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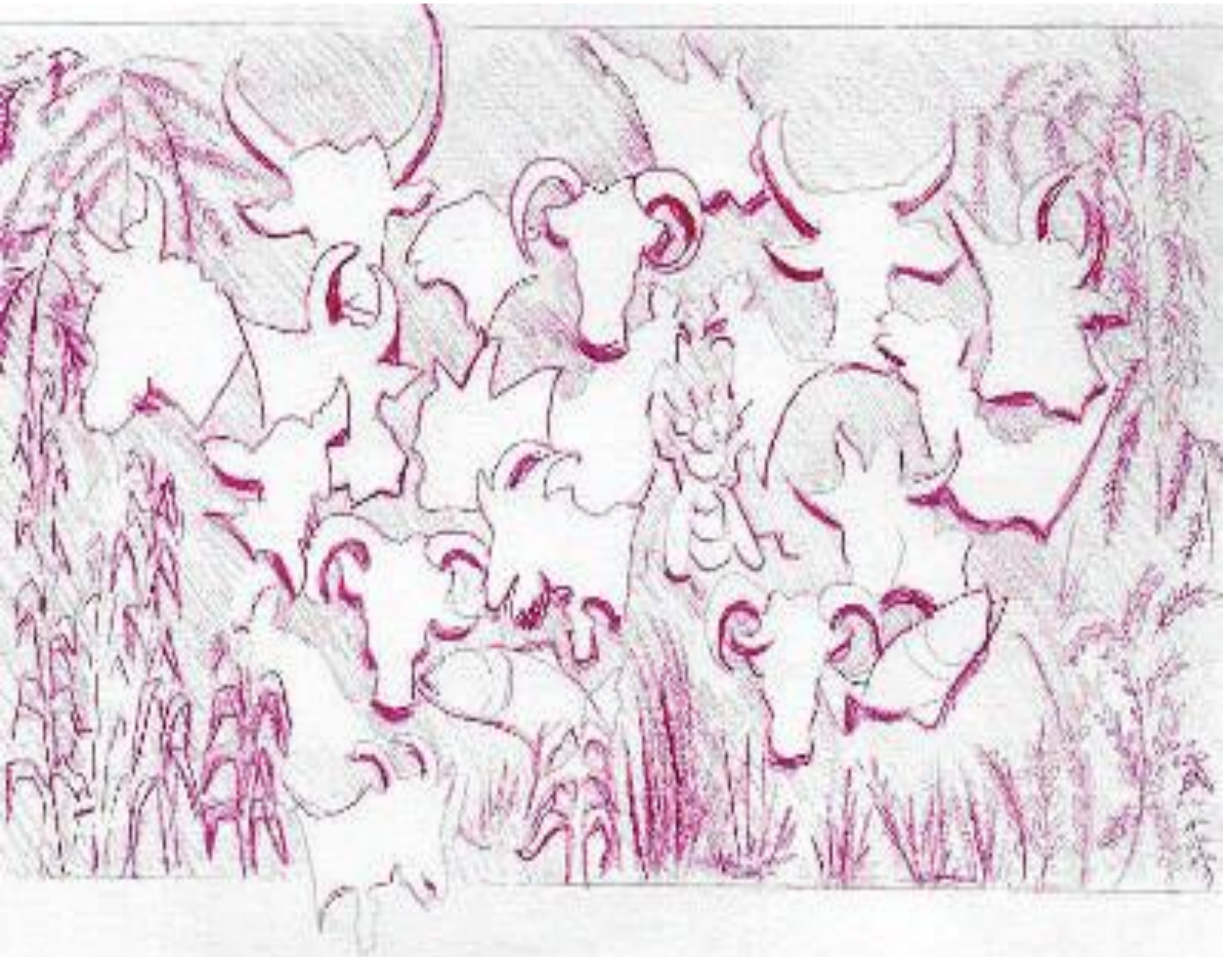

Official Journal of the Ethiopian Society of Animal Production (ESAP)

Ethiopian Journal of Animal Production

An Official Journal of the Ethiopian Society of Animal Production (ESAP)

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On-Farm and On-Station Comparison of Early Growth and Survival Performances of Horro Sheep in Western Ethiopia

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ABSTRACT

Even though sheep is one of the most important species of livestock with estimated population size was about 52.5 million heads, the genetic improvement made to this species was not encouraging. On station small ruminant research was reported for being inefficient and Community Based Breeding Program (CBBP) has emerged as alternative. However, empirical evidences were not available which presented performance evaluation results of Horro sheep under on station and on farm conditions. Hence, the objective of the current study was to compare early growth and survival performance of Horro sheep breed managed under on-farm conditions with those managed under on-station condition. The on-farm and on-station data for this study was collected from two Kebeles in Horro district namely Gitilo and Laku Igu and at Bako Agricultural Research Center (BARC). The effect of fixed factors including location (on farm and on station), parity, type, sex, season and year of births of lambs were investigated on early growth traits including birth weight (BWT), three-month weight (3MW), six-month weight (6MW) and survival to three months of age using data collected from 2009 through 2018 at BARC and CBBP of sheep in Horro district. The overall means (kg) for BWT, 3MW and 6MW, in respective order, was 2.80±0.70, 12.27±3.27 and 16.31±2.86. The location of birth, year of birth, and type of birth of lambs had highly significant effect (p<0.0001) on the early growth traits where the early growth traits from on-farm (from the CBBP in this context) and single birth were heavier. Regarding the year of births, the growth performance of the lambs had shown an improving trend from 2009 to 2013 and declined thereafter. However, the trend BWT was almost constant across years compared 3MW and 6MW. The place of birth (being on farm or on station), type of birth (being born single or twin) and the magnitude of birth weight had highly significant effect (p<0.0001) on Horro lambs' odds ratio of survival to three months of age. Sex of lambs also had significant effect (p=0.0313) on Horro lambs' odds ratio of survival to three months. It was concluded that unless full commitment, at government and technical staff level, is ensured neither genetic improvement nor conservation of Horro sheep breed could be realized under on-station condition. The genetic improvement of Horro sheep at village level, under on-farm condition was confirmed to be better alternative as health interventions and use of selected rams for breeding backstopped the traditional raising practices of sheep owners in Horro district.

Keywords: Early growth; fixed factors; on farm sheep research; survival.

INTRODUCTION

Sheep production is one of the most important agricultural activities in Ethiopia. Sheep is the second most important species of livestock next to cattle in the country where about 99.6% are indigenous breeds (CSA, 2020) where estimated population size was about 52.5 million heads (CSA, 2020). Duguma (2010) reported that different indigenous sheep breeds are owned and managed by resource poor smallholder farmers and pastoralists under traditional and extensive production systems. There are nine identified and characterized sheep breeds through phenotypic and molecular methods in Ethiopia (Gizaw, 2008).

Even though sheep plays important roles in the country's economic development and livelihoods of farmers and pastoralists, their productivity remains low due to several reasons. Some of the major problems were weak genetic improvement efforts associated with absence of planned breeding programs and breeding policies, diseases and parasites, feed shortage, inadequate extension service delivery or lack of improved technologies, poor infrastructure and lack of market information (Duguma, 2010; Mirkena, 2010; Gizaw et al., 2013).

In fact, many efforts have been conducted on genetic improvement for improving production and productivity of sheep but the success was limited. Characterization of the indigenous sheep breeds, genetic improvement via crossbreeding using exotic breeds and genetic improvement using open nucleus breeding systems were some of the efforts that have been undertaken indicating that Ethiopia is a country where different livestock breeding programs have been practiced for a long period of time. However, the country has not succeeded with sheep genetic improvements due to lack of clear and documented breeding and distribution strategies, very little consideration of farmers' needs and indigenous practices and unsuitability of the environment (Tibbo, 2006; Duguma, 2010; Haile et al., 2011).

Government station based open nucleus breeding programs of small ruminants were blamed for not yielding significant improvement in Ethiopia; hence community based breeding programs has become as alternative to the station based breeding programs in developing countries. However, it was not proofed whether community based breeding programs, commonly implemented under on-farm condition, of small ruminants could be better option than the on-station breeding programs with the help of empirical evidences.

On-station research was started on Horro sheep at Bako Agricultural Research Center (BARC) in 1977 but there was an argument regarding the Horro sheep flock maintained there in relation to adaptation to hot and humid climate of the center. Horro highland, where the current CBBP of Horro sheep was implemented, was believed to be the natural ecological niche of Horro sheep breed. Hence, there is a need to compare the on-farm productivity performances (i.e. from Horro highland) with the on-station performances from BARC.

In the current study, the early growth and survival performances of Horro sheep under on-farm conditions were compared with the on-station conditions using data collected from 2009 through 2018. The data collected from the CBBP of Horro sheep at Horro district, Horro Guduru Wollega zone, Ethiopia was used as on-farm data and data collected during the same period at BARC represented the on-station condition. Therefore, the objective of the current study was to compare early growth and survival performance of Horro sheep breed managed under on-farm conditions with those managed under on-station condition.

MATERIALS AND METHODS

Description of the Study Areas

The map of the study areas is presented in Figure 1. The on-farm and on-station data for this study was collected from two Kebeles in Horro district namely Gitilo and Laku Igu and at BARC. Horro district is located at about 315 km from Addis Ababa (9^0 34´N and 37^0 06´ E) in Oromia Regional State in Western Ethiopia. Mixed crop-livestock production system is common farming practice in Horro district. The area has one long rainy period extending from March to mid-October with mean annual precipitation of about 1800 mm and maximum and minimum temperatures of about 22.67 and 11.750C, respectively. Gitilo and Laku Igu were where Community based sheep genetic improvement program was implemented since 2009. Among the kebeles of Horro district, Gitilo and Laku Igu had the highest sheep population and they were accessible. They are situated at about 12 km and 7 km, respectively, to the west of Shambu town, the capital of Horro district and Horro Guduru Wollega zone. The altitude of both kebeles ranges from 2170 to 2853 m.a.s.l.

BARC is located in Oromia Regional State at about 258 km from Addis Ababa to the west on the main road to Nekemte and it is about 8 km away from Bako town. It lies between $9^0 6$'N latitude and $37^0 9$'E longitude at an altitude range of 1579 to 1789 m.a.s.l. The BARC area receives an annual average rainfall of about 1238 mm and the area experiences a hot humid weather of minimum temperature of 13.3^0C and a maximum of 34^0C.

Flock Management

On-farm flock management

In the two kebeles of Horro district namely Gitlo and Laku Igu, farmers keep their sheep flock together (in group) in a communal grazing land during daytime and depart during night time. Most of the farmers prepared flock house enclosed to kitchen house for night time. However, some farmers who own only small flock do tie their sheep to a peg together with calves. The main feed sources in the study area were natural pasture and aftermaths. Sometimes, few farmers prepare supplemental feeds (local brewery by-product called 'atela', and salt) for the pregnant, breeding rams and castrated rams. As reported by Tufa (2019) sheep flocks were de-wormed against internal parasites four times per year. They were also vaccinated against different diseases including bacterial and viral causes.

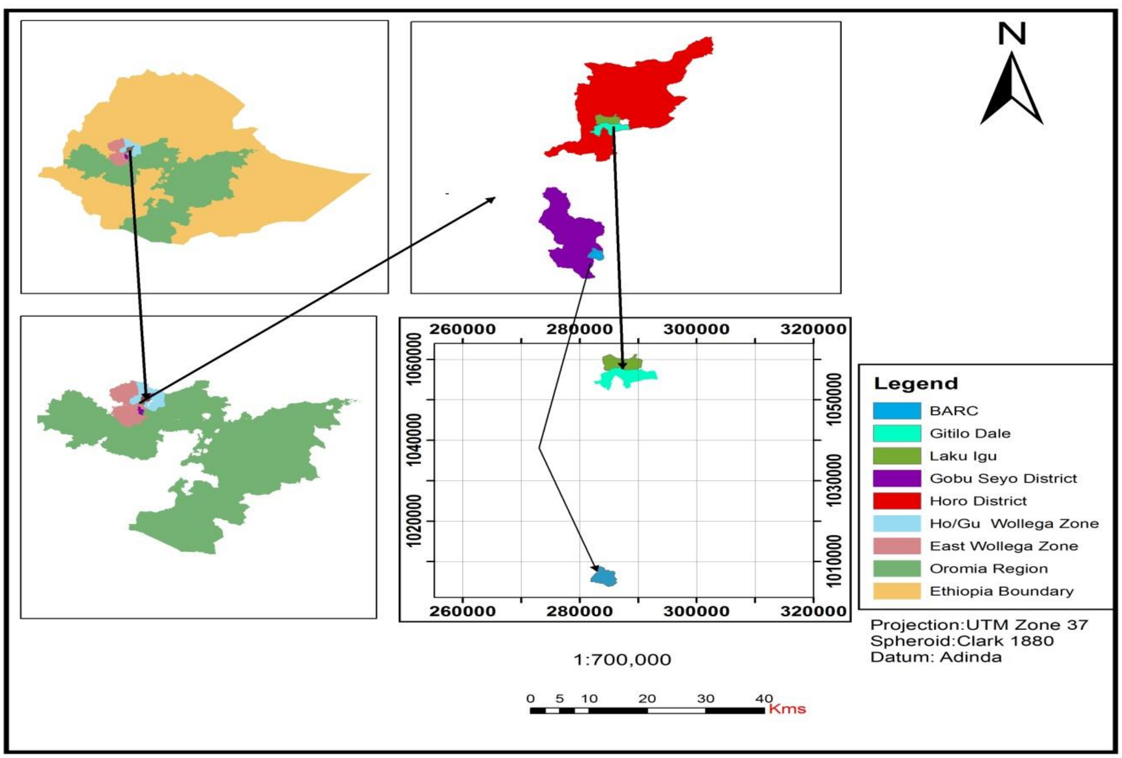

Figure 1. Map of the study areas

In these two kebeles, breeding was uncontrolled (year-round); breeding rams were selected by researchers, CBBP representatives and development workers (two times: screening at six-month age and selection at 12 month age) for mating based on their conformation (body size, color and appearance) and based on maternal history (Mirkena et al., 2011). Selected breeding rams were mixed with flocks for mating purpose. Scholars stated that the selected breeding rams give service for two years after selection. After two years of breeding services, the selected breeding rams were sold or castrated. As CBBP regulation, ram lambs born in the flock and not selected for breeding should be sold or castrated before reaching mating age. Enumerators were hired and data were being collected rounding on farm gate of the participating farmers. The CBBP of the sheep at Horro was started with about 120 farmers in the 2009 and the number had increased gradually. The CBBP of sheep at Horro district was first implemented by collaborating research institutions including the Austrian university of life sciences (BOKU), International center for agricultural research in dry areas (ICARDA) and Oromia Agricultural Research Institute. Horro district is found at about 70 km north of Bako and the research team from BARC was making a frequent monitoring of the implementation.

On-station flock management

Horro sheep flocks at BARC were kept under semi-intensive production system. Flocks houses were constructed from bamboo and corrugated iron sheet separately for different ages and sexes. Feed sources for sheep at on-station were natural pasture, aftermaths, hay and concentrate feed. During daytime (8:00 AM- 5:00 PM) sheep flock freely graze from natural pasture by separating mature females from mature males (Abegaz, 2002) (however, the sheep flock were allowed to graze for shorter time due to various reasons since recently). However, concentrate feed was given in the morning before letting the flock to grazing land and afternoon when the flock were back to their house according to necessitated for different categories of sheep. For instance, breeding ram and breeding ewes during breeding season (for 42 days) fed higher amount of concentrate feed (about 300 g) than other categories of flock. However, during the last one and half decade, the management level allotted to the flock was reduced because of various factors. In BARC, controlled breeding is practiced (two times per year that takes place during November and during June; for long period of times, mating was taking place only once in a year); rams and breeding ewes were screened by researchers. During breeding season both breeding ram and screened ewes were not allowed to graze in the field and they were confined in separate houses in a male to female ratio of 1:20 at daytime (8:30 AM- 5:30 PM) and adjoin during night time. All the breeding activities were recorded during this time by trained enumerator.

Data Analyses

For the analysis of early growth traits, *general linear model* procedure of SAS (2002) was used. The influences of class variables like location of births as on farm and on station (where on farm is the CBBP in Horro district and on station was the flocks at BARC), sex of lambs, type of births, parity of births, season and year of births on the early growth traits of Horro lambs (birth weight, three months' weight and six months weight) were investigated. The least squares mean of early growth variables were compared and separated by *pdiff* procedure of SAS (2002).

The survival analyses of Horro lambs up to three months of age were also conducted. The influences of location, birth type, sex, parity, birth year, season of birth and birth weight itself were investigated by the *logistic regression* procedure of SAS (2002). Lambs that died before three months of age because of infectious diseases only were considered as lambs that not survived; based on information from owners and attendants, lambs that were eaten by predators, died of mechanical accidents, and metabolic disorders were before three months of age were added to lambs that survived up to three months of age. This was done by assuming that had the animals get chance of surviving, they would have survived. In the case of on station condition, survival data of lambs was collected from flock record book at BARC. Odd ratio survival of lambs up to three months of age was then compared for the factors including for the on farm and on station conditions.

RESULTS AND DISCUSSION

Early Growth Performances of Horro Sheep On-farm and On-station

The least square means and standard errors of birth weight, three and six months of Horro sheep are given in Table 1. The overall means (kg) for the traits, in respective order, was 2.80±0.70, 12.27±3.27 and 16.31±2.86. The location of birth, year of birth, and type of birth of lambs had highly significant effect ($p<0.0001$) on the early growth traits where the early growth traits from on-farm (from the CBBP in this context) and single birth were heavier. On the other hand, sex of lambs, season of birth of lambs and parity of birth of lambs had highly significant effect ($p<0.0001$) on the birth weight and did not significantly ($p>0.05$) affected 3MW and 6MW.

Table 1. Least squares means of birth weight, three-month weight and six-month weight of Horro sheep by different production conditions, sex, birth type, season and parity of births in Western Oromia, Ethiopia during 2009 to 2018.

	Birth weight		Three month weight		Six month weight	
Factors *	N	LSmean ± SE	N	LSmean ± SE	N	LSmean ± SE
Overall	3710	2.80±0.70	1525	12.27±3.27	987	16.31±2.86
Site	***		***		***	
On farm	1305	2.69±0.03	1261	12.78±0.35	862	18.92±0.50
On station	405	2.45±0.04	264	10.26±0.35	125	14.00±0.48
Sex	***		NS		NS	
Male	1853	2.64±0.03	765	11.58±0.24	471	16.98±0.42
Female	1857	2.51±0.03	760	11.46±0.24	516	15.94±0.44
Type of birth	***		***		***	
Single	2479	2.68±0.03	1058	12.30±0.24	693	16.98±0.42
Twin	1231	2.46±0.03	467	10.73±0.26	294	15.95±0.44
Season¥	***		NS		NS	
1	1143	2.63±0.03	411	11.56±0.28	267	16.88±0.44
2	394	2.44±0.04	345	11.31±0.29	303	16.21±0.45
3	968	2.68±0.03	308	11.85±0.29	212	16.38±0.46
4	1205	2.54±0.03	461	11.36±0.25	205	16.39±0.45
Parity	***		NS		NS	
1	736	2.45±0.03	333	11.33±0.27	209	16.27±0.46
2	835	2.57±0.03	411	11.50±0.26	265	16.68±0.44
3	718	2.61±0.04	314	11.61±0.26	195	16.71±0.45
4	644	2.64±0.04	254	11.57±0.29	167	16.33±0.47
5	777	2.57±0.04	213	11.68±0.31	151	16.33±0.47

N=number of observations; LSmean=least squares means, SE=standard error, ***=p<0.0001, NS=p>0.05, ¥ means 1=December, January and February; 2=March, April, May; 3=June, July, August; 4=September, October, November.

