P<0.001). Mean±SD values of age at first lambing, lambing interval and annual reproductive rate of Washera sheep were 11.69±1.96 months, 9.27±3.53 months and 2.12 lambs, respectively. The corresponding values for Gumuz sheep were 12.51±1.95 months, 10.43±1.25 months and 1.71 lambs, respectively. Production and reproduction performance values for traits of Washera and Gumuz sheep were comparable to other Ethiopian and African breeds. These values can be used to set up breeding objectives for optimizing breeding schemes of sheep breeding program. In addition, the varied minimum and maximum values of growth and reproductive performance traits indicates that there is within breed variability. This variation could be used as a basis for within breed selection among indigenous sheep by giving special consideration to growth rate traits, believed to have medium heritability values.
Keywords: breeding practice, ewe, growth and reproductive performance, lamb, productivity
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1. Introduction

Sheep enterprises in Ethiopia are used as sources of cash income and provide social security in the bad crop years (IBC 2004; Getachew *et al*. 2010). With 30.7 million sheep (CSA 2016), Ethiopia is a home of most populous indigenous sheep breeds (Gizaw 2008), more than 99% of which are indigenous (CSA 2016). These indigenous breeds of sheep have special adaptive features such as: tolerance to a wide range of diseases, water scarcity tolerance and ability to better utilize the limited and poor quality feed resources (Kosgey and Okeyo 2007). However, the productivity of local sheep is low with high mortality of lambs (Tibbo 2006; Sebsibie 2008). Because of this the increasing need for food of animal origin has largely been met with increasing number of sheep while productivity per sheep has remained low (FAO 2015).

Live weight and growth rate are economically critical features, requiring particular attention in any breeding program intended to improve overall productivity since lambs are mainly raised for mutton (Tibbo 2006). Besides, good reproductive performance is a prerequisite for any successful genetic improvement and it determines production efficiency which depends on various factors including age at first lambing, litter size, lambing interval and the life time productivity of the ewe (Ibrahim 1998; Abebe 2008; Edea 2008). Conservation of local breeds of sheep is part of animal husbandry and should, ideally, be based on complete information on distribution, structures, and trends, productive and adaptive performances of populations of the existing breeds (IBC 2004). On-farm monitoring involves monitoring the productive and reproductive performance of a breed on selected representative village flocks or herds. On-farm performance evaluation gives a more representative performance level of the breed since it is undertaken under the natural production environment of the breed (Gizaw *et al*. 2011). Previous studies on production performance of Washera sheep has been reported for Washera sheep in Quarit and Yelmandensa districts of Amhara region, Ethiopia (Taye *et al*.2009).

Nevertheless, most Ethiopian sheep breed types are characterized by high within-population variability and have undergone little selection for improved meat production and true breed potentials are not known

(Lauvergne *et al*. 2000; Sebsibie 2008). Thus, the objective of this study was to evaluate growth and reproductive performance traits of indigenous sheep breeds and generate information for further establishment of selective breeding, conservation and productivity improvement programs of indigenous sheep under low input sheep production systems in northwestern Ethiopia. We hypothesized that there is no significant variation regarding performance of growth and reproductive traits within and between Washera, Gumuz and Rutana sheep populations of northwestern Ethiopia.

2. Materials and methods

2.1 Geographic coordinates of the study areas

This study was conducted in two districts, Burie and Mandura considered as potential areas for Washera and Gumuz sheep breed types in North Western Ethiopia (Figure 1). According to altitudinal location, rainfall and crop yields, the agro-ecological zone of Burie is highland and the agro-ecological zone of Mandura is lowland (Hurni 1998)

2.2 Sampling size and sampling methods

After preliminary survey, two districts Burie and Mandura were selected by purposive sampling method (ILCA1990) based on sheep production potential. Similarly, two rural peasant associations (Wanegedam and Daez Baguna) were selected from their respective districts. The key informants including the development agents and peasant association administrators were given training to enumerate smallholders engaged in sheep production keeping three sheep or more and how to fill questionnaires.