The BWT, 3MW and 6MW of Horro lambs under the on farmer condition were heavier (kg) by 0.24, 2.52, and 4.92 than the respective values of the traits under on-station condition. Single born Horro lambs were also heavier (kg) by 0.22, 1.57 and 0.93 than twin born lambs for BWT, 3MW and 6MW, respectively during the study periods. The BWT of male Horro lambs was heavier by about 0.13 kg than the BWT of female Horro lambs during the study period. Regarding the season of birth, Horro lambs born during the second season (in March, April and May) had lighter birth weights (2.44 kg) compared to the rest seasons of births (greater than 2.54 kg). BWT of Horro lambs from the first parity was also lighter (2.45 kg) than the subsequent parities (where the BWT of Horro lambs was at least 2.57 and above).

The early growth performance of Horro lambs was also given in Figure 1 for various years of study. The growth performance of the lambs had shown an improving trend from 2009 to 2013 and declined thereafter. However, the trend BWT was almost constant across years compared 3MW and 6MW (Figure 1).

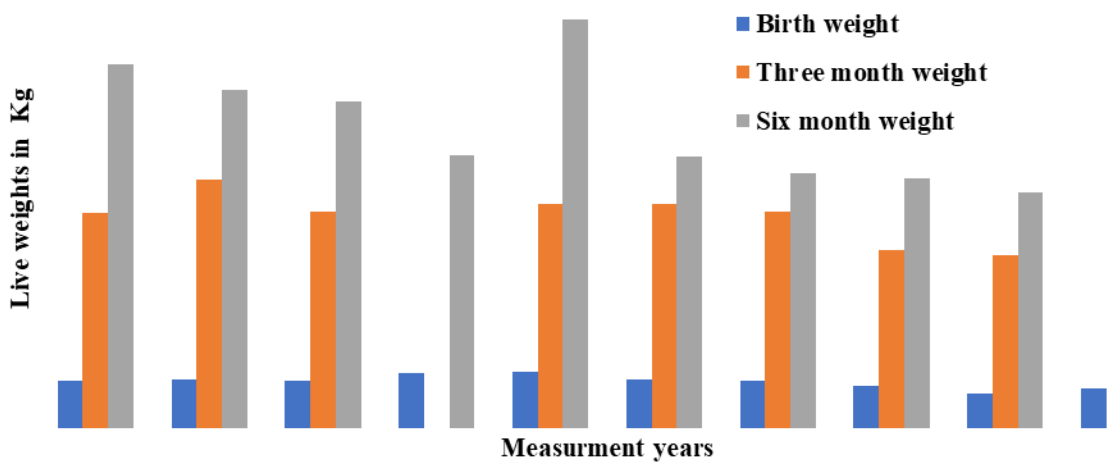

Figure 1. Early growth performances by year of births for Horro sheep from Bako Agricultural Research Center and fro CBBP of Horro district

Survival analysis Horro lambs up to three months of age

The odds ratio of survival of Horro lambs to three months of age is given in Table 2. The place of birth (being on farm and on station), type of birth (being born single or twin) and the magnitude of birth weight had highly significant effect (p<0.0001) on Horro lambs' odds ratio of survival to three months of age. Sex of lambs also had significant effect (p=0.0313) on Horro lambs' odds ratio of survival to three months. The odds ratio of survival to three months under the on farm condition (the community based breeding program in this case) was about 36 times the odds ratio of survival to three months under on station condition (Table 2). Similarly, single born lambs had about 1.5 times odds ratio of survival to three month of twin born lambs. The odds ratio of survival to three months for male lambs was 0.76 times the odds ratio of survival of female Horro lambs during the study period. Regarding the influence of birth weight, there was about 1.36 increment of odds ratio of survival to three months for a unit increase of birth weight of Horro lambs (0.5 to 4.5 kg).

Table 2. The odd ratio estimates of survival of Horro lambs up three months as affected by various fixed factors in western Oromia, Ethiopia during 2009 to 2018.

Factors	Odds ratio of survival to three months	p-value
On farm births versus On station births	36.25	<0.0001
Single birth versus multiple births	1.49	0.001
Male lambs versus female lambs	0.76	0.0313
Birth weight	1.36	0.0009

In developing countries, research performances on animals are becoming inferior under on-station because of various reasons. The poorer early growth and survival performances of Horro sheep under on-station conditions could be due to (1) the management level the animals received, (2) the environmental factors, (3) combination of both. The management levels could include the feeding, health and housing. Under on-station conditions of BARC, sheep flock graze for about 9:00 hrs (8:00 to 17:00) during day times. Sometimes, the sheep flock were taken to grazing after 8:00 and brought back to their pens before 17:00 which lessens the time of grazing and hence contributed in poor growth performances. On top of this, the preset or recommended amount of concentrate supplementations and basal hay supplementations for different categories of sheep under the on-station conditions during controlled breeding and the rest parts of the year were hardly fulfilled owing to the fluctuating annual government budget dedicated to the sheep research at BARC. The shortage of hay at the farm level again contributed to the shortage of beddings to newly born and young lambs. The night time housings were also those constructed in the late 1970s with wood called bamboo tree and roofed corrugated iron sheet. These all could have contributed to the poorer early growth performances of Horro sheep at BARC.

In addition to the poor management levels at BARC, the agro-ecology of BARC is hot and humid and might be less suitable for Horro sheep compared to where the current CBBP of Horro sheep was implemented. The hot and humid weather was said to be convenient for diseases that demanded the highest commitments of animal health workers at the center. Hence, the early growth performances of Horro sheep under the on-station conditions were inferior to that of on-farm.

However, the current early growth traits of Horro sheep under on-station conditions were higher than previous reports for the same breed from on-station. The early growth traits of Horro lambs obtained under the on-farm condition in the current study was higher than values reported under on-station condition for same sheep breed in earlier works (Awgichew, 2000; Tibbo, 2006; Alemayehu et al., 2017).

The odds ratios of survival to three months for Horro lambs during 2010 to 2018 were compared to the odds ratio of survival to three months of age during 2009 (the initial implementation year of the CBBP). The odds ratio of survival for Horro lambs during the 2012 and 2013 were significantly higher (at least $p<0.05$) than odds ratio of survival during 2009. The odds ratio of survival during 2012 was about 26 times the odds ratio of survival of Horro lambs during 2009 (Table 3). Lamb Survival rate varies from one flock to another depending mostly on management level. Lamb losses also occur during the peri-natal, pre-weaning and post-weaning phases of the reproduction process (Awgichew, 2000). The overall survival rates (%) to three months of age were about 97 and 59 under on-farm and on-station conditions, respectively.

Table 3. Comparison of odds ratio of survival to three months of age for Horro lambs

Years compared	Odds ratio of survival to 3 months	p –values
2010 vs 2009	0.759	0.4914
2011 vs 2009	0.614	0.2043
2012 vs 2009	26.23	<0.0001
2013 vs 2009	1.697	0.1660
2014 vs 2009	0.429	0.0226
2015 vs 2009	0.557	0.1315
2016 vs 2009	0.688	0.3233
2017 vs 2009	0.566	0.1504
2018 vs 2009	1.761	0.1658

A direct comparison of lamb survival rates could be difficult even within a region as lambs under on-farm and on-station are reared in different management practices and weaned at different ages. In traditionally managed sheep production systems of the tropics, lamb mortality between birth and 150 days of age is estimated to be between 10-30 % (Gatenby, 1986). The major factors affecting lamb survival include age of lamb, litter size, birth weight, and season of birth, nutrition and parity of the ewe (Gatenby et al., 1997; Armbruster et al., 1991; Notter et al., 1991). According to Fitzhugh and Bradford (1983), improvement in ewe nutrition during pregnancy has reduced lamb mortality from 23 % to 11 %. In most cases birth weight has a quadratic relationship with mortality rate whereby mortality tends to increase at extremely low or extremely high birth weights (Mendel et al., 1989; Cooper, 1982). Litter size affects the survival rates of lambs by reducing the birth weight (Awgichew, 2000) and up to 40% pre-weaning mortality rates were reported for multiple births in small ruminants (Gatenby et al., 1997).

The survival value obtained under on-farm condition during the current study was lower than the value reported by Abegaz et al. (2005) who reported that was about 97.3%. Abegaz and Duguma (2000) reported an overall mean of pre-weaning survival rate of 80.5% for the same breed under on-station management based on over data collected for 21. From the above findings it can be observed that on-station pre-weaning survival of Horro sheep maintained at BARC was very low warranting investigation of suitability of the center for the indicated sheep breed or reminding commitment required at higher level. The likely differences in the pre-weaning survival rate between on-station and on-farm flocks of Horro sheep may be mainly due to agro-ecology. Horro sheep breed was believed to be originated from the Horro highland and might be unable to adapt under the hot-humid lowlands of Bako areas. During the beginning of the CBBP, both Duguma (2010) and Mirkena (2010) reported lamb survival rate of 90.5% which was lower by 6.5% than the value reported in the current study. The likely reason may be the health intervention made by the project. According to Tufa et al. (2019), the CBBP sheep producers use anthelmintics (AH) at least four times per year per animal.

CONCLUSION

From the findings of this study, it can be concluded that unless full commitment, at government and technical staff level, is ensured neither genetic improvement nor conservation of Horro sheep breed could be realized under on-station condition at Bako Agricultural Research Center. The genetic improvement of Horro sheep at village level, under on-farm condition was confirmed to be a better alternative as health interventions and use of selected rams for breeding backstopped the traditional raising practices of sheep owners in Horro district.

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On-Farm Phenotypic Characterization of Indigenous Sheep in West Shewa Zone, Oromia Regional State, Ethiopia

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ABSTRACT

The current study was conducted in Tokke Kutaye, Ambo and Dandi districts of West Shewa zone to investigate the phenotypic characteristics of indigenous sheep found in the areas as a step towards developing sustainable sheep breeding strategy. The districts were purposively selected based on their potential for indigenous sheep production and the long-standing issues of demarcating clear boundaries between Horro and the central highland sheep breeds. Field observation, measuring and recording of sheep physical and morphmetrical characters were employed to capture all relevant information. Body weight and linear measurements were taken on 690 adult sheep (200 females and 30 males from each district). Age was estimated from dentition. The Statistical Analysis System (SAS, 2008) software was used to analyze the qualitative and quantitative data. Plain coat color was the dominant color with 76.2%, 70.9% and 70.9 % in Tokke Kutaye Ambo and Dandi districts, respectively. Almost all of male sheep in Dandi and about half in Ambo districts were horned while the majority of male sheep were polled in Tokke Kutaye district. Pair wise comparison of the least squares means of body weight and linear body measurements were significantly affected by the district, sex and age (P<0.01). The recorded body mature weight was 28.4±0.24, 26.1±0.19 and 25.9±0.15kg for sheep in Tokke Kutaye, Ambo and Dandi, respectively. All linear body measurements considered in this study were significantly (p<0.01) higher for male. Chest girth had the highest correlation coefficient for both males (0.79) and females (0.73). Based on results obtained from both qualitative and quantitative traits, the geographical demarcation of Horro and the central high land sheep breeds is Ambo district. Further investigation is warranted to put clear demarcation between the two breeds through deepest phenotypic and molecular characterizations.

Keywords: Body weight, Indigenous sheep, Linear body measurements, Phenotype characterization

INTRODUCTION

Livestock, which is kept by more than 70% of the Ethiopian population, is an integral part of agriculture, accounting for about 45% to the total value of agricultural production and supporting the livelihoods of a large share of the population (FAO, 2019). Beyond providing foods and other goods and services to the population, the livestock sector is a major contributor to export earnings, mainly through the export of live cattle and small ruminants. According to FAO (2019), Ethiopian livestock contribute about 10% to total export earnings, of which 69% accounted for by live animal exports.

Small ruminants are one of the most preferred livestock species that make an important contribution to household food and economic security. They have great potential to contribute more to the livelihood of low-income farmers in low input and low output smallholder, and pastoral production systems (Kosgey and Okeyo, 2007; Tesfaye, 2008). For men and women in developing countries, small ruminants are important assets and sources of income where women are more likely to be owners of small ruminants while men tend to own large livestock (Hiwot et al., 2020). According to the authors, the preferences of women directly matches to the four food security dimensions: the accessibility of small ruminants to be sold or exchanged to fulfill immediate cash requirements, nutritional value to meet basic food needs through consumption of meat and milk, production availability with short reproductive cycles and high reproductive rates to ensure sufficient food resources for the family and resistance to extreme weather conditions which makes them a stable asset for the household.

The small ruminant industry in Ethiopia contributes substantially to the livelihood of the rural poor and the country at large but is faced with various challenges. At the national level, sheep and goat account for about 90% of meat and 92% of skin export trade value (Sisay, 2010). The population of sheep in Ethiopia is estimated to be 39.89 million, out of which about 70. 28% are females, and about 29.72% are males. From the total sheep population of the country, about 99.56% are indigenous breeds (CSA, 2020).

While most Ethiopian sheep are currently well characterized, sheep populations found in the central highlands of the country need further characterization. For instance, sheep breed/s available in the central highlands of the country including those available in west Shewa zone is/are generally named as central highland sheep mainly due to lack of proper characterization. Tokke Kutaye, Ambo and Dandi districts are some of the districts situated in western Shewa zone where characterization information on the available sheep breed/s is needed to design genetic improvement and other development strategies. In the indicated districts, phenotypic characterization like morphological information and breeding practices on the existing sheep breed/types in their respective production environments are not well studied or documented. In addition, there are controversial ideas about the sheep breed/s found in the indicated districts, particularly Ambo and Tokke Kutaye. Literature reports (eg. Galal, 1983) indicated that Horro sheep breed are distributed in some parts of western Shewa zone, but no one tells the exact demarcation of the Horro sheep breeds or in other words points where the Horro sheep breed and the central high land sheep breeds are delineated. Therefore, the current study was aimed to characterize the phenotypic feature of indigenous sheep populations found in the districts and determine the boundaries among the available sheep breeds/types, particularly between Horro and the central high land sheep breeds.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted in three districts of West Shewa zone of Oromia region, Ethiopia. Map of the study areas is indicated in figure 1. The districts are: Tokke Kutaye, Ambo and Dandi. West Shewa Zone is one of the 18 zones in Oromia National Regional State. The altitude of the zone ranges from 1166 to 3238 meters above sea level (m.a.s.l). It receives a mean annual rainfall of about 900 mm (range 800 to 1000 mm) and annual temperature ranging from 15 to 29°C with an average annual temperature of 22°C (AARDB, 2016). West Shewa zone has mainly midland and highland topography and mixed crop-livestock production system is the main stay of livelihood of the community of the zone. The livestock sub-sector plays an important role in the livelihood of the rural people in terms of providing alternative income sources and also contributing to their food security. According to Agricultural and Rural Bureau of West Shewa zone (AARDB, 2016), the total livestock population of the zone are estimated at 3,764,183 head of cattle,1,138,236 head of sheep, 818,792 head of goat, 282,633 head of horse, 275,738 head of donkey, 42,188 head of mule and 1,634,423 head of chicken.

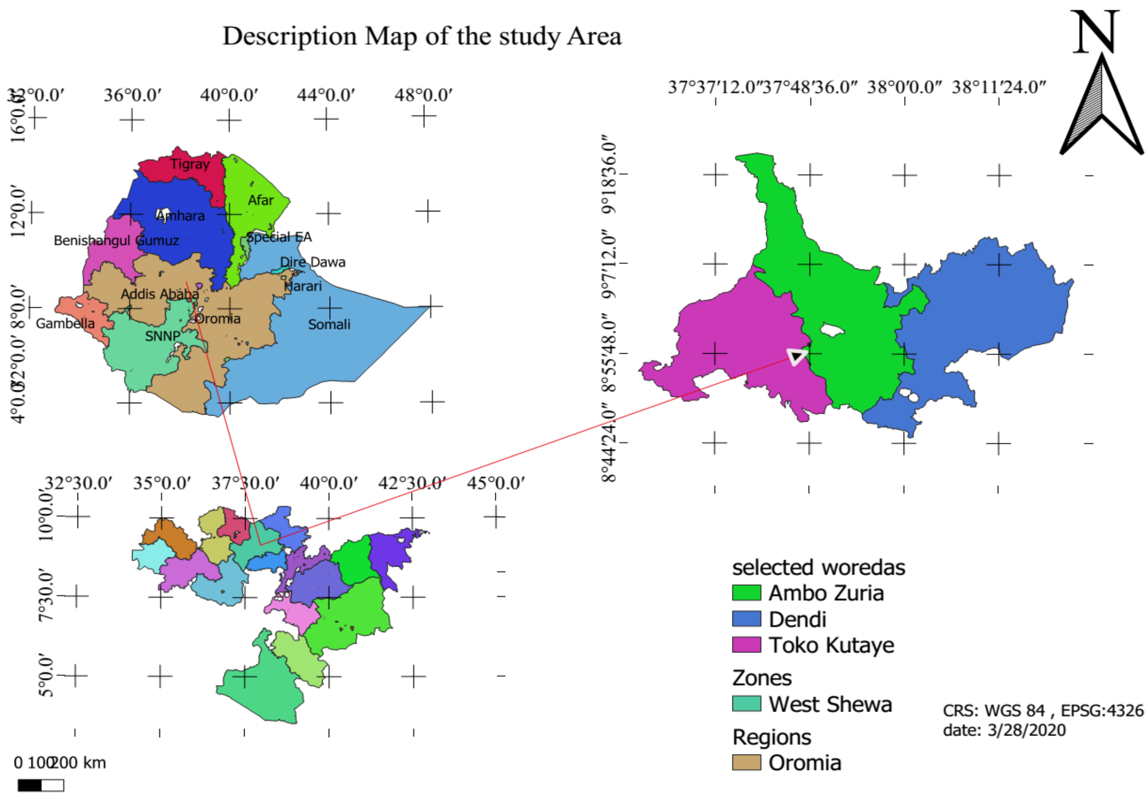

Figure 1. Map of the study area

Sampling and Data Collection Procedure

Sampling procedure

Tokke Kutaye, Ambo and Dandi districts were purposively selected based on their potential for indigenous sheep production and the long-time standing issues of demarcating clear boundaries between Horro sheep and the central highland sheep breeds. Furthermore, targeted peasant associations (PAs) were purposively selected from the three districts based on sheep population based on a rapid reconnaissance survey which was conducted in each district to know the distribution and concentration of indigenous sheep to establish sampling framework. Body weight and linear measurements were taken from a total of 690 adult sheep (600 female and 90 male) which were randomly selected within the selected districts based on (FAO. 2012).

Data collection method

Secondary data sources, observation and linear body measurements were used to capture necessary information during the current study.

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Morphological and linear body measurement

Qualitative traits such as coat color pattern, coat color type, hair type, head profile, ears, wattle, horn, ruff and tail types were observed and recorded. Leaner body measurements like heart girth (HG), body length (BL), wither height (WH), ear length (EL), head length (HeL), horn length (HL), tail length (TL), tail width (TW), rump length (RL), rump width (RW) and scrotum circumference (SC) were measured using flexible measuring tape while body weight (BW) was measured using suspended spring balance having 50kg capacity with 0.2kg precision. Experimental animals were identified by sex, districts and age group. Adult sheep were classified into three age groups: 1PPI (one pair of permanent incisors), 2PPI (two pair of permanent incisors and ≥3PPI (more than three pair of permanent incisors). Linear body measurements were taken by restraining and holding the animals in a stable condition. The standard breed descriptor list for sheep developed by FAO (2012) was closely followed in selecting morphological variables.