In the mean time, from a total of 1103 households of Burie district engaged in sheep production, 276 households owning an ewe giving birth at commencement of data collection were selected by random sampling method. A total of 406 Washera(130 ram and 276 ewe) sheep were considered for the monitoring of reproductive performance. A total of 412 Washera (162 male and 250 female) lambs were considered for the monitoring of growth performance.

Similarly, from a total of 622 households of Mandura district engaged in sheep production, 213 households owning an ewe giving birth at commencement of data collection were selected by probability random sampling method (International Livestock Centre for Africa, 1990). A total of 213 Gumuz(75 ram and 138 ewe) sheep were considered for the monitoring of reproductive performance. A total of 208 Gumuz (72 male and 136 female) lambs were considered for the monitoring of growth performance.

2.3 Data collection and animal management

The necessary data on growth and reproductive parameters were collected from sheep flocks managed under mixed - crop livestock farming system of Burie and Mandura districts. Data collection was carried out for two years from September, 2017 to October, 2018 G.C. Smallholders owning rams, ewes and lambs were asked for voluntarily for sparing their sheep and time while recording monitoring data on growth and reproductive performance traits. Live weight measurements were taken five times at the age of day 1, 90 days, 180 days, 270 days and 365 days. Live weight measurements were taken in the mornings, before the animals left the shelter to graze to avoid undesirable variations because of changes in rumen volumes (FAO 2011c; FAO 2012). Lamb weight measurements were taken taking ethical and animal welfare into account. Suspended weighing scale, rope and soil fertilizer bags were used for measuring live weight of lambs. Concurrently, date of birth, birth weight, type of birth, sex of lamb, season of birth, lambing interval, age at first lambing, age at first mating, number of lambs born during life time of the ewe, reproductive age of the ewe, number of offspring produced, number of offspring weaned and ewe parity were recorded starting from 24 hours of the new born by the recruited enumerators in each respective study site. During the course of data collection, dams and lambs were managed to graze in communal grazing lands and crop aftermaths for an average of eight hour and supplemented with crop residues and *atella* (bi-product of local brewery). Different formulas were used to calculate some parameters:

Weight records at various ages were adjusted for actual age using different formulas used by Inyangala *et al*.(1992) and Abebe *et al*. (2015)

Adjusted Weaning Wt (kg) = 90(W2-W1)/D +W1…………………………….(Formula 1)
Adjusted 6 Month Wt (kg) =180(W3-W1)/D +W1…………………………….(Formula 2)
Adjusted Yearling Wt (kg) =365(W4-W1)/D +W1…………………………….(Formula 3)

Where, W2, W3 and W4 = weight at a given age
W1 = birth weight
Wt=Weight
D = number of days between weighing date and date of birth

And average daily weight gain was calculated by the formulas:

Average daily weight gain from birth to weaning (g)

= (AWWT(kg) – BWT (kg))/ 90*1000…….(Formula 4)

Average daily weight gain from weaning to 6 month age (g)
= (A6MWT(kg) – AWWT(kg))/ 90*1000…….(Formula 5)
Average weight gain from 6 month age to 365 days yearling (g)
= (AYWT9(kg) – AWWT(kg))/ 275*1000…….(Formula 6)

Where :
BWT = Birth weight
AWWT = Adjusted weaning weight at 90 days
A6MWT = Adjusted 6 month weight at 180 days
AYWT = Adjusted yearling weight at 365 days
Annual reproductive rate (ARR) of Washera and Gumuz ewes was calculated by a formulae adopted from Wilson (1986):
Annual reproductive rate (ARR) of Washera ewe
= 365 * average litter size/average days of lambing interval…….(Formula 7)

Lamb survival rate was calculated by the formulae adopted from Kocho (2007):
Lamb survival rate (%)
= (Number of offspring weaned/ number of offspring produced) *100 …….(Formula 8)

2.4 Statistical analysis

Data on birth weight, weaning weight, six month and yearling weight at different age groups were collected and later converted to birth weight, adjusted weaning weight , adjusted 6 month weight , adjusted yearling weight, pre weaning and post weaning average daily weight gain . The data collected on growth and reproductive performance traits were arranged in an excel spread sheet. Ultimately, the data were analyzed using General Linear Model(GLM) univariate procedure of Statistical Package for Social Science for window version 20.0(2011) fitting non-genetic factors such as breed, sex of lamb, parity of the dam, season of birth and type of birth as fixed factor(s). Data analysis of growth and reproductive performance traits were carried out using two different statistical models:

The statistical model for analyzing growth performance was written as follows:

$Y_{ijklmno} = \mu + B_i + S_j + P_k + S_l + T_m + (B_i x S_l)_n + (B_i x T_m)_o + e_{ijklmno}$ …….. ….. (mode1 1)

Where :

$Y_{ijklmno}$ = the body weight and average daily weight gain of the *n*th lamb of n^{th} growing lamb

μ=population mean

B_i= effect of i^{th} breed (Washera, Gumez)

S_j = effect of j^{th} sex of lamb (male or female)

P_k= effect of k^{th} parity of the dam (P=first, second, third and fourth)

S_l= effect of lth season of birth (B(*belg*)= short rainy season (March – May), S=cold dry season (September-November), DS = Dry Season (December-February), RS=Rainy Season (June-August)

T_m= effect of m^{th} type of birth (single, twin)

$B_i x S_l$= interaction effect of i^{th} breed and l^{th} season of birth

$B_i x T_m$= interaction effect of i^{th} breed and m^{th} type of birth

$E_{ijklmno}$= error/residual effect

The statistical model for analyzing reproductive performance was written as follows:

$Y_{ijklmn} = \mu + B_i + S_j + P_k + S_l + T_m + (PxT)_n + e_{ijklmn}$…………….. (model 2)

Where:

Yijklmn= reproductive performance traits (age at first lambing, lambing interval, annual reproductive rate, number of lambs born per ewe life time)

U –population mean

B_i – the effect of i^{th} breed (Washera, Gumuz)

S_j = the effect of j^{th} sex of lamb (male, female)

P_k= the effect of k^{th} parity of the dam (P=first, second, third, fourth)

S_l= the effect of l^{th} season of birth (B(*belg*)= short rainy season (March – May), Rainy Season (June-August) , cold dry season (September-November), Dry Season (December-February)

T_m= the effect of m^{th} type of birth (single, twin)

$(P_k x T_m)_n$= the interaction effect of n^{th} parity and type of birth

E_{ijklmn} – Error/residual effect

3. Results and discussion

3.1 Birth weight and the effect of non-genetic factors

The minimum and maximum values of live weight for Washera and Gumuz sheep were shown in Figure 2. As shown in Table 1, mean±SD values of birth weight of Washera lamb was close to 2.2±0.04 kg of Wollo highland lambs (Amare *et al*. 2018) and 2.4±0.2 kg of Bonga sheep (Abate 2018) under village management condition.

Growth and development are essentially ecological responses and it is thus appropriate to consider the factors affecting their outcome in an ecological framework (Charles 2009). Breed type and sex affect birth weight significantly (P<0.05)(Table 1). Type of birth affects birth weight significantly (P<0.05). Larger birth weight was recorded for single born lambs than their twin contemporaries. This is due to the fact that single born lambs have got a better chance of getting good nourishment at the fetal stage. The effects of breed, sex and type of birth on birth weight were in consistence with the report of Tibbo(2006) for Horro and Menz sheep.