Data Management, Morphological and Body Measurement Data Analysis

Observations on morphological characters were analyzed for male and female sheep using frequency procedure while quantitative data such as body weight and linear body measurements were analyzed using the Generalized Linear Model (GLM) procedures of the Statistical Analysis System (SAS, 2008, version, 9.2). District, sex and age group were fitted as fixed independent variables while body weight and linear body measurements except scrotal circumference and horn length were fitted as dependent variables. Scrotal circumference was analyzed by fitting district and age group as fixed factor. When analysis of variance declares significance, least square means were separated using adjusted Tukey-Kramer test.

Except for scrotum circumference (SC), which was only considered for males, parameters such as body weight and other body measurements like heart girth (HG), body length (BL), wither height (WH), ear length (EL), horn length (HL), head length (HL), tail length (TL), rump length (RL), rump width (RW) and rump height (RH) were considered for both female and male sheep.

Model fitted to analyze adult body weight and other linear body measurements except the scrotal circumference and horn length was: $yijkl = \mu + Ai + Sj + Dk + (A*S)ij + eijkl$

Where: Yijkl= the observed l (body weight or LBMs) in the ith age group, jth sex and kth district; μ= overall mean; Ai = the effect of ith age group (i= 1, 2, ≥3) PPI; Sj= the effect of jth sex (j = female or male); Dk= the effect of Kth district; (A*S) ij = the effect of the interaction of i of age group with j of sex; and eijkl= random residual error

Model fitted to analyze the scrotum circumference and horn length was:

$$yikl = \mu + Ai + Dk + eikl$$

Where: Yikl= the observed l (SC) in the ith age group and kth district; μ = overall mean; Ai = the effect of ith age group (i= 1, 2, ≥3) PPI; Dk= the effect of kth district and eikl= random residual error

Pearson's correlation coefficients were used to estimate the correlation between body weight and all body measurements using the Statistical Analysis System (SAS, 2008, version, 9.2).. Furthermore, body weight was regressed on body measurements (HG, BL, WH, RW, RL, RH, TL, HL, EL and SC) using backward elimination stepwise multiple regression to determine the best fitted regression equations for the prediction of body weight from linear body measurements for adult animals. Best fitted models were selected based on higher coefficient of determination (R^2) and lower the Mallows (C) parameters C (p), Alkaike's Information Criteria (AIC) and Schwarz Bayesian Criteria (SBC) Values for simplicity of measurement under field condition. The following model was fitted for the multiple linear regression analysis within sex classes.

For females: $yij = a + \sum \beta ixj + eij$

Where: Yij= the dependent variable body weight; a = the intercept, β1, β2... βi are the partial regression coefficient considering each independent variables. X1, X2…Xj are independent variable like Heart girth, height at wither, body length, rump length, rump width, rump height, tail length, head length and ear length, respectively; and ei = the residual error

For males: $yij = a + \sum \beta ixj + eij$

Where: Yj = the dependent variable body weight; a = the intercept, β1, β2..., βi are the partial regression coefficient respecting for independent variables. X1, X2…Xj are independent variable like heart girth, height at wither, body length, rump length, rump width, rump height, tail length, head length, ear length and scrotal circumference, respectively; and ej = the residual error

RESULTS AND DISCUSSIONS

Phenotypic Characteristics of Sheep in the Study Areas

Characterization of qualitative traits

There was an increasing interest in the characterization of African small ruminant populations because of their major role in the maintenance of genetic resources as the basis of future improvement at both the production and the genetic levels (Nsoso *et al.,* 2004). Description of the physical characteristics of livestock breeds is very important for developing a breeding strategy in a particular production system (Taye *et al*., 2016). The current study areas are believed to be boundary areas for two sheep breeds, Horro and the Central Highland sheep breeds. That means characterization in here serves multiple purposes: to exactly locate the exact boundary of the two breeds and for genetic improvement and conservation intervention.

All traits except head profile, ruff and wattle were significantly different (P<0.05) among districts. The major qualitative traits such as coat color patterns, coat color type, hair type, head profile, ear form, horn, horn shape, horn orientation, wattle and ruff of physical traits of body parts as observed in an individual head of sheep at Tokke Kutaye, Ambo and Dandi districts are summarized in Table 1. The dominant coat color pattern in the study areas was plain with 76.2%, 70.9% and 70.9 % in Tokke Kutaye Ambo and Dandi districts, respectively. The rest of the sampled populations were patchy and spotted coat color pattern (Table 1). The most frequently observed color type in all study districts was brown followed by black and white for both sexes. Coat color of sheep breed in Tokke Kutaye was more uniform than it was in Ambo and Dandi districts. Because sheep breed in Tokke Kutaye share the Horro sheep breed morphological traits that have uniform coat color while sheep breed in Dandi district had mixed coat color due to share centeral high land sheep breed morphological trait. However, the coat color of sheep breed in Ambo districts was the mixtures of Horro and Centeral high land sheep breed coat color characters. This is consistent with the report of Zewdu et al. (2012) for Horro sheep breed where above 80.0% of the indicated sheep breed exhibited uniform brown coat color. In the current study, about 60%, 44.3% and 40.5% of sampled sheep color types were brown, 10.9%, 14.3% and 14.4% were black and 7.8%, 13% and 12.2% were white color type were dominantly observed among sheep population in Tokke Kutaye, Ambo and Dandi districts, respectively. As one moves from sole Horro ecotype area, in this case Tokke Kutaye, to Ambo and then Dandi coat color uniformity decreases.

About 90.4% of the sampled sheep population from Tokke Kutaye, 71.3% from Ambo and 76.5% from Dandi districts had coarse smooth hair followed by coarse and short (Table 1). The head profiles of about 62.6%, 64.3% and 73% and about 37%, 35.7% and 27.4% of the sampled sheep population were straight and concave in Tokke Kutaye, Ambo and Dandi, respectively. The result was in agreement with Mesfin *et al.* (2016) who reported that about 93.8% of local sheep did have straight head in Wolaita zone. In contrast to the current findings, about 87.0% of rams and ewes with concave head profile were reported from Gamogofa and Gurage Silite (Abera *et al*., 2013). The majority of indigenous sheep in the current study districts had long fat tail (79.6%) followed by long thin tail (20.4%). The proportions of sheep which had long fat tail and long thin tail were about 79.6% and 20.4% in Tokke Kutaye, 60.0% and 40% in Ambo, respectively. However, in Dandi district long thin tail was the most frequently observed tail type followed by long fat tail (Table 1). Their proportions for the long thin tailed and long fat tailed sheep were about 58.3% and 41.7%, respectively. Almost all sampled sheep population in Tokke Kutaye was hornless. Only, about 4.3% of sheep was horned in Tokke Kutaye. Nevertheless, about 49.1% and 72.6% of the sheep populations found in Ambo and Dandi districts were horned. Almost all rams in Dandi and around half of the rams in Ambo were horned. The higher percentage of sheep did have semi pendulous ear form 81.3%, 69.6% and 76.0% followed by horizontal ear form 18.7%, 30.4% and 23.9% in Tokke Kutaye Ambo and Dandi, respectively. Based on the above qualitative parameters, sheep populations in Tokke Kutaye are likely Horro breed but sheep breed in Dandi district was different from Horro sheep breed. The breed may be attributed to the central high land sheep breed while sheep breed in Ambo district was the admixture of the two breeds.

In the current study, ruff was mainly sex and age dependent. Females were totally devoid of ruff and it was more readily observed in adult males as compared to young growing males. With regard to ruff, similar findings were also reported Zewdu (2008) for Horro sheep. About 7%, 4.3% and 3.5% of sampled sheep population in the present study had ruff from Tokke Kutaye, Ambo and Dandi districts, respectively. Ruff was observed on adult ram (male) in all study districts and most of the sampled sheep population did not have wattle.

Table 1. Description of qualitative traits in study areas

		Districts								
Traits	Attributes	Toke kutaye			Ambo			Dandi		
		M	F	T	M	F	T	M	F	T
		N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Coat color pattern	Plain	22(73.3)	153(76.1)	176(76.2)	24(80)	138(69.3)	163(70.9)	19(63.3)	144(72)	163(70.9)
	Patchy	3(10)	29(14.4)	32(13.9)	3(10)	27(13.6)	30(13.3)	7(23.3)	13(6.5)	20(8.7)
	Spotted	5(16.7)	18(9)	23(10)	3(10)	34(17.1)	37(16.2)	4(13.3)	43(21.5)	47(20.4)
Test	**X^2& p_value**								**11.75**	**0.019**
Color type	White	1(3.3)	17(8.5)	18(7.8)	4(13.3)	26(13)	30(13)	1(3.3)	27(13.5)	28(12.2)
	Black	0(0)	25(12.5)	25(10.9)	3(10)	30(15)	33(14.3)	1(3.3)	33(16.5)	34(14.4)
	Brown	22(73.3)	116(58)	138(60)	16(53.3)	86(43)	102(44.3)	20(66.7)	81(40.5)	101(43.9)
	Red	3(10)	14(7)	17(7.4)	3(10)	16(8)	19(8.3)	2(6.7)	12(6)	14(6.1)
	Grey	0(0)	0(0)	0(0)	0(0)	6(3)	6(2.6)	2(6.7)	4(2)	6(2.6)
	White and black	3(10)	9(4.5)	12(5.2)	3(10)	19(9.5)	22(9.6)	3(10)	23(11.5)	26(11.3)
	Red and white	1(3.3)	19(9.5)	20(8.7)	1(3.3)	17(8.5)	18(7.8)	1(3.3)	19(9.5)	20(8.7)
	Red, white and black	_	0(0)	0(0)	_	0(0)	0(0)	_	1(0.5)	1(0.4)
Test	**X^2 and p_value**								**27.77**	**0.021**
Hair type	Coarse and short	8(26.7)	14(7)	22(9.6)	11(36.7)	54(27)	65(28.3)	13(43.3)	40(20)	53(23)
	Coarse and smooth	22(73.7)	186(93)	208(90.4)	19(63.3)	145(72.5)	164(71.3)	17(56.7)	159(79.5)	176(76.5)
	Coarse and long	_	0(0)	0(0)	_	1(0.5)	1(0.4)	_	1(0.5)	1(0.4)
Test	**X^2 and p_value**								**27.76**	**<0.0001**
Head profile	Straight	18(60)	126(63)	144(62.6)	17(56.7)	131(65.5)	148(64.3)	21(70)	146(73)	167(72.6)
	Concave	12(40)	73(36.5)	85(37)	13(43.3)	69(34.5)	82(35.7)	9(30)	54(27)	63(27.4)
	Convex	_	1(0.5)	1(0.4)	_	0(0)	0(0)	_	0(0)	0(0)
Test	**X^2 and p_value**								**7.69**	**0.104**
Tail type	Long thin tailed	1(3.3)	46(23)	47(20.4)	2(6.7)	90(45)	92(40)	3(10)	131(65.5)	134(58.3)
	Long fat tailed	29(96.7)	154(77)	183(79.6)	28(93.3)	110(55)	138(60)	27(90)	69(34.5)	96(41.7)
Test	**X^2 and p_value**								**68.84**	**<0.0001**
Tail Form	Cylindrical and straight	18(60)	127(63.5)	145(63)	16(53.3)	123(61.3)	139(60.4)	11(36.7)	91(45.5)	102(44.3)
	Cylindrical and turned up at the end	4(13.3)	64(32)	68(29.6)	3(10)	21(10.5)	24(10.4)	6(20)	58(29)	64(27.8)
	Bi lobbed without appendage	8(26.7)	9(4.5)	17(7.4)	11(36.7)	56(28)	67(29.1)	13(43.3)	51(25.5)	64(27.8)
Test	**X^2 and p_value**								**63.08**	**<0.0001**

Table 1. (*Continued*)

Horn	Present	1(3.3)	9(4.5)	10(4.3)	17(56.7)	96(48)	113(49.1)	28(93.3)	139(69.5)	167(72.6)
	Absent	29(96.7)	191(95.5)	220(95.7)	13(43.3)	104(52)	117(50.8)	2(6.7)	61(30.5)	63(27.4)
Test	**X^2 and p_value**								**227.07**	**<0.0001**
Horn shape	Straight	0(0)	0(0)	0(0)	6(20)	30(15)	36(157)	1(3.3)	44(22)	45(19.6)
	Rudimentary	0(0)	2(1)	2(0.9)	4(13.3)	27(13.5)	31(13.5)	6(20)	59(29.5)	65(28.3)
	Spiral	1(3.3)	6(3)	7(3)	7(23.3)	30(15)	37(16.1)	21(70)	35(17.5)	56(24.3)
	Corkscrew	_	0(0)	0(0)	_	7(3.5)	7(3)	_	1(0.5)	1(0.4)
Test	**X^2 and p_value**								**245.74**	**<0.0001**
Horn orientation	Lateral	0(0)	0(0)	0(0)	4(13.3)	26(13)	30(13)	1(3.3)	54(27)	55(23.9)
	Oblique up ward	0(0)	0(0)	0(0)	3(10)	21(10.5)	24(10.4)	3(10)	18(9)	21(9.1)
	Back ward twisted	1(3.3)	8(4)	9(3.3)	10(33.3)	46(23)	56(24.3)	24(80)	67(33.5)	91(39.6)
Test	**X^2 and p_value**								**236.53**	**<0.0001**
Ear form	Semi pendulous	22(73.3)	165(82.5)	187(81.3)	23(76.7)	137(68.5)	160(69.6)	22(73.3)	153(76.5)	175(76.1)
	Horizontal	8(26.7)	35(17.5)	43(18.7)	7(23.3)	63(31.5)	70(30.4)	8(26.7)	47(23.5)	55(23.9)
Test	**X^2 and p_value**								**8.64**	**0.013**
Ruff	Present	16(53.3)	0(0)	16(7)	8(26.7)	2(1)	10(4.3)	8(26.7)	0(0)	8(3.5)
	Absent	14(46.)	200(100)	214(93)	22(73.3)	198(99)	220(95.7)	22(73.3)	200(100)	222(96.5)
Test	**X^2 and p_value**								**3.23**	**0.20**
Wattle	Present	1(3.3)	8(4)	9(3.9)	0(0)	14(7)	14(6.1)	1(3.3)	6(3)	7(3)
	Absent	29(96.7)	192(96)	221(96.1)	30(100)	186(93)	216(93.9)	29(96.7)	194(97)	223(97)
Test	**X^2 and p_value**								**2.72**	**0.26**

M= male; F= female; T=total; N= Number of sheep exhibiting a particular qualitative character (_) = Not existed

Live body weight and linear measurements

Information on body weight and physical linear measurements of specific sheep population at constant age has paramount importance in the selection of genetically superior animals for production and reproduction purposes (Mohammed *et al.,* 2017). Universally, body weight of sheep increases with age. The main source of variation in live body weight and linear body measurements were district/location, sex, age group and the interaction of both sex and age group. The least squares mean and standard errors for the effect of district, sex, age group and interaction of age group and sex on body weight and other body measurements are presented in Table 2

Districts/location effect

The least squares mean and standard errors for the effect of districts/location on body weight and other body measurements are presented in Table 2. In the current study, body weight and most of the linear body measurements (BL, HG, WH, EL, HL, RH and TL) were significantly affected ($p<0.01$) by district, except rump width and rump length which were not influenced ($p>0.05$) by district. Body weight and most of the linear body measurement were highest in Tokke Kutaye than they were in Ambo and Dandi districts. Average body weight obtained for Tokke Kutaye, Ambo and Dandi districts were 28.4±0.24 kg, 26.1±0.19 kg and 25.9±0.15kg, respectively. This indicate mean body weight obtained in Ambo district was lower than the mean body weight obtained from Tokke Kutaye, but higher than the mean body weight obtained from Dandi district. The mean live body weight obtained in Tokke Kutaye was in close agreement the 27.7±0.21kg mean body weight reported by Zewdu (2008) for Horro sheep. On the other hand, the mean live body weight obtained from sheep population of Dandi district was somewhat comparable with the 24.6 kg reported by Sisay (2002) for the Central highland sheep. As body weight increases other linear body measurements were also increased. The highest mean leaner body measurements such as HG, WH, BL, and RH were also recorded for sheep population found in Tokke Kutaye followed by those found in Ambo district and the least mean leaner body measurements were reported from Dandi district (Table 2). Amelmal Alemayehu (2011) and Abera *et al*. (2016) reported that most of the linear body measurements and live body weight were affected by district.

Sex effect

Sex of the sheep had significant ($p<0.01$) effect on BW, HG, BL, WH, RH EL, HL, RW, R L, except TL that was not affected ($P>0.05$) by sex of the sheep. Similar influence of sex was also reported by Taye *et al*. (2016) on body weight, heart girth, body length and height at rump. On the other hand, Haylom *et al*. (2014) reported that sex had no effect on body weight; heart girth, body length and height at wither in highland sheep found in Atsbi Wonberta. In the current study, live body weights obtained for male and female sheep were 29.0±0.41 and 24.6±0.12kg, respectively. A difference of 2 cm was observed in heart girth between male and female sheep in the current study. Heart girth values of 75±.57cm and 73±.20cm were obtained for male and female sheep, respectively.

Age effect

In current study, body weight and all linear body measurements of the sampled sheep were significantly ($P<0.01$) affected by age group (Table 2). Body weight and all linear body measurements were increased as the age increased from the youngest (1PPI) to the oldest (≥ 3 PPI). Live body weight of 24.0±0.17kg 26.8±0.15kg 29.6±0.18kg were recorded for age group 1PPI, 2PPI, ≥ 3PPI, respectively. The corresponding heart girth (HG) measurement recorded were 69.8±0.30cm, 74.4±0.23cm and 78.5±0.27cm for age groups 1PPI, 2ppI and ≥3PPI, respectively. Results obtained in the current study were in agreement with literature reports (Hizkel *et al.*, 2017; Mohammed *et al*., 2017).

Age by sex interaction effect

Age by sex interaction had significant effect ($P<0.01$) on body weight (BW) and rump width (RW). However, they have no significant effect ($P>0.05$) on all other linear body measurements included in the current study (Table 2). The result was contradicted with Abera *et al.* (2014) who reported that all linear body measurements and live body weight were significantly ($P<0.05$) influenced by the interaction effects of age and sex.