3.2 Weaning weight and the effect of non-genetic factors

Mean±SD values of adjusted weaning weight were 8.59±0.79 and 7.44±1.26 kg for Washera and Gumuz sheep, respectively (Table 1). Breed exerted significant effect on live weight. Season of birth affects weaning weight significantly (P<0.05). Lambs born during rainy season (June-August) and short rainy season (March – May) of the year were found to be heavier than lambs born during cold dry season (September-November) and dry season (December-February). This could be due to feed availability during these seasons for the dam to meet its production requirement for lactation beyond maintenance requirement to suckle the lamb until weaning and to the lamb side to graze on green pasture from weaning onwards.

3.3 Yearling weight and the effect of non-genetic factors

The minimum and maximum yearling weight of Washera sheep and Gumuz sheep is shown in Figure 2. Yearling weight values of Washera and Gumuz sheep (Table 1) were close to 23.7 ± 0.04 kg of Horro sheep (Abegaz & Gemeda 2000). But, it is much less than 26–30 kg of Menz sheep (Awgichew & Abegaz 2008).

Breed, parity and season of birth were non-genetic factors exerting significant (P<0.001) effect on yearling weight (Table 1). Parity affects adjusted yearling weight significantly (P<0.001). Larger yearling weight observed during 2nd and 3rd parities. Season of birth affects yearling weight significantly (P<0.001). Lambs born during rainy season (June-August) and short rainy season (March – May) of the year were found to be heavier than lambs born during cold dry season (September-November) and dry season (December-February). This could be due to feed availability during these seasons for the lamb to graze on green pasture.

3.4 Pre-weaning average daily weight gain and the effect of non-genetic factors

Breed type affected pre-weaning average daily weight gain significantly (P<0.01). In that regard, pre-weaning average daily weight gain for Washera was 70 g/day much better performance than 60 g/day of Gumuz. The variation in pre-weaning average daily weight gain between Washera and Gumuz sheep concur with Sebsibe (2008), suggesting that wide variability exists among Ethiopian small ruminant breeds with respect to potential growth rates and mature weight. Type of birth affected pre-weaning average daily weight gain significantly (P<0.01). This result was in consistence with Tibbo (2006) report for Horro and Menz sheep.

3.5 Post weaning average daily weight gain and the effect of non-genetic factors

The post-weaning growth rate of Washera sheep is reported to be comparable and even better than some other indigenous breeds indicating its potential for commercial mutton production for the local and export markets (Awgichew & Abegaz 2008). For instance, post-weaning growth rate of Washera sheep found by this study was 60 g/day, which was close to 63.4±4.0 of Bonga sheep (Abate 2018).

3.6 Descriptive statistics of reproductive performance traits

Measures of reproduction commonly used in sheep and goats include age at puberty, age at first lambing/kidding, post-partum interval, parturition interval and fertility indices (Abebe 2008). Average age of first mating for males, average age of first mating for females, average age at first lambing of ewes, average lambing interval of ewes, litter size, annual reproductive rate, average reproductive age of ewes and number of lambs born during life time of the ewe of Washera sheep was 6.18±1.85 months, 6.52±1.30 months, 11.69±1.96 months, 9.27±3.53 months, 1.62 lambs/birth, 2.12 lambs/ewe/year (author calculation), 6.63±1.87 years and 12.27±4.56 lambs, respectively.

Similarly, average age of first mating for males, average age of first mating for females, average age at first lambing of ewes, average lambing interval of ewes, litter size, annual reproductive rate, average reproductive age of ewes and number of lambs born during life time of the ewe of Gumuz sheep was 7.27±2.00 months, 7.64±1.67 months, 12.51±1.95 months, 10.43±1.25 months, 1.43±0.49 lambs/birth, 1.71 lambs/ewe/year (author calculation), 6.67±0.17 years and 9.89 lambs, respectively.

The impact of reproduction on sheep and goat productivity is best estimated by the annual reproductive rate (Ibrahim 1998). Long-term studies carried out over periods of several years have shown that the annual reproductive rate (number of young produced per breeding female per year) varies from 1.5 to over two lambs (Wilson 1986c). This rate of reproduction results in part is from the uncontrolled access of rams to ewes on a permanent basis and in part from the litter size ; in that annual reproductive rate(ARR) is a function of litter size and parturition interval(ARR=Liter size*365/ parturition interval. Annual reproductive rate (ARR) of this study was calculated by a formulae adopted from Wilson (1986c).

Annual reproductive rate (ARR) for Washera ewe is

= (365 * average litter size)/average days of lambing interval …… (Formula 7)

Annual reproductive rate (ARR) for Gumuz ewe is

= (365 * average litter size)/average days of lambing interval

Hence; annual reproductive rate (ARR) was 2.12 and 1.71 lambs/ewe/year for Washera and Gumuz sheep , respectively. Annual reproductive rate of Washera(2.12 lambs/ewe/year) and Gumuz (1.71 lambs/ewe/year) was within the range of Wilson (1986c) report.

Lamb survival rate was calculated by the formulae used by Kocho (2007):

Lamb survival rate (%)

= (number of offspring weaned/number of offspring produced)*100 …. (Formula 8)

Thus, lamb survival rate were 70.7 % and 70.1 % for Washera and Gumuz sheep, respectively. This comparable value of lamb survival rate between Washera and Gumuz sheep was attributed to similar poor management practices under similar mixed crop livestock sheep production system to which these indigenous breeds are kept. Lamb survival rate of Washera and Gumuz were higher than 68 % of Horro sheep, but were less than 83 % of Menz sheep (Mukasa-Mugerwa *et al.* 2002).

Thus, the tendency of pre weaning lamb loss was higher for Washera and Gumuz than Menz sheep but less than from Horro sheep. This variation in lamb survival rate between Washera , Gumuz and Menz could be due variation in agro-ecology within which these indigenous breeds were kept. Moreover, the variation could be explained by varied sheep production systems (mixed crop - livestock of Washera and Gumuz Versus sheep barley system of Menz sheep).

The overall mean±SD value for average age of first mating for females was 6.93±1.54 months (207.9 days). These ewes were early maturing than Djallonké gimmers of Ghana mated when they are 8 months old (Salifu 2014). Litter size of Washera and Gumuz sheep was higher than 1.23 of Yankasa of Nigeria, 1.30 of Desert of Sudan and 1.12 of Awassi of Egypt(Ibrahim 1998), indicating that Washera and Gumuz sheep were prolific compared to most African sheep breeds. This figure was even higher than 1.34 ± 0.01 of Horro sheep (Abegaz & Gemeda 2000) in South Western Ethiopia. Lambing interval of Washera ewe is 8 to 24 months. Lambing interval of Gumuz ewe is 7 to 12 months. The overall mean±SD value for lambing interval of this study was 9.69±2.96 months (290.7 days). This lambing interval was longer than 262 ±53.4 days of sheep in South Western part of Ethiopia (Bela and Haile, 2009). Improving the management practice will make shorter parturition intervals (below 9.69±2.96 months) enabling approximately three lamb crops to be obtained in two years. Annual reproductive rate (ARR) of Washera ewe (2.12 lambs/ewe/year) was found to be greater than 1.88 ± 0.44(Bela & Haile 2009) while annual reproductive rate (ARR) of Gumuz ewe (1.71 lambs/ewe/year) looks closer to 1.88 ± 0.44(Bela & Haile 2009). Annual reproductive rate (ARR) of Washera ewe (2.12 lambs/ewe/year) and of Gumuz ewe (1.71 lambs/ewe/year) under smallholder mixed farming system of North Western Ethiopia found to be better compared to 1.20 and 1.05(Wilson 1986c) for pastoral and agro-pastoral areas of Ethiopia, respectively.