Table 2. Body weight and leaner body measurement

Level	N	BW	HG	BL	WH	EL	HL	RL	RW	RH	TL	SC
		LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE
Overall	690	26.8±.27	74.2±.39	64.1±.34	67.6±.35	12.5±.08	20.3±.14	21.0±.15	20.1±.13	67.7±.31	34.8±.31	22.5±.43
R^2		0.70	0.45	0.36	0.42	0.57	0.59	0.29	0.35	0.32	0.23	0.54
CV%		6.89	5.16	5.44	4.98	7.28	5.83	7.97	6.17	5.23	10.31	10.1
District		**	**	**	**	**	**	Ns	Ns	**	**	*
Tokke Kutaye	230	28.4±.24^{a}	75.5±.35^{a}	65.3±.28^{a}	68.6±.29^{a}	12.8±.08^{a}	20.5±.12^{a}	21.0±.13	20.1±.11	68.5±.30^{a}	36.3±.25^{a}	23.0±.44^{a}
Ambo	230	26.1±.19^{b}	74.1±.34^{b}	63.4±.29^{b}	67.3±.29^{b}	12.3±.09^{b}	20.0±.12^{b}	20.9±.15	20.1±.10	67.4±.28^{b}	34.4±.27^{b}	22.8±.42^{a}
Dandi	230	25.9±.15^{b}	73.1±.30^{c}	63.5±.25^{b}	66.8±.27^{b}	12.4±.09^{b}	20.3±.12^{a}	20.8±.11	19.9±.09	67.3±.26^{b}	34.3±.27^{b}	21.4±.42^{b}
Sex		**	**	**	**	**	**	**	**	**	Ns	
Male	90	29.0±.41^{a}	75.4±.57^{a}	65.2±.50^{a}	68.7±.53^{a}	12.8±.15^{a}	20.6±.20^{a}	21.2±.22	20.3±.20^{a}	68.5±.50^{a}	35.1±.45	22.5±.43
Female	600	24.6±.12^{b}	73.0±.20^{b}	63.0±.17^{b}	66.5±.17^{b}	12.2±.06^{b}	19.9±.07^{b}	20.7±.08	19.8±.06^{b}	66.9±.17^{b}	34.5±.16	
Age		**	**	**	**	**	**	**	**	**	**	**
1PPI	183	24.0±.17^{a}	69.8±.30^{a}	60.7±.24^{a}	63.9±.28^{a}	11.2±.08^{a}	18.14±.08^{a}	19.5±.12^{a}	18.7±.09^{a}	64.6±.28^{a}	33.0±.27^{a}	19.4±.44^{a}
2PPI	279	26.8±.15^{b}	74.4±.23^{b}	64.0±.24^{b}	64.0±.22^{a}	12.5±.06^{a}	20.2±.07^{b}	20.8±.11^{a}	20.1±.07^{b}	68.0±.22^{b}	34.9±.23^{b}	23.8±.37^{b}
≥3PPI	228	29.6±.18^{c}	78.5±.27^{c}	67.5±.23^{c}	71.0±.19^{b}	13.7±.05^{b}	22.1±0.09^{c}	22.4±.09^{b}	21.4±.08^{c}	70.7±.23^{c}	37.1±.33^{c}	24.0±.47^{b}
Sex By Age		**	Ns	Ns	Ns	Ns	Ns	Ns	**	Ns	Ns	
Male*1PPI	27	25.9±.24^{a}	71.0±.71	61.5±.63	64.9±.86	11.5±.25	18.8±.24	19.8±.35	18.8±.29^{a}	65.4±.83	33.1±.91	
Male*2PPI	39	29.1±.58^{b}	75.2±.78	64.9±.63	68.9±.73	12.7±.15	20.4±.18	20.8±.29	20.2±.26^{a}	68.6±.74	35.2±.57	
Male*≥3PPI	24	32.2±.75^{c}	80.1±.71	69.2±.78	72.1±.70	14.0±.16	22.7±.31	23.0±.26	22.0±.27^{b}	71.6±.67	37.1±.79	
Female*1PPI	156	22.1±.16^{d}	68.6±.33	59.9±.26	62.9±.28	10.9±.08	18.1±.08	19.3±.13	18.6±.10^{d}	63.7±.29	32.8±.28	

Table 2. *(Continued)*

Level	N	BW	HG	BL	WH	EL	HL	RL	RW	RH	TL	SC
Female*2PPI	240	24.6±.10^{e}	73.6±.24	63.1±.25	66.6±.22	12.3±.06	20.1±.07	20.8±.12	20.0±.07^{e}	67.4±.22	34.6±.25	
Female*≥3PPI	204	27.0±.15^{f}	76.8±.28	65.8±.23	69.9±.20	13.5±.05	21.7±.09	21.9±.09	20.8±.09^{e}	69.8±.24	37.1±.25	

BW = Body weight; HG = Heart Girth; BL = Body Length; WH = Wither Height; EL = Ear Length; HL = Horn Length; RL = Rump Length; RW = Rump Width; RH = Rump Height; TL = Tail Length; SC = Scrotal Circumference; Means with different superscripts within the same column and class are statistically different (at least P<0.05). Ns = non-significant; * Significant at 0.05; **significant at 0.01. 1PPI = 1 pair of permanent incisors, PPI = 2 pairs of permanent incisors and≥3PPI=3or more pair of permanent incisors.

Correlation among Body Weight and Linear Body Measurements

Correlation coefficients of live body weight and linear body measurements for male and female indigenous sheep in the three districts are presented in Table 3. Determining animal live body weight, linear body measurements and their interrelationship and correlation are very important for determining the genetic potential, breed standards and improved breeding programs for higher meat production (Younas *et al*., 2013). All linear body measurements of male sheep and female sheep showed highly significant (*P*<0.01) positive associations with body weight, except for horn length which was significantly and negatively associated (*P*<0.05) with body weight in both sexes. Among the measured linear body measurements, body length (r = 0.63), heart girth (r = 0.79), wither height (r = 0.61) rump width (r= 0.70) and rump height (r = 0.65) while for female sheep or ewe body length (r = 0.64), heart girth (r = 0.73), wither height (r = 0.70) and rump height (r = 0.64) were strongly correlated with body weight. The highest correlation of heart girth with body weight than other body measurements was in agreement with literature reports (Tesfaye, 2008; Dejen, 2010; Mohammed *et al.*, 2017). This would imply that chest girth is the best variable for predicting live body weight than other measurements. The high correlation coefficients between body weight and linear body measurements for male and female imply that either of these variables or their combination could provide a good estimate for predicting the live weight of sheep from body measurements.

Table 3. Phenotypic correlations among linear body measurements for both sex; below and above the diagonal is for male and female,

	HeL	HL	EL	HW	HG	BL	RL	RW	RH	TL	SC	BW
HeL		-0.07^{NS}	0.63**	0.62**	0.61	0.63**	0.53**	0.63**	0.60**	0.39**	0.16^{NS}	0.60**
HL	0.04 ^{NS}		-0.16 ^{NS}	-0.08 ^{NS}	-0.22*	-0.28*	0.08 ^{NS}	-0.14 ^{NS}	-0.09 ^{NS}	0.04 ^{NS}	0.12 ^{NS}	-0.31*
EL	0.70**	-0.01 ^{NS}		0.45**	0.65**	0.61**	0.54**	0.65**	0.54*	0.41**	0.26*	0.58**
HW	0.57**	-0.04 ^{NS}	0.57**		0.78**	0.73**	0.65**	0.69**	0.84**	0.62**	0.42**	0.61**
HG	0.55**	-0.01 ^{NS}	0.55*	0.68**		0.79**	0.71**	0.76**	0.78**	0.58**	0.43**	0.79**
BL	0.49**	-0.03 ^{NS}	0.51**	0.61**	0.66**		0.65**	0.72**	0.76**	0.59**	0.26*	0.73**
RL	0.49**	0.02 ^{NS}	0.48**	0.45**	0.50**	0.45**		0.83**	0.67**	0.56**	0.43**	0.56**
RW	0.55**	0.05 ^{NS}	0.51**	0.49**	0.54**	0.49**	0.71**		0.74**	0.59**	0.42**	0.70**
RH	0.52**	-0.00 ^{NS}	0.53**	0.70**	0.74**	0.67**	0.51*	0.53**		0.60**	0.50**	0.65**
TL	0.37**	-0.08*	0.43**	0.40**	0.39**	0.33**	0.36**	0.35**	0.36**		0.26*	0.52**
SC	_	_	_	_	_	_	_	_	_	_		0.38**
BW	0.64**	-0.08*	0.65**	0.70**	0.73**	0.64**	0.50**	0.52**	0.64**	0.51**	_	

respectively.

*=significant at (P<0.05); **=significant at (P<0.01); Ns= not significant at (P<0.05) BL=Body Length; HG=Heart Girth; EL=Ear Length; HeL=Head length HL=Horn Length; HW= height at wither; RH= Rump Height; RW = Rump Width; RL=Rump length; TL=Tail Length; (-) = No value take

Prediction of Body Weight from Different Linear Body Measurements

Multiple regression analysis was presented in Table 4. Regression analysis is commonly used in animal research to describe quantitative relationships between a response variable and one or more explanatory variables such as body weight and linear body measurements especially when there is no access to weighing equipment (Cankaya, 2008). The accuracy of functions used to predict live weight or growth characteristics from live animal measurements is of vast financial contribution to livestock production enterprises (Mohamed *et al.,* 2017). Multiple regression equations were developed for predicting body weight from other linear body measurements.

In the current study, all the body measurements were built-in the regression model and through elimination procedures, the optimum model were identified for both male (ram) and female (ewe). Except for the scrotum circumference (SC) which was not included in the model used for female, linear measurements such as heart girth (HG), height at wither (HW), body length (BL) rump width (RW), rump length (RL), rump height (RH), head length (HeL), ear length (EL), and tail length (TL) were fitted in the model of analysis. Stepwise regression was carried out for each sex by entering all the above traits at a time for male and by excluding SC for females to predict body weight. The fitted prediction model was selected with smaller value of C (p), AIC, SBC, RMSE and higher R^2 and A.R^2 values. Heart girth selected first, which explain more variation than any other linear body measurements in both rams (0.62) and ewes (0.53). Similarly, this measurement was reported for Gumuz, Jarso, and Nedjo sheep (Solomon, 2007; Kedjela, 2010). However, predictions of body weight from combinations of LBMs, having these multiple variables possess a practical problem under field settings due to the higher labor and time needed for measurement. Furthermore, the change in R^2 due to inclusion of additional variables in the model was not strong strengthening the preceding argument that chest girth alone could serve as a best predictor of body weight under field condition. Measuring heart girth with tape is easy, cheap and rapid. Thus, body weight prediction from chest girth alone would be a practical option under field conditions with reasonable accuracy.

Two regressor variables with significant contribution to the prediction model which include heart girth and body length were fitted in first and second step for ram whereas five regressor variables like heart girth (HG), height at wither (HW), tail length (TL), body length (BL) and rump width (RW) were first, second, third, fourth and fifth steps for female was best fitted model for study area. The overall equation HG as explanatory variable may be used for the prediction of body weight for male and female sampled sheep population in all districts. Thus, prediction of body weight could be based on regression equation:

$y = -14.21 + 0.57x$ for male sample population and

$y = -3.49 + 0.39x$ for female sample sheep population

Where; y = body weight and x= heart girth,

Table 4. multiple regression analysis of live body weight on different linear body measurements for indigenous sheep for both sexes in the study area

Sex	Model	Intercept	β_1	β_2	β_3	β_4	β_5	R^2	$A.R^2$	C(p)	AIC	Root MSE	SBC
Male	HG	-14.21	0.57					0.62	0.62	12.27	161.51	2.43	166.51
	HG + BL	-17.21	0.41	0.23				0.65	0.65	6.61	156.21	2.34	163.71
Female	HG	-3.49	0.39					0.53	0.53	233.57	713.49	1.81	722.28
	HW+HG	-9.25	0.24	0.25				0.61	0.61	102.46	610.55	1.66	623.74
	HW+HG+TL	-10.08	0.20	0.22	0.14			0.64	0.64	39.96	554.25	1.58	571.83
	HW+HG+BL+TL	-11.94	0.17	0.18	0.12	0.14		0.66	0.66	8.69	523.79	1.54	545.77
	HW+HG+BL+RW+TL	-12.57	0.16	0.17	0.11	0.12	0.13	0.66	0.66	5.80	520.87	1.54	547.25

BW= body weight; BL= body length; HG= Heart girth; RW=Rump width; TL=tail length; R^2 = R- square; MSE= Mean square of error; A.R2= adjusted R^2; C (p) =Mallows C parameters; AIC =Alkaike's Information Criteria; SBC =Schwarz Bayesian Criteria.

Demarcation between Horro and Central Highland Sheep Breeds

Sheep breed/s available in the central highlands of the country including those available in west Shewa zone are generally named as Centeral highland sheep mainly due to lack of proper characterization. On the other hand, reports (Galal, 1983) indicated that Horro sheep breed is distributed in some parts of western Shewa zone. These controversial ideas were persisting for long period of time and there is no geographical demarcation between two breeds. Thus, results of the current study tried to put geographical demarcation based on physical and morphmetrical characters (traits) of sheep. Some qualitative and quantitative traits were used for demarcation of the boundary between the two breeds.

Qualitative traits

Sheep breeds that are previously characterized have more or less their own typical morphological characters. Among these Horro and Central high land sheep breeds are considered under previously characterized breed. Thus, horn, coat color pattern, color types and hair type were the most indicators of qualitative traits that are used for demarcation of these breeds.

Horn

Horn is the typical characters of the Central high land and poldness is the typical character of Horro sheep breed. Results of the current study indicated that about 4.2% from Tokke Kutaye, 41.1% from Ambo and 72.6% from Dandi district sheep were horned, respectively (Table 1). Almost all sheep breed in Tokke Kutaye was hornless, this indicate they share Horro sheep breed characters. On the other hand, majority sheep breed in Dandi district were horned as a result of the share centeral high land sheep breed characters. Although sheep breed in Ambo district was average of the two breeds (Fig.2). Therefore, both breeds are found in Ambo district being mixed.

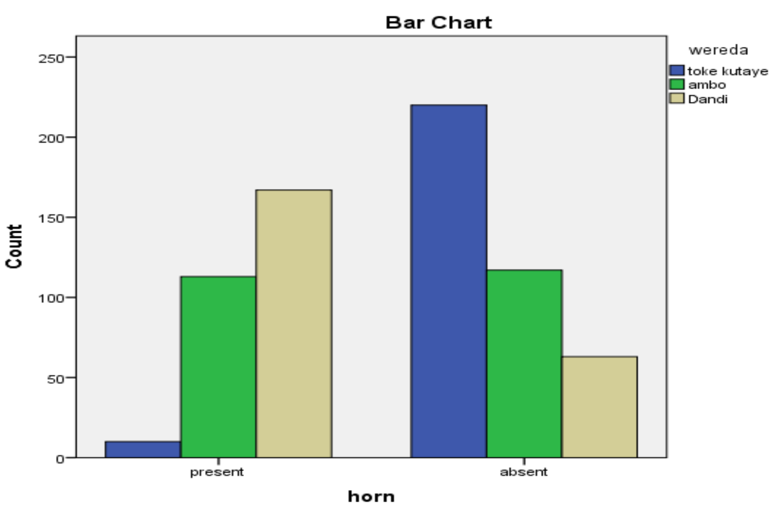

Figure 2. Cluster bar graph showing horn of sheep

Coat color types

Coat color type is one of the most important qualitative traits in discrimination of breed. Previously characterized breed had their own most dominant coat color type. Zewdu (2008) reported that 55.6% of Horro sheep breed had uniform brown coat color. In the current study, about 60.0%, 44.3% and 43.9%

of the sampled sheep population from Tokke Kutaye, Ambo and Dandi districts were brown, respectively (Table 1 and Figure 3). Sheep population in Dandi district had mixed coat color types. On the other hand, sheep population in Tokke Kutaye had more uniform coat color followed by those sheep populations from Ambo district indicating that sheep in Ambo district had the characteristics of sheep population found in Tokke Kutaye and Dandi district.

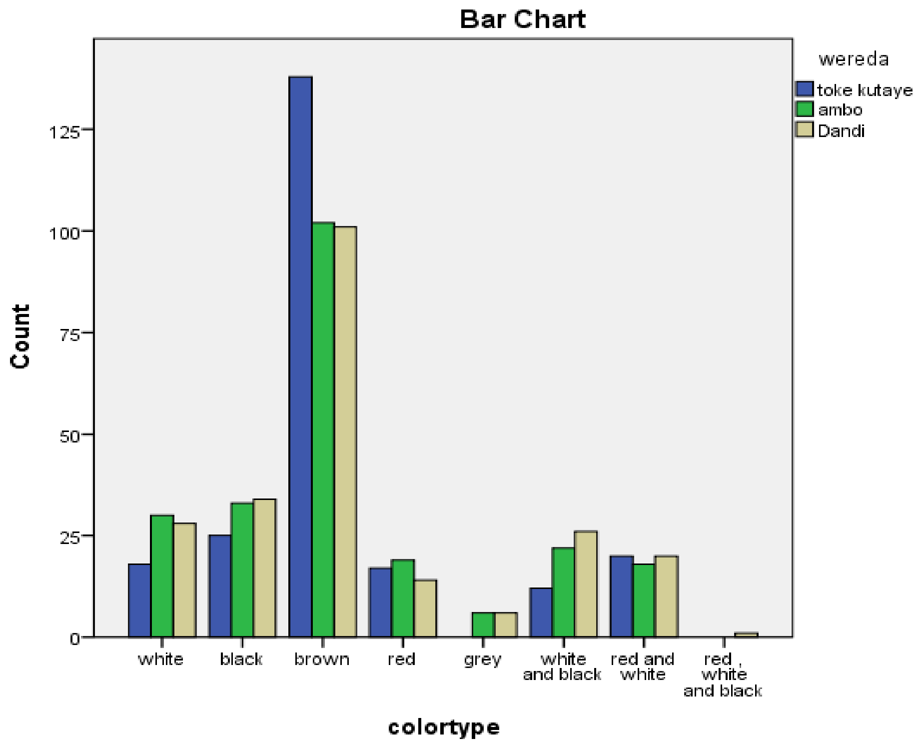

Figure 3 Cluster bar graph showing color types of sheep

Hair type

Hair type was another trait used for identification of breeds in this study. About 90.4% of sampled sheep population from Tokke Kutaye, 71.5% from Ambo and 76% from Dandi districts had coarse and smooth hair type (Tables 1). Tokke Kutaye sheep encompass higher percentage of short and smooth hair type but sheep breed in Dandi district had lower when compared with Tokke Kutaye. Sampled sheep population found in Ambo district was slightly lower than the two breeds with regard to hair type but more approach to sheep breed in Dandi district (Fig. 3).

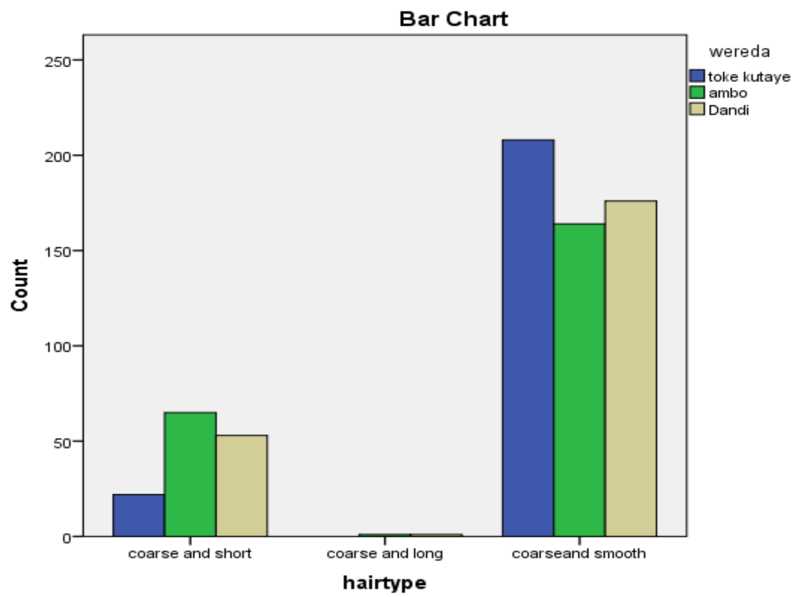

Figure 4 Cluster bar graph showing hair type of sheep

Quantitative traits

Almost all quantitative variables (traits) included under this study were significantly (*P*<0.01) different within districts (Table 2). Among these, the most explanatory variables were taken for demarcation of sheep breeds targeted in study areas. These are body weight (BW), heart girths (HG), body length (BL), wither height (WH) and rump height (RH). The results of current study indicate that the least square means of selected traits were higher in Tokke Kutaye and lower in Dandi districts while the result obtained from Ambo was existed at the middle of the two districts.

Body weight and heart girth were the most explanatory traits among the selected traits. About 28.4±0.24kg, 26.1±0.19kg and 25.9±0.15kg of body weight were obtained, respectively, from Tokke Kutaye, Ambo and Dandi districts. The result obtained from Tokke Kutaye was higher and relatively approach the 29.7±0.68kg live weight reported for Horro sheep by (Zewdu 2008). On the other hand, body weight obtained from Dandi district was lower than Body weight obtained from Ambo district. Similar to body weight heart girth decreases from Tokke Kutaye to Dandi districts. Least square mean (LSM) of heart girth of sheep breed/s were 75.5±0.35 cm form Tokke Kutaye, 74.1±0.34 cm from Ambo and 73.1±0.30 cm from Dandi districts. Therefore, the result obtained from Ambo district falls in between results of the two breeds (Horro and Central Highland sheep).

Body length (BL), wither height (WH) and rump height (RH) were other quantitative traits used for breed identification in study areas. In Tokke Kutaye district BL, WH and RH of the sampled sheep population were 65.3±0.28, 68.6±0.29 and 68.5±0.30, respectively. The results were in line with Zewdu (2008) report on Horro sheep breed. Correspondingly, the results obtained from Dandi district were 63.5±0.25, 66.8±0.27 and 67.3±0.26 for BL, WH and RH, this is agreement with Abera *et al.* (2014) for local sheep in Salale area which is considered as the Central highland sheep breed. About 63.4±0.29 for BL, 67.3±0.29 for WH and 67.4±0.28 for RH were obtained from the sampled population from Ambo district (Table 2). Except for the body length results obtained from Ambo district were fallen between results obtained from Tokke Kutaye and Dandi districts.

Generally, based on the results obtained from qualitative and quantitative traits geographical demarcation between Horro sheep breed and the Central highland sheep breed is Ambo district, where admixture of the two breeds, Horro and the Central Highland sheep breeds is observed.

CONCLUSION

The current study results showed that sheep population in Tokke Kutaye are Horro sheep breed and those in Dandi district show characters of the Central highland sheep breed. Nevertheless, sheep population found in Ambo district exhibit characters of both sheep breeds, Horro and the Central highland sheep breeds. Therefore, Ambo district is the geographical demarcation of Horro sheep and the Central high land sheep breeds. In fact, further in-depth study supported by molecular characterization is warranted to clearly demarcate the boundary lines of the two breeds and investigate their level of admixture.

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Determinants of the Probability and Intensity of Improved Forage Crops Adoption in Oromia National Regional State

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ABSTRACT

The objective of this study was to investigate the determinants of the adoption rate and intensity of improved forage in Oromia National Regional State following multi-stage sampling procedure to collect primary data from a total of 1630 randomly selected smallholder dairy producers. Both descriptive analysis and Craggit econometric model were used to analyze the data. The overall adoption rate of improved forage crops in the region was only 10%. The intensity of adoption was also eight percent indicating a very low size of land allocated for the production of improved forage crops. Among the adopters, varietal level adoption rate indicated that 35% of them have commonly grown oat-vetch while 15% have grown elephant grass. The Craggit model result indicated that family size increased the probability of improved forage adoption while age of the household head increased the intensity of improved forage adoption. It also revealed that volume of milk production, land owned and the use of feed resources other than grazing were noted to have a positive impact on both the probability and intensity of improved forage adoption. Furthermore, access to extension services, relevant training, knowledge on improved feeds, access to big cities and experiences on food crop adoption were found have positive impact on the probability of improved forage adoption. Therefore, policies that target to enhance availability of improved forage seeds, knowledge and skills of family labor, experience sharing between older and younger farmers, relevant training, extension services and better infrastructure would have a positive impact on improved forage adoption. Raising awareness of the farmers on the importance of adopting improved forages would also help to allocate a plot of land for growing forage crops.

Keywords: Craggit model, forage, adoption

INTRODUCTION

The share of feed cost ranges from 40% to more than 70% of the total cost of dairy production depending on the region where the dairy farm operation is performed. In farms located in north Asia, Europe and North America, feed cost accounts for 40-50% of the total cost of milk production whereas it accounts for 50-70% of the total cost of milk production in most farms of Africa (Alqaisi *et al*., 2011). Recent studies in emerging economies such as Ethiopia show that the cost of feed accounts for as high as 80% of the total variable cost of milk production (Diro *et al*., 2019). One of the ways to reduce feed cost is by using the improved forage.

To avail improved forage that is usually disseminated as a package for improved dairy farms, national research institutes such as Ethiopian Institute of Agricultural

Research (EIAR), regional agricultural research institutes (RARIs), and international research agencies, such as International Livestock Research Institute (ILRI), generated several improved forage technologies and disseminated through various extension mechanisms. According to the report by Feyissa *et al.* (2015), 24 improved forage varieties were released and disseminated to the farmers until 2014. Out of these, 20 improved varieties of forage were reported to be in production (MoANR, 2018). The most commonly produced improved forage varieties included tree lucerne, elephant grass, Rhodes, panicum, trifolium, vetch, cow pea, pigeon pea, oats, sesbania, lupin, alfalfa, Pennisetum, perennial grass and d*esho* grass (MoANR, 2018). In the process of scaling up of these improved forages, marketing and commercializing of the improved forage seed and seedling is believed to be crucial.

Studies indicated that a strong forage market and commercialization is fundamental for the production of adequate amount of good quality improved forages, better adoption and transforming livestock and dairy sub-sectors in general, and forage sub-sector in particular (Lemma *et al*., 2010; Aranguiz and Creemers, 2019). However, forage marketing has remained informal, opportunistic and seasonal that has been controlled by traders and retailers, and characterized by underdeveloped commercialization (Aranguiz and Creemers, 2019). In Ethiopia, forage seed and planting material production, marketing and commercialization have been given less attention despite the potential to establish large scale seed production (Tolera *et al*., 2012). Furthermore, poor market orientation, shortage and poor-quality forage seed, high cost of feed resources, inadequate economic incentives of forage adoption, shortage of land, and lack of support services contributed to low level of improved forage adoption in Ethiopia (Gebremedhin *et al*., 2003; Lemma *et al*., 2010; Tolera *et al*., 2012).

Several other studies have also reported factors affecting forage technology adoption which broadly included household and farm characteristics, institutional factors and infrastructure. Household characteristics include sex, age, education of the head, family size and labor force (Abebe *et al*., 2018; Bashe *et al*., 2018; Bashir, 2014; Bassa, 2016; Gebremedhin *et al*., 2003; Jera and Ajayi, 2008; Martínez-García *et al*., 2013; Salo *et al*., 2017; Wambugu *et al*., 2011). Some other studies have also revealed the gender dimension that male household heads allocated more proportion of land to improved forage production than female headed households (Bashir, 2014). The same study has also reported that old age household heads are associated with high intensity of improved forage adoption (Bashir, 2014) while educational level of the household head has a positive impact on the adoption of improved forage (Bassa, 2016; Gebremedhin *et al*., 2003. Family size and adult male members of a household have a positive impact on the probability of adopting improved forage *(*Abebe *et al., 2018;* Bashe *et al*., 2018; Martínez-García *et al*., 2013).

Findings on the influence of farm characteristics on forage adoption have shown that the impact of land size is mixed. While some studies reported that land size had a positive impact on improved forage adoption (Jera and Ajayi, 2008; Martínez-García *et al*., 2013), others observed a negative impact (Bashe *et al*., 2018; Bashir, 2014). Farm characteristics such as dairy herd size (Bassa, 2016; Jera and Ajayi, 2008; Martínez-García *et al*., 2013), livestock ownership (Bashir, 2014; Martínez-García *et al*., 2013), and milk yield (Martínez-García *et al*., 2013) had a positive impact on the likelihood of improved forage adoption.

Institutional factors such as access to cooperative membership, credit, extension services and livestock training play important role in forage adoption. Membership of dairy cooperatives (Jera and Ajayi, 2008), access to extension service (Abebe *et al*., 2018; Bashir, 2014), access to credit service (Bashir, 2014) and livestock training (Abebe *et al*., 2018; Bassa, 2016) had a positive impact on the probability of improved forage adoption. Regarding the impact of infrastructure, studies have shown negative association between distance to development agents' office or farmers' training center and the likelihood of adopting improved forage (Abebe *et al*., 2018; Bashe *et al*., 2018; Bassa, 2016).

While several of the past studies on improved forage adoption are vital to serve as a guide for adoption study, they also had some limitations. Some of the past studies including that of Gebremedhin *et al*. (2003) conducted long time ago are rarely used to guide current policy making process related to forage improvement. Other studies including that of Abebe *et al*. (2018), Bashe *et al*. (2018), Bassa (2016), Bashir (2014), Jera and Ajayi (2008), and Martínez-García *et al*.(2013) had limited coverage focusing on one or two woredas[1] and hence had inherent limitation to represent wider areas. Furthermore, most of the past studies investigated the probability of adoption using a binary logit or probit model. However, both logit and probit models fail to capture the intensity of adoption which is as equally important as the probability of adoption. The exception is the study done by Bashir (2014) who investigated both the probability and intensity of improved forage adoption using double hurdle model and Gebremedhin *et al*. (2003) who investigated the intensity of adoption using Tobit model. The work of Bashir (2014) was limited to only one administrative zone in the northern part of the country in the Amhara National Regional State with limited sample size which will be difficult to make inferences and policy suggestions. Furthermore, the study of Gebremedhin *et al*. (2003) was not only limited to investigating the intensity of adoption, but also conducted long time ago which hardly helps to explain the recent situation.

The present study aimed to fill the stated gaps of past studies. Specifically, A Craggit double hurdle model that enables to investigate both the probability and the

[1] Woreda, also known as district, is the third-level of the administrative division of Ethiopia after zones and regions.

intensity of adoption solves the drawbacks of Tobit and Heckman two stage models. It also covers large area of land with reasonably large sample size. The objective of this paper is, therefore, to analyze adoption rates and the determinants of the probability and intensity of adoption of improved forage crops technologies in Oromia National Regional State.

METHODOLOGY

Scope of the Study

Improved forage is usually disseminated as a package with crossbred dairy technology. Therefore, the target population of this study is the households who owned cows. The study was conducted in Oromia National Regional State which possesses over 24 million cattle, accounting for 41% of the national cattle population (CSA, 2015). Eight Administrative zones that are believed to represent the region in dairy production were selected for the study including North Shewa, West Shewa, South West Shewa, East Shewa, West Hararghe, Arsi, Bale and West Arsi. Two woredas[1] were again selected from each of the zones based on their representativeness in dairy production along with associated packages, making a total of 16 woredas. From each of the woredas, two kebeles[2] were selected again based on representativeness in dairy production and package utilization practices making a total of 32 kebeles.

Data Collection Approaches

The required dataset and information were collected by employing blends of standard data collection methodologies. The major stages of data collection included desk review, qualitative and quantitative survey techniques. In the first stage, extensive desk review was made from electronic and print media including published and unpublished materials. Information obtained from desk reviews and qualitative approaches has helped to design survey instruments, such as structured questionnaire, at initial stages of the study. In the second stage, supplementary information and further details on specific parameters were collected through qualitative survey techniques, such as focus group discussions and key informant interviews. This approach has largely contributed to understand details of particular issues and learn more about dairy production technologies. Qualitative information was collected from selected farmers, Office of Agriculture representatives, senior livestock research and social science scientists and others. Information collected through this technique helped to describe and narrate quantitative findings. The third stage was devoted to collection of quantifiable data through quantitative survey approaches.

[2] Kebele is the lowest administrative unit in Ethiopia

This stage was fundamental to collect concrete and measurable data from randomly selected households using a structured and pre-tested questionnaire.

Sampling Frame and Sample Selection Techniques

Since the purpose of the study is to analyze the adoption status of improved forage technologies, the sampling frame was the population of households who owned dairy cows either local or crossbred. The complete list of households from where samples were drawn randomly was retrieved from Office of Agriculture. Once the list was secured, data was collected on the cow ownership status of each of the households along with kebele and village representatives. With this process, the sampling frame of the population of households who own cows was established. Out of this sampling frame, the sample of households was drawn randomly using systematic random sampling procedure.

To determine a representative sample size for the study, the following sample size determination formula by Kothari (2004) was used:

$$N = \frac{Z^2 pq}{e^2} = \frac{(1.96)^2\ (0.5)(0.5)}{(0.025)^2} = 1537 \qquad (1)$$

Where N is the sample size needed, Z is the inverse of the standard cumulative distribution that corresponds to the level of confidence, *e* is the desired level of precision, *p* is the estimated proportion of an attribute that is present in the population, and *q* = 1-*p*. The value of Z is found from the statistical table which contains the area under the normal curve of 95% confidence level. In the determination of sample size, setting the value of p=0.5 and hence q=0.5 yields the maximum optimum sample size while any other combination of the values of p and q yields less sample size using the Kothari formula. Therefore, using 0.5 for the values of p and q, and *e* = 0.025 the Kothari formula gives a total of 1537 samples to sufficiently represent the population in the selected study areas assuming a 95% confidence level and ±5% precision. However, assuming a response rate of 94%, additional 93 samples were added to have a total of 1630 samples.

Table 1. Sample sizes selected from each of the study zones in Oromia Region

Zones	Male	Female	Overall
North Shewa	167	57	224
West Shewa	175	60	235
South West Shewa	155	42	197
Arsi	130	42	172
Bale	140	60	200
West Arsi	138	61	199
East Shewa	140	58	198
West Hararghe	125	80	205
Overall average	1170	460	1630

Data Analysis

Both descriptive and econometric models were used to analyse the data. Econometric model used in this study was the Craggit model, the specification of which is given in subsequent section.

Empirical Model and Hypotheses

Farmers make two types of decisions: The first is whether or not to participate in adopting improved forage whereas the second is on the proportion of area allocated to grow improved forages out of the total land owned. Econometric models commonly used to handle such decisions can be Tobit (Tobin, 1958), Heckman two-stage (Heckman, 1979) and Craggit double hurdle (Cragg, 1971). The Tobit model has two shortcomings. First, it cannot separate the participation and intensity of participation decisions as it assumes both equations are affected by the same factors, which is not always true. Second, it assumes zero corner solution which may not hold true as the zero value of the intensity of participation equation may not be necessarily the corner solution but can be due to a discrete choice of not to participate in the adoption decision. Hence, Heckman two stage and the Craggit double hurdle models could be best candidates for this study.

The Heckman two-stage sample selection model solves the drawbacks of the Tobit because the participation and intensity of participation decisions are successively regressed in this modelling approach. In the Heckman selection model, the zero observations in the dependent variable are assumed to be discrete choices not to participate and only positive quantities are expected in the intensity (second) equation once a farmer decides to participate in adoption. That is, the second stage does not have a room for a corner solution in the intensity decision, which may not always be true. The Craggit model formulated by Cragg (1971) and further developed by Jones (1989) is more flexible and designed to solve the drawbacks of both the Tobit and the Heckman two stage models. However, to choose between the Tobit and the Craggit models, a log likelihood ratio test can be used. Based on Burke (2009), the specification of the Craggit double hurdle model that integrates the Probit model in the probability of adoption equation (to determine the probability of y > 0) and the truncated normal model for the intensity of adoption (given positive values of y) is given as:

$$f(w, y|x_1, x_2) = \{1 - \Phi(x_1\gamma\}^{1(w=0)}[\Phi(x_1\gamma)(2\pi)^{\frac{-1}{2}\sigma^{-1}}\exp\{-(y - x_2\beta)^2/2\sigma^2\}/\Phi(x_2\beta/\sigma)]^{1(w=1)} \quad (2)$$

Where w is a binary indicator equal to 1 if y is positive and 0 otherwise, x_1 and x_2 are the explanatory variables affecting the participation and the intensity equations, respectively, with no restrictions on the elements of x_1 and x_2 which means each decision may be determined by a different vector of explanatory variables altogether; Φ is the standard normal cumulative distribution function. In Craggit double hurdle model, the probability of y > 0 and the value of y, given y > 0, are determined by different mechanisms through the parameter vectors of γ and β, respectively.

From the Craggit model, the probabilities regarding whether y is positive are:

$$P(y_i = 0|x_{1i}) = 1 - \Phi(x_{1i}\gamma) \qquad P(y_i > 0|x_{1i}) = \Phi(x_{1i}\gamma) \tag{3}$$

The expected value of y, conditional on y > 0 can be given as:

$$E(y_i|y_i > 0, x_{2i}) = x_{2i}\beta + \sigma \times \lambda(x_{2i}\beta/\sigma) \tag{4}$$

Where λ (c) is the inverse Mills ratio (IMR) given as $\lambda(c) = \phi(c)/\Phi(\mathrm{c})$.

Where ϕ is the standard normal pdf (probability distribution function). The unconditional expected value of y is given as:

$$E(y_i|x_{1i}, x_{2i}) = \Phi(x_{1i}\gamma)\{x_{2i}\beta + \sigma \times \lambda(x_{2i}\beta/\sigma)\} \tag{5}$$

The partial effect of an independent variable, x_j, around the probability that *y* > 0, for a given observation is given as:

$$\frac{\partial P(y>0 \mid x_1)}{\partial x_j} = \gamma j \phi(x_1\gamma) \tag{6}$$

Where γ_j is the part of γ that represent the coefficient of x_j. The partial effect of an independent x_j on the expected value of y, given y > 0, is given as:

$$\frac{\partial E(y_i|y_i>0, x_{2i})}{\partial x_j} = \beta_j[1 - \lambda(x_2\beta/\sigma)\ \{x_2\beta/\sigma + \lambda(x_2\beta/\sigma)\} \tag{7}$$

Where β_j is part of β that represent the coefficient on x_j .

Finally, the partial effect of an independent x_j on the unconditional expected value of *y* is not straight forward because it depends on whether x_j is an element of x_1, x_2, or both. If it is an element of both x_1 and x_2, the partial effect is:

$$\frac{\partial E(y|x_1, x_2)}{\partial x_j} = \gamma_j \phi(x_1\gamma) \times \{x_2\beta/\sigma)\} + \Phi(x_1\gamma) \times \beta_j(1 - \lambda(x_2\beta/\sigma)\ \{\frac{x_2\beta}{\sigma} + \lambda(x_2\beta/\sigma)\}]\ \ if\ x_j \epsilon x_1, x_2 \tag{8}$$

However, if x_j is only determining the probability of y > 0, then β_j = 0, and the second term on the right-hand side of (8) is canceled. In contrast, if x_j is only determining the value of y, given y > 0, then γ_j = 0, and the first right-hand side term in (8) is canceled. In order to choose between the Tobit model and Craggit model, a likelihood ratio (LLR) test that compares the double hurdle model with the Tobit model was used. Following Greene (2012), the LLR can be given as:

$$LLR = 2 * [Log_{Craggitmodel} - Log_{Tobitmodel}]$$

Variables and Hypotheses

Dependent variables: The dependent variable in the first hurdle of the Craggit model is the dichotomous variable which takes the value of one if a farmer participated in improved forage production and 0 otherwise. During the survey period, ten improved forage varieties, namely: oat-vetch, elephant grass, tree lucerne, sesbania, alfalfa, fodder beet, rhodes grass, leucanea, cow pea, and pigeon pea were noted to be the major forage crops disseminated to the farmers. A farmer was considred as an adopter if s/he used at least one of the ten listed improved forage varieties. The dependent variable in the second hurdle (the intensity equation) is the percentage of land allocated to grow improved forage out of the total crop land owned by the farmer.