Number of lambs born per ewe life time of Washera sheep is 3(minimum) and 4(maximum). Number of lambs born per ewe life time of Gumuz sheep is 4(minimum) and 16(maximum). The overall mean±SD value for number of lambs born per ewe life time (NLBE) of Washera and Gumuz sheep was 11.4±4.13 lambs/ewe/life time of the Ewe.

Number of lambs born per ewe life time (NLBE) of Washera and Gumuz sheep was greater than 9.31 lambs/ewe/life time of the ewe under mixed - crop livestock and 12.06 lambs/ewe/life time of ewe under pastoral sheep production systems of Ethiopia(Gizaw *et al.* 2013) .

3.7 Factors affecting reproductive performance traits

Breed type exerts significant($P<0.05$) effect on average age of first mating for males , average age of first mating for females, average age at first lambing of ewes, number of lambs born per life time of ewe and average lambing interval of ewes. But, the effect of breed type on litter size is non significant. Age at first lambing, lambing interval, annual reproductive rate and number of lambs born per life time of ewe all vary across the two breed types (districts). This result was in consistence with Abate (2018) for Bonga sheep in Southern Ethiopia. But, this result was against to Bela & Haile (2009) and Gebregiorgis *et al*.(2016) report, suggesting that, district has no influence on age at first lambing, lambing interval, annual reproductive rate and number of lambs born per life time of ewe traditionally managed in the South Western part of Ethiopia and Begayt sheep of North-Western Zone of Tigray Region, in Humera district, Northern part of Ethiopia. Parity, season of birth, birth type, sex of lamb and the interaction effect between parity and type of birth does not affect age at first lambing, lambing interval, annual reproductive rate and number of lambs born per life time of ewe.

4. Conclusions and recommendation

This study was aimed at evaluating growth and reproductive performance traits of indigenous sheep breeds under on-farm sheep management conditions of northwestern Ethiopia. The result of this study indicated that there exists variation in growth rate within Washera and Gumuz sheep populations. In that regard, the minimum weaning weight of Gumuz sheep is 5.03 kg and the maximum value is 10.09 kg. The minimum and maximum weights of Washera sheep at six months of age were 10.89 and 17.83 kg, respectively. The minimum and maximum weights of Gumuz sheep at six months of age were 8.91 and 16.84 kg, respectively. The minimum and maximum yearling weights of Washera sheep were 19.04 and 25.06 kg, respectively. The minimum and maximum yearling weights of Gumuz sheep were 16.04 and 24.06 kg, respectively. Post-weaning growth rate of Washera sheep was comparable and even better than some other Ethiopian indigenous breeds. Annual reproductive rate (ARR) was 2.12 and 1.71 lambs/ewe/year for Washera and Gumuz sheep, respectively. Lamb survival rate were 70.7 % and 70.1 % for Washera and Gumuz sheep, respectively. Lambing interval of Washera ewe is 8 to 24 months. Lambing interval of Gumuz ewe is 6 to 12 months. Number of lambs born per ewe life time of Washera sheep is 3(minimum) and 24(maximum). Number of lambs born per ewe life time of Gumuz sheep is 4 (minimum) and 16 (maximum). The overall larger litter size indicates that these sheep populations were prolific and encouraging values of annual reproductive rate were found.

Production and reproduction performance values for traits of Washera and Gumuz sheep were comparable to other Ethiopian and African breeds. These values can be used to set up breeding objectives for optimizing breeding schemes of sheep breeding program. In addition, the varied minimum and maximum values of growth and reproductive performance traits indicates that there is within breed variability. This variation could be used as a basis for within breed selection among indigenous sheep by giving special consideration to growth rate traits, believed to have medium heritability values.