Explanatory variables and hypotheses: Based on economic theories and past empirical findings, relevant explanatory variables hypothesized to affect the participation and intensity equations are given in subsequent sections. However, some explanatory variables that are assumed to have less impact on the intensity equation were excluded from the second tier. Excluding some explanatory variables that are less likely to have extended impact on the intensity equation is a common practice in estimating the Craggit model to solve the difficulties of correctly identifying the parameters of the model (Newman *et al*., 2003; Shumeta *et al*., 2018).

Based on economic theories, past findings and field observation, major explanatory variables along with their definitions, measurements and expected sign of influence are presented in Table 2.

Table 2. Summary of explanatory variables included in the Craggit model

Variables	Definition and measurement	Expected sign
Age of HHH*	Age of the household head in years	+
Family size	Number of family members	+
Gender	Household type (Male=1)	+
Education of HHH	Elementary/junior education (Yes=1)	+
Number of cows	Number of total cows owned	+
Milk production	Milk yield in liters	+
Cow adoption	Adoption of crossbred cows (Yes=1)	+
Total land	Total land operated by the household (ha)	+-
Income	Household income (ETB/year)	+/-
Grazing feed	Feed source other than grazing (Yes=1)	-
Credit for dairy	Access to credit services for dairy (Yes=1)	+
Forage extension	No forage extension services (Yes=1)	-
Member of coops	Membership of milk cooperatives (Yes=1)	+
Access to big cities[3]	Within 100km radius from big cities (Yes=1)	+
Crop adoption	Adoption of improved crop varieties (Yes=1)	+
Feed problem	Availability of feed problem (Yes=1)	+
Training	Training on improved feeding practices (Yes=1)	+
Feed knowledge	Knowledge on feed technologies (Yes=1)	+

*HHH = Household head

[3] Milk-sheds supply milk to big cities are mainly located within the radius of 100kms.

RESULTS AND DISCUSSION

Household Characteristics

The result shows that the average age of improved forage technology adopters was significantly higher (45 years) than their non-adopter counterparts (42 years) (Table 3). Likewise, the average family size of adopters was significantly higher (7.9 persons) than their counterparts (6.8 persons). Family size, especially those at economically working ages (15–64 years) is a vital factor for farming households as they largely depend on family labor for livestock management operations such as land preparation, planting, harvesting and collection of forage crops, and other dairy management activities. The practice of engagement on hired labor is limited for smallholder farmers for they largely depend on family labor. Age of the household head usually serves as a proxy for farming experiences which is noticed to have either positive or negative influences on adoption of agricultural technologies. In this study, if we assume that the household heads started farming at 20 years, they accumulated more than 20 years of faming experiences which is helpful for the management of forage crops and other farming practices in a better way than those with limited experiences. With increased age, the opportunity of farmers' exposure to new technologies and practices also increases.

Table 3. Mean difference between adopters and non-adopters of improved forage

	Adopter (n=159)	Non-adopter (n=1471)	Overall (n=1630)	t-value
Age of head (years)	44.75 (12.35)	42.48 (12.8)	42.7 (12.8)	2.2**
Family size (number)	7.86 (3.07)	6.80 (2.96)	6.90 (2.99)	4.3***
Total land (ha)	3.79 (3.23)	2.13 (1.92)	2.29 (2.14)	9.5***
Total number of cows	2.75 (2.13)	2.12 (2.09)	2.18 (2.10)	3.7***
Milk yield (L/cow/day)	5.63 (9.3)	2.39 (4.6)	2.7 (5.31)	7.5***
Income (1000 ETB)	30 (34.6)	26.0 (42.6)	26.4(41.9)	-1.2

Note: numbers in parenthesis are standard deviations

Table 4 also reveals that the proportion of households who attended primary and junior school was significantly higher for improved forage adopters (79%) than non-adopters (71%). Education enhances knowledge of the farmers which helps for informed decision making whether to adopt new technologies or not. It also helps to practice improved crop management practices which eventually contributes to increased production and productivity. Similarly, the proportion of households headed by male was significantly higher for adopters (89%) than non-adopters (84%). Male household heads are relatively better in their resource status than female heads of households which largely contributes to afford adoption of new practices and technologies.

Farm and Economic Characteristics

The findings further present the farm and economic characteristics of the adopters and non-adopters of improved forage. It was revealed that improved forage adopters owned significantly larger number of cows and land, and also produced larger volume of milk per annum than their non-adopter counterparts, on average. Land is important to adopt improved forage as it is a key factor to produce improved forages. Farmers who owned more dairy cows needed more feed including improved forages. More milk production would also generate more income that can partly be reinvested to adopt improved forage production. The results also show that there was no mean difference between income level of improved forage adopters and non-adopters.

Table 4. Percentage difference between adopters and non-adopters of improved forage (discrete variables)

	Adopter (n=159)		Non-adopter (n=1471)		Overall (N=1630)		Chi2 value
	Freq.	%	Freq.	%	Freq.	%	
Elementary and junior education (Yes=1)	125	78.62	1047	71.18	1172	71.90	3.93**
Household type (Male headed=1)	142	89.31	1240	84.30	1382	84.79	2.79*
Feed source other than grazing (Yes=1)	153	96.23	1299	88.61	1452	89.35	8.75***
Knowledge of improved feed practices (Yes=1)	84	52.83	666	45.28	750	46.01	3.3*
Adoption of crossbred cows (Yes=1)	76	47.80	384	26.10	460	28.22	33.34***
Adoption of food crop technologies (Yes=1)	150	94.94	1192	81.31	1342	82.64	18.46***
Perception of feed as a problem (Yes=1)	142	89.31	1285	87.36	1427	87.55	0.50
Access to trainings on improved feeds (Yes=1)	79	49.69	495	33.65	574	35.21	16.17***
Member of dairy coops (Yes=1)	23	14.47	102	6.93	125	7.67	11.49***
Dairy and forage related credit (Yes=1)	6	3.77	104	7.07	110	6.75	2.48
No extension services on forage (Yes=1)	22	13.84	391	26.58	413	25.34	12.32***
Close proximity to big cities (Yes=1)	109	68.55	745	50.65	854	52.39	18.45***

Improved Forage Related Technologies

The findings indicate that the proportion of households who reported to have feed sources other than grazing was significantly higher for improved forage crops adopters (96%) than non-adopters (88%). Households who adopted improved forage crops also owned crossbred bred cows which require additional feed resources other than grazing, such as concentrates, hay and pasture grass. Knowledge of improved feed practices was also significantly higher for adopters (53%) than non-adopters (45%). Adopter households also had better access to education which helped them gain more knowledge to make informed decision than non-adopters. The proportion of households who adopted crossbred cows was also significantly higher for adopters (48%) than non-adopters (26%). The farmers opt to grow improved forage crops to meet the high feed demands of crossbred cows. However, there is no significant difference between the two groups regarding the perception of feed problem for dairy production. Feed is a problem not only for adopters of improved forages but also for non-adopters. It is a common phenomenon that the farmers who own local breed cows also faced shortages.

Institutional and Infrastructural Factors

Institutional factors such as access to trainings on improved feeds, dairy cooperative membership, access to dairy and forage related credits, availability of forage related extension services and distances from big cities are expected to influence the adoption of improved forage crops. The result indicates that the proportion of improved forage adopters had higher chance of participation in trainings (50%) than non-adopters (34%). Access to trainings has created awareness on improved technologies, including improved forage crops, and also contributed for enhanced knowledge and skills. Similarly, improved forage adopter households (14%) have better chances of participation in dairy cooperatives than non-adopters (7%). This has helped them get the required inputs, such as concentrate feeds and seeds of improved forages, through cooperatives at reasonable prices for their dairy cows.

It was also recognized that the proportion of households who are situated at a distance closer to big cities was higher for adopters (69%) than non-adopters (51%). Adopters of improved forages are also adopters of crossbred cows who produce milk and sale to the nearby towns. Accessibility to woreda and zonal towns, and capital cities is one of the favorable conditions to adopt dairy technologies including improved forages for it creates easy access to markets of perishable products, such as milk. In contrast, the proportion of households who did not receive extension services on improved forages was significantly lower for adopters (14%) than non-adopters (27%). This might be because, adopters had better exposure to formal schooling where they go basic knowledge and may not necessarily rely on the knowledge obtained from extension services. The result also indicates that there was no significant difference between the proportion of the two groups regarding access to dairy and forage related credit services. Non-adopters also require access to credit especially to purchase oxen.

Overall Adoption Rates and Intensity of Adoption of Improved Forage Crops

The overall adoption rate of improved forage crops in Oromia National Regional State was 10% (Table 5). This is regional level adoption rate from the perspective of all the samples taken in this study. Among the study zones, improved forage crops were most adopted in North Shewa zone (23%) followed by South West Shewa (16%) and Arsi (14%) zones. In response to increased demands for crossbred cow technologies and feed shortage problems, adoption of improved forage crops is expected to grow over time. Tens of improved forage crop varieties have also been generated through research and released to beneficiaries. Strengthening promotion and dissemination of these varieties is also expected to enhance adoption of improved forage crops. FGD and KII discussants have also indicated that improved forage seeds need to be available at reasonable cost to help them increase the adoption status.

Intensity of adoption of improved forages is defined as the size of farmland allocated for growth of improved forage crops. The findings revealed that the sample households have allocated eight percent of their farmlands on average for the growth of improved forage crops. Some of the adopter households, such as those in Arsi zone, allocated as high as 10% of their farmlands for the growth of improved forage crops while other adopters, such as those in South West Shewa zone, allocated five percent. Conventionally, the farmers tend to allocate more area of farmlands for the production of food than forage crops. This is partly because of limited landholding and attitudes of the farmers who perceived that animals can get feed freely from elsewhere and it is a waste of land to allocate a plot for the production of forage crops.

Table 5. Adoption intensity of improved forage crops in the study zones of Oromia Region

The study zones	Adoption rates			Adoption intensity		
	Total sample (N)	Number of improved forage growers (n)	Adoption rates of improved forages (%)	Improved forage growers mean farm size (ha)	Area allocated for improved forage (ha)	% of area allocated for improved forage
North Shewa	224	51	23	5.1	0.44	8.6
West Shewa	235	23	10	3.6	0.25	6.9
South West Shewa	197	32	16	3.1	0.15	4.8
Arsi	172	24	14	3.5	0.36	10.3
West Arsi	199	15	7.5	3.5	0.23	6.6
East Shewa	198	3	1.5	2.8	0.16	5.7
West Hararghe	205	0	0	0	0	0
Overall	1630	159	10	3.8	0.31	8
		X^2=98.6106, df=7, P<0.001		F=3.93 df=6 P=0.0011	F=4.96 df=6 P<0.001	F=3.09 df=6 P=0.007

Varietal Level Adoption Rates of Improved Forage Crops

Until 2014, a total of 24 improved varieties of forage crops were officially released for different agro-ecological zones of Ethiopia (Fekede Feyissa *et al*., 2015). Various stakeholders were engaged in the promotion of these forage crops, such as Offices of Agriculture, Agricultural Research Institutes, Higher Learning Institutes, special purpose projects, such as 4th Livestock Project, ILRI (the then ILCA) projects, and Smallholder Dairy Development Projects.

Households are said to be improved forage crop adopters if they grow at least one of the improved forage varieties. Accordingly, oat-vetch was relatively most grown improved forage variety with adoption rate of 35% followed by elephant grass (15%) (Table 6). On the otherhand, pigeon pea (0.2%), cow pea and Leucanea (1% each) were the least adopted improved forage varieties. The major reasons behind the less adoption rates of improved forage crops was associated with shortage of farmlands and the consequent interest of the farmers to give priority for food than forage crops.

Table 2. Varietal level adoption rates of improved forage crops in the Oromia Region

S.No.	Improved forage variety	% of aware hh N=1630	Years since awareness	Adoption rate (%) N = 1630
1	Oat-vetch	53	9.5	35
2	Elephant grass	43	4.7	15
3	Tree Lucerne	19	8.3	7
4	Sesbania	14	5.1	6
5	Alfalfa	11	4.6	2
6	Fodder beet	9	6.0	2
7	Rhodes grass	7	8.7	1.3
8	Leucanea	5	6.4	1
9	Cow pea	4	4.4	1
10	Pigeon pea	2	5.6	0.2

Determinants of Improved Forage Technology Adoption

The Craggit double hurdle model was used to investigate the factors affecting the probability and intensity of improved forage technology adoption. Before deciding to run the Craggit model, the Tobit model was tested. Accordingly, the null hypothesis which states ‘the Tobit model fits for the data at hand against the alternative Craggit model’ was rejected (the calculated value of the LLR = 70 while the tabulated value using loglikelihood ratio test with a value of 70.12 compared to the tabulated value at 95% level of signficnance and 13 degree of freedem is 22.36).

Older household heads were positively associated with the intensity of improved forage crop adoption. As age of the household head increases by one year, the conditional level of area allocated to improved forage inceased by 0.2% on average, cetires paribus (Table 7). This could be because older farmers accumulated more experiences and knowledge on the importance of improved forages than youths. Another posible explanation is that older farmers usually have more access to land, out of which some can be allocated to improved forage. In contrast, the youth is constrained by access to land as witnessed by FAO (2014). According to this report, access to land is one of the six challenges of youth to participate in agriculture. In addition, studies show that younger generation is losing interest in subsistence and traditional agriculture and try to run away from farming in developing countries (White, 2012). The migration is commonly from rural areas to urban centers, which is also happening in Ethiopia.

Table 7. Results of Cragg's double hurdle regression model for determinants of improved forage adoption

Variables	1st hurdle (participation)	2nd hurdle (intensity)	Probabilities $\frac{\partial P(y>0 \mid x_1)}{\partial x_j}$	Unconditional $\frac{\partial E(y \mid x_1, x_2)}{\partial x_j}$	Conditional $\frac{\partial E(y_i \mid y_i>0, x_{2i})}{\partial x_j}$
	Coef. (Std. Err.)	Coef. (Std. Err.)	APE	APE	APE
Age of head	-0.0001 (0.004)	0.006*(0.003)	0.000	0.000	0.002
Family size	0.041** (0.02)	0.001 (0.014)	0.006	0.002	0.000
Gender	0.18 (0.15)	-0.14 (0.14)	0.026	0.002	-0.051
Education of head	0.098 (0.12	-0.02 (0.10)	0.014	0.003	-0.009
Total cows owned	-0.025 (0.025)	0.025 (0.02)	-0.004	0.00	0.009
Milk production (liters)	0.03***(0.009)	0.01* (0.005)	0.004	0.001	0.004
Crossbred cow adoption	0.163 (0.12)	-0.145 (0.10)	0.024	0.001	-0.053
Total land (ha)	0.11*** (0.02)	0.07***(0.01)	0.016	0.008	0.026
Income (Birr)	-0.000 (0.000)	-0.000 (0.000)	0.000	0.00	0.000
Feed other than grazing	0.44** (0.21)	0.82** (0.40)	0.065	0.054	0.301
Credit access for dairy	-0.37* (0.22)	-0.03 (0.23)	-0.054	-0.017	-0.01
Access to big city	0.24** (0.10)	-0.23** (0.1)	0.036	0.001	-0.084
Feed problem	0.08 (0.15)	-0.19 (0.13)	0.012	-0.005	-0.07
Member of coops	0.14 (0.16)		0.02	0.006	
Crop adoption	0.43** (0.18)		0.063	0.018	
No forage extension	-0.39*** (0.13)		-0.058	-0.017	
Access to training	0.22** (0.10)		0.032	0.009	
Had feed knowledge	0.193**(0.098)		0.028	0.008	
Constant	-3.25*** (0.38)	-0.8 (0.49)			
Sigma					
Constant		0.33*** (0.04)			

Observations = 1,619, Wald chi2 (18) = 123.34, Log likelihood = -388.21, Prob > chi2 = 0.0000; Note: APE=Average partial effect

Family size was also found to have a positve impact on the probability of improved forage adoption. As family size of able persons (15-64 years) increases by one person, the probabilty and unconditional (overall) level of adopting improved forage increases by an average of 0.2 and 0.6%, respectively. Family is the main source of labor in rural setting, because of which a positive relationship is usually expected. Previous findings also confirmed this positive relationship (Abebe *et al*., 2018; Bashe *et al*., 2018; Martínez-García *et al*., 2013).

The annual quantity of milk production was found to have a positive impact on both the probability and intensity of improved forage adoption. A liter increase in milk production would result in a mean increment of a 0.4% probability of adoption, 0.1% overall (unconditional) and 0.4% conditional levels of improved forage adoption. This could be because high milk production helps to generate more income that can be reinvested for purchase of improved forage seeds to meet feed demands and sustain higher milk production. This result is in line with the findings of Martínez-García *et al.* (2013) who found a positive relationship between milk production per herd and improved grassland management by small scale dairy farmers in central Mexico.

As expected, total land owned was also found to have a positive impact on both the probability and intensity of improved forage adoption. As the land owned increases by one hectare, the probability of adopting improved forages increases by 1.6% on average while the overall (unconditional) and conditional levels of adoption increased by 0.8 and 2.6%, respectively. This is because land is a key resource to grow improved forage crops. This finding is in conformity with the past findings (Gebremedhin *et al*., 2003; Jera and Ajayi, 2008; Martínez-García *et al*., 2013).

The result also indicates that households who have feed sources other than grazing were positively associated with both the probability and intensity of improved forage adoption. Compared to households who totally depend on grazing as a feed source, households who have other feed sources than grazing had 6.5% higher probability of adopting improved forages. Likewise, the overall (unconditional) and conditional level of improved forage adoption of households who have more feed sources than grazing was 5.4 and 30% higher than their counterparts. The plausible explanation for this could be acute feed shortages where households opt to depend on different sources including improved forages to ensure adequate supplies especially for their crossbred animals.

Contrary to our expectation, credit for dairy was found to have a negative impact on the probability of adopting improved forages. Households who had access to credit were less likely to adopt improved forage by 5.4% with an overall (unconditional) level of adoption of 1.7%. This result is in contrast with the past findings (Bashir, 2014). This might be because of more dependence of households on purchased feed resources than planting and managing of forage crops. With increased access to money, they would like to depened on purchased feeds, such as green and dry feeds, or concentrates.

Close vicinity to big cities was also found to have a positive impact on the probability but a negative impact on the intensity of improved forage adoption. The probability of a household who is living within 100kms radius of big cities had 3.6% higher probability and 0.1% overall (unconditional) level of improved forage adoption but 8.4% conditional level of adoption.

The result also reveals that experience on crop technology adoption was found to have a positive impact on the probability of adopting improved forage. As compared to the households who did not have experiences in food crop technology adoption, the probability and unconditional (overall) level of improved forage adoption of households who have experience of food crop technology adoption was high by 6.3 and 1.8%, respectively. This is because, households have already developed exposure to technologies and also realized the importance from improved food crops which has also driven them to adopt new technologies such as improved forage crops.

Unavailability of forage extension service was found to have a negative impact on the probability of improved forage adoption. The probability and unconditional (overall) level of improved forage technology adoption of households with no exposure to extension services were lower by 5.8 and 1.7%, respectively, as compared to those who have exposure. This finding is consistent to the reports of past findings (Abebe *et al*., 2018; Bashir, 2014).

The results also indicated that the training and knowledge of improved forages were found to have a positive impact on improved forage technology adoption. The probabilities of households who had access to training on improved forages and those who have knowledge on improved forages were higher by 3.2 and 2.8%, respectively, as compared to their peers. The overall (unconditional) level of adoption of improved forage of households who had access to training and had knowledge of improved forage were 0.9 and 0.8%, respectively, compared to their counterparts. Past studies also reported that access to trainings had a positive impact on the probability of improved forage adoption (Abebe *et al*., 2018; Bassa, 2016).

CONCLUSION AND POLICY IMPLICATION

This study investigated determinants of the probability and intensity of improved forage technology adoption in Oromia National Regional State. The adoption rate of improved forage crop was generally low standing at only 10% of the surveyed households. These households also allocated eight percent of the land for the production of improved forage crops, which reveals the very low intensity of adoption. The low adoption rates are indications that tens of improved forage crop varieties generated and released through research have not yet been well promoted and disseminated. Not only that awareness levels were low, but also limited availability of improved forage variety seeds has contributed to the low adoption rate and intensity. The attitude is still persistent that farmers marginalized allocation of a plot of land to growth of forage crops which largely contributed to limited intensity of adoption.

The Craggit model result indicated that family size increases the probability of improved forage adoption while age of the household head increases the intensity of improved forage adoption. It also revealed that volume of milk production, land owned and diversifying feed sources were also found to have a positive impact on both the probability and intensity of improved forage adoption. Furthermore, access to extension services, relevant training, knowledge on feed, access to big cities and experience on food crop adoption were found have positive impacts on the probability of improved forage adoption. Therefore, policies that target to improve sustainable knowledge and skills of family labor, experience sharing between older and younger farmers, relevant training and better infrastructure would have a positive impact on improved forage adoption. Qualitative analysis has also suggested increased availability of improved forage seeds at reasonable costs. Awareness should be raised further to change attitude of the farmers and help them allocate a plot of land for the growth of forage crops. Since technology adoption is a dynamic phenomenon, this paper suggests conducting nationwide research on improved forage adoption trends and investigating impact of adoption on farmers' wellbeing as a future research direction.

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Adoption Probability and Intensity Determinants of Crossbred Cows Technologies in Oromia National Regional State

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ABSTRACT

Modern dairy production technologies dated back to 1950s in Ethiopia. Efforts have been made by governmental and non-governmental organizations to expand the use of crossbred cows to boost yield. However, adequate empirical information on adoption of crossbred cows in Ethiopia is lacking. This study investigated the determinants of crossbred cows adoption in Oromia National Regional State using large dataset collected from eight zones. Multistage sampling procedure was used to select the study zones, districts, kebeles and households. Using a standard formula to determine sample size, a total of 1630 samples were selected using systematic random sampling technique. The data collection procedure was implemented using a structured questionnaire designed to collect better quality data. Both descriptive and econometric models were used to analyze the data. Heckman's two-steps selection model was used to investigate the determinants of adoption probability in the first stage and determinants of adoption intensity (number of crossbred cows) in the second stage. Result shows that the adoption level of crossbred cows in Oromia Region was 28%. The probability of adoption was positively influenced by education and age of household head, grazing, perceived feed cost, knowledge on improved feed, milk selling experience, and milk market distance but negatively influenced by price of crossbred cows. The intensity of adoption was positively influenced by farm size, dairy related training, milk production and experience in milk selling, but negatively influenced by gender (male) and age of household head, perceived high price and unavailability of crossbred cows, high feed cost and distance from big cities. Therefore, socio-demographic, institutional and dairy related attributes should be taken into consideration in designing policies that target crossbred dairy cow expansion in Oromia and other regions that share similar characteristics of dairy development with Oromia. Formal heifer rearing centers should also be established and strengthened not only in Oromia but also other regions of the country to ensure adequate suppliers of dairy cows as affordable prices.

Keywords: crossbred cows, Heckman two-steps, adoption

INTRODUCTION

Introduction of modern dairy production in Ethiopia dated back to 1950s which started by importing 300 exotic cows (Staal and Shapiro, 1996). Since then, various research and developmental activities such as generating and disseminating crossbred heifers along with improved feed, management and husbandry practices were implemented for smallholders (Ahmed, 2004). Starting from 1974, the research approach changed to upgrading the local indigenous cows, especially boran breed by Ethiopian Institute of Agricultural Research (EIAR) using semen from Holstein Friesian bull to obtain 50% crossbred heifers (Gojam *et al*., 2017). Considering the social and economic context of smallholder farmers, the exotic blood level of crossbred cows was set at affordable level of 50% (Kebede, 1992; Shapiro *et al*., 2015). On the other hand, up to 62.5% of exotic blood level of crossbred cows was recommended for urban and peri-urban market oriented dairy producers (Shapiro *et al*., 2015).

The reason for maintaining this level of exotic blood was mainly to ensure adaptability and create affordable management levels for smallholder farmers. According to the research results of Kebede (1992), crossbred dairy cows with higher levels of exotic blood are not able to express their potential productivity with minimum management levels provided by smallholder farmers. This was the reason why research fixed manageable and affordable level of exotic blood of crossbred cows for smallholder farming and production settings.

With an objective of supplying crossbred heifers in different parts of the country, parastatal ranches such as Chilalo Agricultural Development Unit (CADU) which was part of the Arsi Rural Development Unit (ARDU), Wolaita Agricultural Development Unit (WADU), Abernossa ranch, and Gobe ranch were established in different parts of the country in the 1970-80s (Haile *et al*., 2011; MoA, 1986). In addition, with the aim of conserving indigenous breeds of Fogera, Andassa and Metekel ranches, and to conserve the Begait indigenous breeds, Humera ranch were established under the ministry of agriculture (MoA) in the northern and north western parts of the country. Currently, most of the influential farms including Abernossa and Gobe were privatized whereas Andassa was included under the regional research system (Alemneh, 2015), Wolaita Sodo state farm is currently running under regional government (Lemma *et al*., 2010), Metekel and Humera are still under the MoA ownership. Most of the privatized dairy farms have shifted to other businesses and no longer serve as heifer multiplication center. This made access of improved heifers difficult.

Despite the breeding improvement efforts made by the government, the proportion of improved breed of female cattle is only 2.5%, of which 2.1 and 0.4% are crossbred and exotic breeds, respectively (CSA, 2020). This can be partly attributed to the policy constraints in dairy sector (Ergano *et al*., 2015) and weak livestock extension system (MoA and ILRI, 2013).

Dairy production technologies developed and generated through research were promoted and disseminated to smallholder farmers through various routes of technology transfers including technology verification, demonstration of proven technologies, popularization of selected technologies, providing tailor-made trainings, experience sharing visits and field days, preparation and dissemination of production manuals, fliers and pamphlets (Kuma *et al*., 2006; Abebe and Ponnusamy, 2015). Various programs have also been striving to enhance dairy technology dissemination and use through incorporating in the national development initiatives, such as the growth and transformation plans of the country (NPC, 2016).

Despite several efforts made to modernize the dairy sector, there is no adequate information on the rate and intensity of adoption of dairy production technologies. Public, private and non-governmental organizations have made investments over years in the generation, dissemination and promotion of dairy production technologies. However, these technologies are not impacting the dairy sector to the level expected. To help design appropriate policy, institutional, research and developmental measures, there is a strong need to generate information on the status and intensity of adoption of dairy production technologies. Apart from patchy and inadequate availability of information, past studies conducted in Ethiopia have methodological limitations. The studies conducted on crossbred dairy adoption by Asres *et al*. (2012), Gezie *et al*. (2014), Fita *et al*. (2012), Mekonnen *et al*. (2010) and Tadese (2020) explored the factors affecting the probability of adoption by using either a binary logit, probit or correlation between factors and descriptive analysis. The binary logit and probit analyses, however, can only analyze the probability of adoption without consideration of the intensity of adoption.

Even though the work of Gezie *et al*. (2014) has applied Heckman's selection model to understand the factors affecting adoption probability and intensity of crossbred dairy cows, the methodology used to select the sample rarely fits for adoption study. The authors selected 192 adopters and 192 non-adopter sample households purposively, the methodology which fails to determine the actual adoption rate. To determine the adoption rate of a technology, the sample should be drawn randomly out of the identified sampling frame. The current study adds to the existing dairy adoption literature in three ways: First, it generates up-to-date information on the status of adoption rate and intensity along with determining factors which would help policy makers, private sectors and development practitioners make informed decisions. Second, it draws sample households randomly from the sampling frame of households who own either local or crossbred cows or both. This study also draws relatively large size of sample covering eight zones, 16 districts and 32 kebeles of Oromia National Regional State. Third, Heckman's two step econometric model which is appropriate to analyze factors affecting both the probability and intensity of adoption was engaged. Apart from this, the model takes care of the sample selection problem. The study also fills the gaps of earlier studies with the objective of investigating factors affecting the probability and intensity of adoption of crossbred cows technology.

METHODOLOGY

The Study Area

Multistage sampling technique was adopted to select the region, zones, woredas and kebeles. The study was conducted in Oromia National Regional State which has over 24 million cattle, accounting for 41% of cattle population in Ethiopia (CSA, 2015). Eight zones that are believed to represent the region in dairy production were selected for the study including North Shewa, West Shewa, South West Shewa, East Shewa, West Hararghe, Arsi, Bale and West Arsi. Two districts were again selected from each of the zones based on representativeness of the zones in dairy production, making a total of 16 districts embraced in the study. From each of the districts, two kebeles were selected again based on representativeness in dairy production practices and this makes a total of 32 kebeles.

Data Collection Approaches

The required dataset and information were collected by employing stages of standard data collection methodologies. In the first stage, extensive desk review was made from electronic and print media including published and unpublished materials. Information obtained from desk reviews has helped to design survey instruments, such as checklists and structured questionnaire. In the second stage, qualitative information was collected on specific parameters through qualitative techniques, such as focus group discussions and key informant interviews. Information collected through this technique helped to describe and narrate quantitative findings. The third stage was devoted to collection of quantifiable data through quantitative survey approaches. This stage was fundamental to collect concrete and measurable data from randomly selected households using a structured and pre-tested questionnaire.

Sampling Frame and Sample Selection Techniques

The sampling frame of the study was the population of households who owned cows either local or crossbred. The complete list of households from where samples were drawn randomly was obtained from records of Office of Agriculture. After securing the list, data was collected on the cow ownership status of each of the households along with kebele and village representatives. With this process, the sampling frame of the population of households who own cows was established. Out of this sampling frame, the sample of households was drawn randomly using systematic probabilistic sampling procedure. To obtain a representative sample size for the study, the sample size determination formula by Kothari (2004) was used:

$$N = \frac{Z^2pq}{e^2} = \frac{(1.96)^2\ (0.5)(0.5)}{(0.025)^2} = 1537 \qquad (1)$$

Where N is the sample size needed, Z is the inverse of the standard cumulative distribution that corresponds to the level of confidence, e is the desired level of precision, p is the estimated proportion of an attribute that is present in the population, and q = 1-p. The value of Z is found from the statistical table which contains the area under the normal curve of 95% confidence level. In the determination of sample size, setting the value of p=0.5 and hence q=0.5 yields the maximum optimum sample size while any other combination of the values of p and q yields less sample size using the Kothari formula. Therefore, using 0.5 for the values of p and q and e =0.025, the Kothari formula gives a total of 1537 samples to sufficiently represent the population in the selected study areas assuming a 95% confidence level and ±5% precision. However, assuming a response rate of 94%, additional 93 samples were added to have a total of 1630 samples (Table 1).

Table 1. Sample size selected from each of the study zones in Oromia region

Zones	Male	Female	Overall
North Shewa	167	57	224
West Shewa	175	60	235
South West Shewa	155	42	197
Arsi	130	42	172
Bale	140	60	200
West Arsi	138	61	199
East Shewa	140	58	198
West Hararghe	125	80	205
Overall average	1170	460	1630

Theoretical Framework and Analytical Model

This study was theoretically framed on the random utility theory (McFadden, 1974) with a bounded rationality framework. The original random utility model assumes that a decision maker (dairy producer in this case) is rational which is also termed as 'an economic man' with perfect information to make a decision that gives him/her maximum utility. However, these assumptions are criticized arguing that human beings are limited with cognitive capacity, information asymmetry and limited time availability to make a decision to reach global maximum utility (Simon, 1955). As a result, there is an increasing trend to shift from rationality assumption to bounded rationality theory developed by Simon (1955). Based on this theory, a decision maker cannot make utility maximizing decision but a nearly optimal decision that is sufficient to compare alternatives (Simon, 1955).

To put this theory in analytical form, an individual dairy producer, i, who has two options either to adopt or not to adopt crossbred cow/heifer, chooses option one say, j, if and only if the expected utility (profit or milk yield), U_{ij} derived from adopting crossbred, is greater than the expected utility say, U_{ik} that can be obtained from not adopting, k, in the choice set. In the bounded rationality assumption, the utility, U_{ij} was obtained not at profit maximizing point but sufficient to choose the best alternative. However, the utility is not directly observed while only the action of the decision-maker is observed through the choice he/she made (adopt/not adopt). According to Greene (2012), the linear random utility model for the two choices can be specified as:

$$U_{ij} = \beta_j' X_j + \varepsilon_j \text{ and } U_{ik} = \beta_k' X_k + \varepsilon_k \qquad \forall j \neq k \tag{2}$$

Where β_j and β_k are vectors of parameters to be estimated, ε_j and ε_k are the error terms assumed to be independently and identically distributed, and X_j and X_k are vectors of explanatory variables that affect the perceived utility obtained by adopting crossbred cow j and not adopting k, respectively.

The perceived utility for the i^{th} dairy farmer obtained from adopting crossbred cow, j is greater than the utility from not adopting the option k which is represented as:

$$U_{ij}(\beta_j' X_j + \varepsilon_j) > U_{ik}(\beta_k' X_k + \varepsilon_k), \qquad \forall j \neq k \tag{3}$$

Assume that Y is the decision to adopt j so that Y takes the value of 1 if j is chosen and 0 otherwise, the probability that a dairy farmer adopts crossbred cow conditional on X can be expressed as:

$$\begin{aligned}(Y = 1|X) &= P\big(U_{ij} > U_{ik}\big) \\ &= P(\beta_j' X_i + \varepsilon_j - \beta_k' X_i - \varepsilon_k > 0|X) \\ &= \mathrm{P}(\beta_j' \mathrm{X}_i - \beta_k' \mathrm{X}_i + \varepsilon_j - \varepsilon_k > 0|\mathrm{X}) \\ &= P(\beta^* X_i + \varepsilon^* > 0|X) = F(\beta^* X_i)\end{aligned} \tag{4}$$

where P is a probability function, U_{ij}, U_{ik} and X_{ik} are as defined above, $\varepsilon^* = \varepsilon_j - \varepsilon_k$ is a random error term, $\beta^* = \beta_j' - \beta_k'$ is a vector of unknown parameters to be estimated and can be interpreted as the net influence of the vector of explanatory variables affecting adoption, and $F(\beta^* X_i)$ is the cumulative distribution function of ε^* evaluated at $\beta^* X_i$. The distribution of F depends on the distribution of ε^*.

Analytical Model

Dairy producing farmers make two types of decisions in the crossbred cows adoption process. First, they make a decision on whether or not to participate in adopting crossbred cows. Depending on their first decision, those who decided to participate make the second decision on the number of crossbred cows to hold. Potential empirical models to handle such kinds of decision are Tobit (Tobin, 1958), Heckman two-stage (Heckman, 1979) and

Craggit double hurdle (Cragg, 1971). However, the Tobit model is criticized for two shortcomings. First, it cannot separate the participation and intensity of participation decisions and assumes factors affecting participation also affect the intensity decision in the same way. However, these decisions are separate in reality and participation and intensity can be influenced either by the same factors or not with different direction and magnitude of influence. Second, it assumes the zero values in the intensity equation as a corner solution. Nevertheless, the zero value of the intensity of participation equation may not be necessarily the corner solution but can be due to a discrete choice of not to participate in the adoption decision. Therefore, Heckman two-stage and Craggit double hurdle models are the two better alternatives of the Tobit model.

The difference between the Heckman and the Craggit double hurdle models is that the former assumes there is no zero observation in the dependent variable of the second stage once the first stage is passed whereas the later still considers that there might be a possibility of zero observation. In this study, once the dairy farmers decided to participate in adopting the crossbred cows, there is no possibility that the number of crossbred cows adopted can be zero. That is, as the number of cows cannot be a decimal number, there is no possibility that it can be rounded to zero. Another difference between the two is that the Heckman two stage model assumes the dependence of the hurdles whereas the Craggit double hurdle model assumes the independence of the hurdles (Rufino, 2016). If this holds true, the Heckman is better than Craggit double hurdle model for it corrects the sample selectivity bias.

Rufino (2016) also suggested the way to undertake the empirical comparison of the Craggit and the Heckman two stage models by evaluating the phenomenon of dependence/independence of the hurdles. According to Rufino (2016), the likelihood-ratio test reported at the bottom of the Heckman two stage model output is an equivalent test for Ho: $\rho = 0$. It is computationally the comparison of the joint likelihood of an independent probit model for the selection equation (first hurdle) and a truncated regression model of the intensity equation (second hurdle). If a p-value is less than 0.05, the use of Heckman sample selection model instead of the Craggit model is justifiable.

Heckman's two-steps selection model was used on conditions where there is selectivity bias especially for dependent variables. Therefore, Heckman model was employed here to correct for selectivity bias. Selection bias problems are endemic to applied econometric problems, which make Heckman's original technique and subsequent refinements by both himself and others, indispensable to applied econometricians. Heckman's sample selection model is based on two latent dependent variable models and has developed a two steps estimation procedures model that corrects for sample selectivity bias (Heckman, 1979). Moreover, Heckman's two steps estimation procedures are appropriate in that there are two decisions involved, such as participation in adoption of crossbred cows and the intensity of adoption. The first step of Heckman two steps model, 'the participation equation', attempts to capture factors affecting participation decision.

The selectivity term called 'inverse Mills ratio' (which is added to the second step outcome equation that explains factors affecting the level or intensity) is constructed from the first equation. The inverse Mill's ratio is a variable for controlling bias due to sample selection (Heckman, 1979). The second step involves the Mills ratio to the intensity (level of participation) equation and estimating the equation using Ordinary Least Square (OLS). If the coefficient of the mill's ratio (lambda) is significant, then the hypothesis of the unobserved selection bias is confirmed. Moreover, with the inclusion of extra term (Mill's ratio), the coefficient in the second step selectivity corrected equation is unbiased (Zaman, 2001).

Specification of the Heckman two steps procedures, which is written in terms of the probability of participation and intensity, is:

The participation/the binary probit equation

$$Y_{1i} = X_{1i}\beta_1 + U_{1i} \qquad U_{1i} \sim N(0, 1) \tag{5}$$

$$Y^*=1 \text{ if } Y_{1i} > 0 \tag{5.1}$$

$$Y^*=0 \text{ if } Y_{1i} \leq 0 \tag{5.2}$$

Where Y_{1i} is the latent dependent variable which is not observed,

X_{1i} is vectors that are assumed to affect the probability of participation,

β_1 is vectors of unknown parameter in the participation equation, and

U_{1i} are residuals that are independently and normally distributed with zero mean and constant variance

The observation equation/the intensity equation

$$Y_{2i} = X_{2i}\beta_2 + U_{2i} \qquad U_{2i} \sim N(0, 1) \tag{6}$$

Y_{2i} is observed if and only if $Y^* = 1$. The variance of U_{1i} is normalized to one because only Y^*, not Y_{1i} is observed. The error terms U_{1i} and U_{2i} are assumed to be bivariate, normally distributed with correlation coefficient ρ, β_1 and β_2 are the parameter vectors.

Y_{2i} is regressed on explanatory variables, X_{2i}, and the vector of inverse Mill's ratio (λ_i) from the selection equation by Ordinary Least Square (OLS).