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Table 1. Mean± SD values of live weight and the effect of non-genetic factors

Factors	N	BWT Mean±SD	AWWT Mean± SD	A6MWT Mean± SD	AYWT Mean± SD
Breed		***	***	***	***
Overall	620	1.98±0.60	8.22±0.11	13.35±1.16	21.33±2.00
Washera	412	2.16±0.54	8.59±0.79	13.94±1.2	21.8±1.91
Gumuz	208	1.62±0.55	7.45±1.26	12.16±1.67	20.37±1.85
Sex		***	ns	*	*
Overall	620	1.98±0.60	8.22±1.11	13.35±1.61	21.33±2.00
Male	234	2.19±0.52	8.41±1.09	13.87±1.47	22.08±1.78
Female	386	1.73±0.59	7.99±1.09	12.75±1.56	20.47±1.90
Parity		ns	ns	ns	***
Overall	620	1.98±0.60	8.22±1.11	13.35±1.61	21.33±2.00
1	211	1.78±0.66	7.75±1.14	12.34±1.46	19.67±1.12
2	192	2.15±0.54	8.63±0.79	14.24±1.23	22.9±1.33
3	117	2.08±0.53	8.49±1.13	14.09±1.24	22.98±1.35
4	100	1.94±0.53	8.08±1.16	12.9±1.56	19.9±1.03
Season of birth		ns	*	**	***
Overall	620	1.98±0.60	8.22±1.11	13.35±1.61	21.33±2.00
Short rainy season(March – May)	127	2.12±0.53	8.88±0.63	14.07±0.86	21.68±0.93
Rainy Season(June-August)	208	2.08±0.57	8.42±1.10	14.23±1.37	23.36±1.13
Cold dry season(September-November)	96	1.85±0.57	7.75±1.14	12.6±1.62	20.44±0.79
Dry Season (December-February)	189	1.83±0.65	7.77±1.08	12.26±1.43	19.3±1.34
Type of birth		***	*	**	ns
Overall	620	1.98±0.60	8.21±1.11	13.35±1.61	21.74±2.00
Single	265	2.48±0.60	8.57±1.15	13.95±1.49	21.74±2.00
Twin	355	1.6±0.60	7.95±1.08	12.89±1.70	21.02±2.00
$B_i x S_l$	620	***	***	***	***
$B_i x T_m$	620	***	**	***	***

SD = standard deviation , BWT =birth weight, AWWT = adjusted weaning weight, A6MWT = adjusted six month weight, AYWT =adjusted yearling weight, Bi=breed, Sl=season of birth, Tm=type of birth, values * =significant at p<0.05,**=significant at p<0.01, ***= very high significant at p<0.001, ns = non significant

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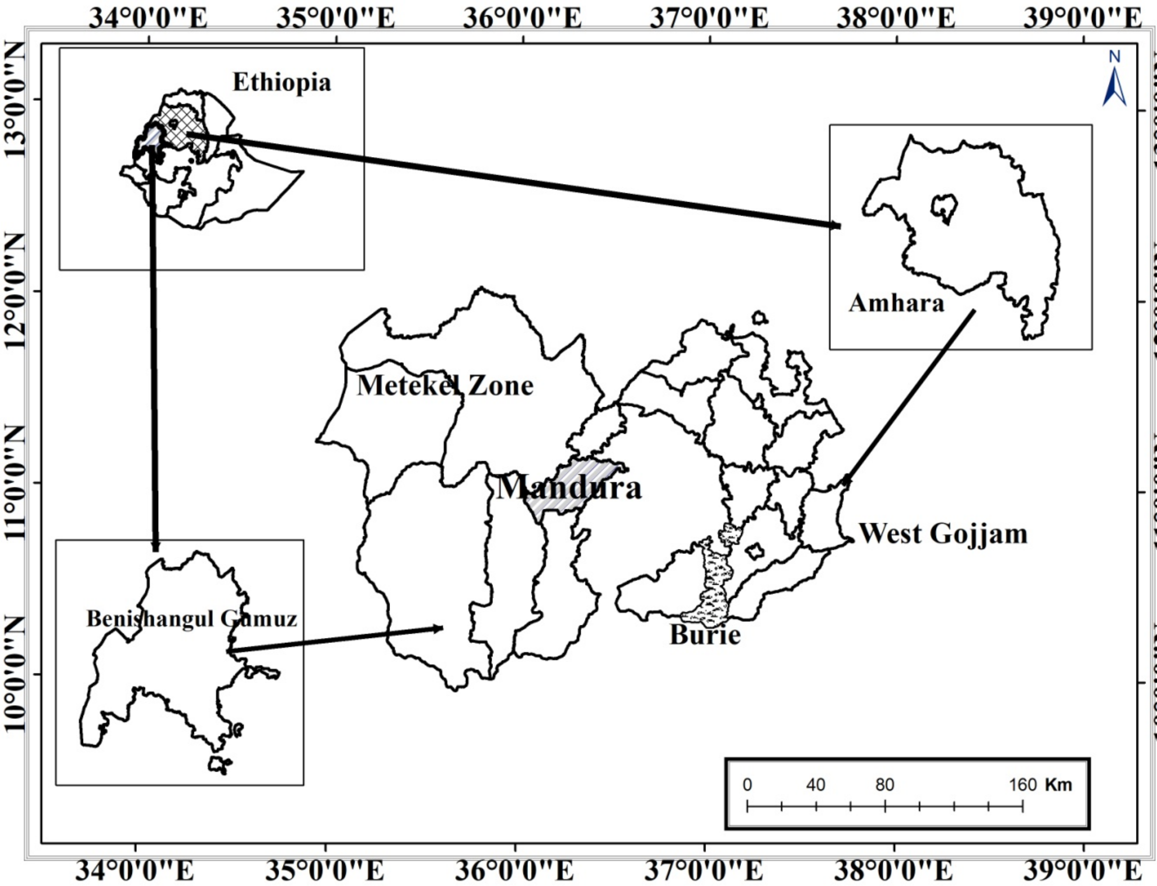

Figure 1. Map of the study districts

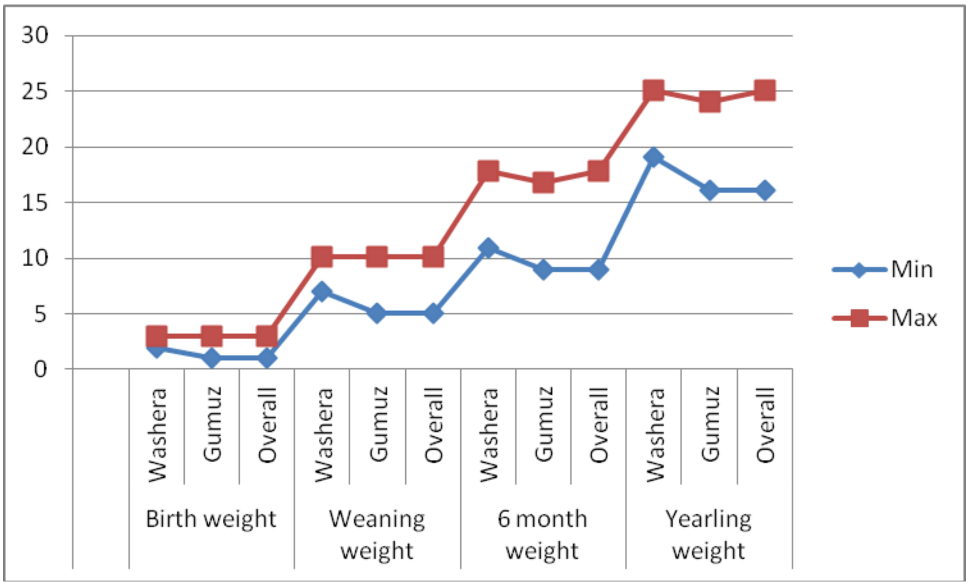

Figure 2. Minimum and maximum values of live weight in kg