Where, Y_{2i} is the observed dependent variable

X_{2i} is factors assumed to affect intensity equation

β_2 is vector of unknown parameter in the intensity equation

U_{2i} is residuals in the intensity equation that are independently and normally distributed with mean zero and constant variance.

$$\lambda_i = \frac{f(XB)}{1 - F(XB)} \tag{7}$$

f ($X\beta$) is density function and 1- F ($X\beta$) is distribution function.

Hypothesis and Definition of Variables

Several studies have often been considering household and farm characteristics, attributes of the technologies, institutional factors such as access to markets, information, credit and extension services. Regarding the dairy technology adoption, previous findings indicated that household background such as age (Gezie *et al*., 2014; Quddus, 2012), education (Asres *et al*., 2012, Fita *et al*., 2012; Mekonnen *et al*., 2010; Quddus, 2012), gender (Tadese, 2020), and family size (Gezie *et al*., 2014; Mekonnen *et al*., 2010) were the key factors included in the model for affecting dairy technology adoption.

Variables such as farm size (Gezie *et al*., 2014), income (Gezie *et al*., 2014; Quddus, 2012), credit (Quddus, 2012), extension services (Gezie *et al*., 2014; Quddus, 2012; Tadese, 2020), training (Gezie *et al*., 2014; Fita *et al*., 2012), cooperative membership (Tadese, 2020), distance to market (Mekonnen *et al.*, 2010), experience in dairy farming (Fita *et al*., 2012), availability of source of crossbred heifers (Gezie *et al*., 2014), and other context specific variables were also reported to be the determinant factors of dairy technology adoption. Based on economic theories and past findings, the hypothesized explanatory variables along with their expected signs are presented in Table 2.

Table 2. Variables hypothesized to influence adoption of crossbred cows

Variable code	Description	Values	Expected sign
Age of HH	Age of household head	years	-/+
Education of HH	Elementary, secondary and above	1=yes, 0=no	+
Family size	Number of family members	number	-/+
Household type	Gender of household head	1=male	-/+
Farm size	Total area of land operated	Hectare (ha)	+
Income	Total household income	Birr	+
Crossbred price	Perceived price of crossbred cows	1=expensive	-
No source cows	No source of crossbred cows	1=Yes	-
Feed cost	Perceived feed cost is expensive	1=Yes	-
Source of feed	Main source of feed is grazing	1=Yes	+
Improved feed knowledge	Household head's knowledge on improved feeding practices	1=Yes	+
Trainings	Trainings received on dairy	1=Yes	+
Credit	Access to credit services for feed and crossbred cows purchase	1=Yes	+
Extension	Access to extension services on improved dairy management	1=Yes	+
Member-coops	Member of dairy cooperatives	1=Yes	+
Milk production	Quantity of cow milk produced	Liters	+
Sale experience	Has milk selling experience	1=Yes	+
Market distance	Distance to milk selling center	km	-
Proximity to big cities	Proximity to big consumer centers, (within 100km radius)	1=Yes	+

Note: HH refers to household head

RESULTS AND DISCUSSION

Descriptive results

Household characteristics

Tables 3 and 4 present descriptions of continuous and discrete variables of the sample households, respectively. The average age of adopters and non-adopters of crossbred cows was 44 and 42 years, respectively, with a significant mean difference between them. Similarly, the average family size of adopters and non-adopters was 7.2 and 6.8 persons, respectively, with a significant mean difference. Age of the household head is believed to be associated with farming experiences which is hypothesized to have either positive or negative influences on the adoption of technologies. Assuming that the household heads started farming at their ages of 20 years, they have accumulated more than 20 years of faming experiences. Family size is also an essential resource for farming households because, farming activities mainly depend on family labor for operations related to livestock management, such as feeding, feed collection, herding, milking and cleaning.

Educational level and sex of the household head are also important demographic factors for crossbred cows adoption process. In this study, 85% of the overall sample households was headed by male with no significant difference between the adopters and non-adopters. Regarding educational status, 44.2 and 27.7% of the overall sample households attended elementary and above levels, respectively. While there is no significant difference between the elementary level of education for adopter and non-adopter sample households, the proportion of adopters above elementary levels was significantly higher for adopters than non-adopters. The results also indicated that the proportion of households with access to dairy related trainings, milk selling experiences and knowledge of improved feeding practices was significantly higher for adopters than non-adopters.

Farm and economic characteristics

The average farm size, milk production per day and annual income of adopter households were significantly higher than non-adopters (Table 3). Land is a crucial input to adopt crossbred cows for it is used for grazing, producing improved forages/hay and staple crops that in turn help to obtain crop residue which is one of the essential animal feeds in Ethiopia. Household income and milk production are also vital to expand the adoption of crossbred cows as they can be used to purchase the required inputs for dairy production.

As the findings indicate, the proportion of households who reported grazing as the main source of feed was significantly higher for adopters (94%) than non-adopters (88%). In the rural setting, grazing is a vital source of feed for dairy production. Moreover, dairy producers depend on purchased feed, especially concentrate feeds, to boost milk yield. The major concern of households on purchased feeds is the cost which they noticed it to be not only high but also increasing over time. As witnessed in this study, the proportion of households who perceived that feed cost is expensive was significantly higher for adopters (78.5%) than non-adopters (71%) (Table 4). It was also revealed that the ever-increasing feed cost could affect further adoption of dairy technologies and productivity.

Table 3. Mean difference of continuous variables between adopters and non-adopters of crossbred cows

Variables	Adopters (n=460)	Non-adopters (n=1170)	Total sample (n=1630)	t-test
Age of HH head*	44.3 (13.0)	42.1 (12.6)	42.7 (12.8)	3.2***
Family size	7.2 (3.3)	6.8 (2.9)	6.9 (3.0)	2.5***
Land size	3.1 (2.6)	2.0 (1.8)	2.3 (2.1)	9.8***
Milk production	7.7 (7.3)	0.7 (2.2)	2.7 (5.3)	29.6***
Income (1000ETB)	34.9 (58.9)	23.0 (32.5)	26.4 (41.9)	5.2***
Distance to market	2.3 (2.5)	1.7 (3.2)	1.8 (3.0)	3.4***

*HH=Household Head, Figures in parentheses indicate standard deviations
*** means significant at 1% level of significance.

Access to sources and affordability of crossbred cows

In the context of Ethiopia, sources of crossbred heifers/cows is one of the fundamental factors affecting adoption of crossbred cows technologies. As presented in Table 4, 24% of non-adopters reported unavailability of sources of crossbred cows/heifers. While the supply of crossbred cows is limited on one side, the demand is growing on the other. This has consequently contributed to the high price which is apparently unaffordable especially by smallholder farmers. This was witnessed by 49% of non-adopters who reported the expensive purchase price of crossbred cows/heifers while this proportion was 12% for adopters. These results suggest that improving the sources of crossbred heifers/cows at affordable price would motivate the non-adopters to adopt crossbred cows technologies. Adopters would also increase the number of crossbred cows/heifers once they find sustainable sources at affordable prices.

Institutional characteristics and market access

Increased access to credit and extension services, membership in dairy cooperatives, milk market and close proximity to consumers in big cities are believed to be contributing factors for the adoption of improved dairy technologies. The findings revealed that the average proportion of overall sample households who had access to credit services for dairy production was low (6.6%) with a significant difference between adopters (8.7%) and non-adopters (6%). However, 45% of the overall sample households on average had access to dairy related extension services with statistically significant differences between adopters (54%) and non-adopters (41%).

Membership in dairy cooperative was also another crucial variable affecting adoption of dairy production technologies. Cooperatives usually play dual roles of input supply for dairy production and source of market purchasing milk and other dairy products from households. According to the findings, less than 10% of the overall sample households were members of dairy cooperatives with a statistically significant differences between adopters (17%) and non-adopters (4%). Encouraging the farmers to be members of dairy cooperatives is believed to be helpful to enhance adoption of dairy production technologies.

Overall adoption rates and intensity of adoption of crossbred cows

The overall adoption rate of crossbred cows in Oromia National Regional State was 28% (Table 5). Among the study zones, crossbred cows were most adopted in North Shewa zone (74%) followed by Arsi (51%) and Bale (33%) zones. In contrast, West Hararghe was the least adopter of crossbred cows (3%) among all the study zones. The reason for higher adoption in North Shewa, Arsi, and Bale zones are due to the fact that dairy development efforts by Addis Ababa dairy development project for the North Shewa and CADA/ARDU, Gode ranch for the Arsi and Bale zones.

In the context of this study, intensity of crossbred cows adoption is defined as the number of crossbred cows owned by the sample households. The findings revealed that the adopters owned nearly two (1.78) crossbred cows on average. It was also noted that there was significant variation among the study zones with the highest intensity of adoption in North Shewa zone (2.02) followed by Bale (1.89) and Arsi (1.76) zones. On the contrary, adoption intensity was the least in Hararghe and East Shewa zones where the adopters owned 1.29 crossbred cows each on average. This was because of the fact that most of the dairy development programs and projects have been implemented in the Selale (North Shewa zone), Arsi and Bale areas since long time ago.

Determinants of the adoption of crossbred cows

In view of the nature of dataset and sampling procedures, Heckman's two-steps selection model was employed to take care of sample selection bias for dependent variable. The first step of Heckman procedure captures factors affecting participation decisions in the adoption of crossbred cows while the second step explains factors affecting the intensity of adoption. The intensity of adoption was attributed to the number of crossbred cows owned by adopters. The mills ratio or lambda of the model reveals a statistically significant value ($P<0.001$). In addition, LR test of independence of the two equations is 5.65 ($P=0.0175$) implying the assumption of Craggit model which states the independence of the two hurdles was rejected but the dependence assumption of Heckman was not rejected. Both the mills ratio and LR test value implied appropriateness of the choice of Heckman model for the analysis.

Table 4. Percentage difference between adopters and non-adopters of crossbred cows (discrete variables)

	Adopter (n=460)		Non-adopter (n=1170)		Overall (N=1630)		Chi2 value
	Freq.	%	Freq.	%	Freq.	%	
Elementary education (Yes=1)	210	45.7	510	43.6	720	44.2	0.57
Above elementary education (Yes=1)	148	32.2	304	26.0	452	27.7	6.3**
Household type (Male=1)	387	84.1	995	85.0	1382	84.8	0.21
Trainings received on improved crossbred cows (Yes=1)	213	46.3	336	28.7	549	33.7	45.7***
Has knowledge of improved feed practices (Yes=1)	229	49.8	521	44.5	750	46.0	3.7*
Milk selling experience (Yes=1)	286	62.2	101	8.6	387	23.7	522.8***
Main feed source is grazing (Yes=1)	430	93.7	1022	87.7	1452	89.4	12.6***
Feed cost is expensive (Yes=1)	361	78.5	835	71.4	1196	73.4	8.5***
Perceived source of crossbred cows (Not available=1)	2	0.90	269	24.3	271	20.4	62.2***
Perceived price of crossbred cows (Expensive=1)	26	11.8	518	46.9	544	41.0	93.8***
Dairy related credit (Yes=1)	40	8.7	70	6.0	110	6.6	3.9**
Dairy extension (Yes=1)	249	54.1	484	41.4	733	45.0	21.7***
Member of dairy coops (Yes=1)	79	17.2	46	3.9	125	7.7	81.8***

Table 5. Adoption rate and intensity of crossbred cows in the study zones of Oromia Region

The study zones	N	Adoption rate		Adoption intensity
		Freq.	%	Mean number of crossbred cows
North Shewa	224	165	73.66	2.02 (1.26)
West Shewa	235	37	15.74	1.54 (0.87)
South West Shewa	197	21	10.66	1.48 (0.75)
Arsi	172	87	50.58	1.76 (0.95)
Bale	200	65	32.50	1.89 (1.08)
West Arsi	199	50	25.13	1.56 (0.95)
East Shewa	198	28	14.14	1.29 (0.6)
West Hararghe	205	7	3.41	1.29 (0.49)
Total	1630	460	28.22	1.78 (1.07)
		X^2=403.23, df=7, P<0.001		F=3.23, df=7, P<0.01

Note: Figures in parentheses indicate standard deviation, Freq.=frequency

According to the Heckman two-steps analysis results illustrated in Table 6, the coefficient estimates for the factors affecting participation of households in the adoption of crossbred cows were provided along with marginal probabilities while the intensity of crossbred cows adoption has been provided along with corresponding marginal effects. In both cases, most of the coefficient estimates are statistically significant with the expected sign. The Wald Chi-square test for the Heckman model was highly significant (P<0.001) confirming a strong explanatory power while the significant value of mill's ratio confirms the appropriateness of using Heckman's two-steps model due to the presence of selectivity bias.

It was hypothesized that the level of education of the household head positively contributes to adoption of crossbred cows and the findings have also supported this. Both elementary and junior secondary levels of education for the household head have positively and significantly (P<0.001) influenced the likelihood of adoption of crossbred cows. The likelihood of owning crossbred cows would be higher by 13.3% for a household with primary level of education while it is 18% for the household with junior level of education. Access to education contributes for increased knowledge and informed decision making. Consequently, enhancing educational access to households is believed to enhance adoption of crossbred cows technologies. This result is in line with a number of previous findings which reported a positive association between educational level and dairy technology adoption (Asres *et al.*, 2012, Fita *et al.*, 2012; Mekonnen *et al.*, 2010; Quddus, 2012). It was, however, noted that education did not have significant influence on the intensity of adoption. This might be because, once the household is an adopter, the number of crossbred cows to be purchased is not determined by the level of education, but rather by some other factors such as price and economic capacity.

The findings also indicated that male headed households had high probability of adoption but negatively associated with the intensity equation. Male headed households perceived that keeping increased numbers of dairy cows would demand more time and affect other farming activities, such as crop production. For female headed households, the probability of adopting crossbred cows was lower by 17.8% while the intensity of owning crossbred cows was higher by 3.7% as compared to male headed households. This is mainly because crossbred cows are often herded around homesteads where women are the ones who have close attachments to look after and manage. Similar findings on the negative relationship between male headed households and the intensity of dairy technology adoption were also reported by Tadese (2020) in Ethiopia.

Age of the household head was observed to have a positive association with the probability of adoption of crossbred cows, but negative association with the adoption intensity. The positive association between age and improved dairy technology adoption was also observed by Quddus (2012) in Pakistan. As the age of the household head increases by a year the probability of adoption increased by 0.8% while the number of crossbred cows to be owned decreased by 0.2%. This might be because of labor shortage to manage more crossbred cows at the later ages. Even though farming households often depend on family labor, the family size declines at later ages of the household head due to engagement of youths and girls in marriage, employment, and various other issues. Moreover, the income of the household declines at later ages due to sharing away of part of the properties and assets for adult children to support them start their own life. The adoption equation disagrees while the intensity equation agrees with the findings of Gezie *et al.* (2014) who reported that age is negatively associated with both the likelihood and intensity of adoption of improved dairy technologies in Ethiopia.

Farm size was found to have insignificant effect on the probability of adoption of crossbred cows but a significant and positive effect on the intensity equation. According to the marginal effect, a one hectare increase in farmland would enhance the number of crossbred cows to be owned by 1.2%. This is because, the farmers are supposed to allocate a certain proportion of land for grazing and production of improved forage crops. Moreover, a farmer with large farm size can produce more crop residues that are still essential sources of animal feed in rural areas.

Table 6. Parameter estimates of the Heckman Two-step model.

	Adoption equation		Intensity equation	
	Coef. (SE)	ME	Coef. (SE)	ME
Elementary level	0.14*** (0.031)	0.133	0.12 (0.16)	0.009
Junior/secondary level	0.18*** (0.031)	0.180	-0.072 (0.17)	-0.005
Household type	0.16*** (0.03)	0.178	-0.4** (0.16)	-0.037
Age of household head	0.01*** (0.001)	0.008	-0.03*** (0.01)	-0.002
Family size	0.002 (0.003)	0.003	-0.004 (0.02)	-0.000
Farm size	-0.001 (0.005)	-0.010	0.17*** (0.03)	0.012
High price of crossbreds	-0.053* (0.031)	-0.017	-0.69*** (0.16)	-0.045
No crossbred cow source	-0.09 (0.11)	0.048	-2.59*** (0.55)	-0.092
Participation in trainings	0.017 (0.02)	0.004	0.22* (0.13)	0.019
Grazing is main feed	0.3*** (0.04)	0.286	0.035 (0.18)	0.002
High feed cost	0.035* (0.021)	0.049	-0.26** (0.13)	-0.021
Improve feed knowledge	0.04** (0.02)	0.034	0.19 (0.12)	0.013
Access to credit services	-0.013 (0.03)	-0.030	0.33 (0.23)	0.031
Access to extension	0.03 (0.02)	0.037	-0.09 (0.13)	-0.006
Member of dairy coops.	-0.01 (0.03)	-0.020	0.24 (0.22)	0.021
Household income	0.001 (0.001)	0.000	0.001 (0.001)	-0.000
Milk production	-	-	0.2*** (0.012)	0.014
Milk selling experiences	0.057** (0.023)	0.023	0.65*** (0.15)	0.071
Distance to milk market	0.012*** (0.003)	0.012	0.002 (0.022)	0.000
Distance to Addis Ababa	0.102*** (0.04)	0.142	-0.78*** (0.19)	-0.053
Lambda			0.06** (0.02)	

Rho = 0.487, Sigma = 0.147

Number of obs.=946, Censored obs.=218, Uncensored obs. = 728

Wald chi2 (19) = 3975.6, Prob > chi2=0.000

LR test of indep. eqns. (rho = 0): chi2(1) = 5.65 Prob > chi2 = 0.0175

Mean dependent var. = 0.396, SD dependent var. = 0.86

****p<0.01, **p<0.05, *<0.1*

The results also revealed that the high price of crossbred cows had a significant negative effect on both the probability and the intensity of adopting crossbred cows. As the price of crossbred cows becomes unaffordable for smallholder farmers the likelihood and the intensity of adopting crossbred cows decrease by 1.7 and 4.5%, respectively. Unavailability of formal sources of crossbred cows/heifers had also insignificant impact on the likelihood of adopting but a significant negative impact on the intensity of adopting crossbred cows. There are almost no formal rearing centers of crossbred heifers in the country unlike the case of seeds for improved crop varieties. With persisting unavailability of crossbred cows the likelihood of having a crossbred cow decreased by

9.2%, ceteris paribus. This result is in line with the previous finding by Gezie *et al*. (2014) who observed a positive association between the availability of crossbred cows and the likelihood and intensity of adoption in Ethiopia.

Participation in training had insignificant impact on the likelihood of adoption but a significant positive impact on the intensity of crossbred dairy adoption. The marginal effect of the intensity of adoption equation indicates that households who participated in training would increase the intensity of having a crossbred cow by 1.9% as compared to those who did not get the training. This suggests that in addition to expanding formal education, arranging practical training for farmers would have a positive impact on technology adoption. This result is consistent with previous findings by Gezie *et al*. (2014) and Fita *et al*. (2012) who found a positive impact of training on dairy technology adoption in Ethiopia.

Grazing is believed to be one of the major sources of livestock feed in the farming community illustrating a highly significant ($P<0.001$) and positive association with the likelihood of adoption of crossbred cows. As the farmers strengthen the choice of grazing as the main source of feed, the likelihood of adoption of crossbred cows increased by 28.6%. Even though crossbred cows are not supposed to depend on grazing as a source of feed, farmers are still practicing it and that is one of the reasons why grazing is positively and significantly associated with the adoption of crossbred cows. However, this variable did not have a significant impact on the intensity equation which suggests that having more grazing land is not a guaranty for having more crossbred cows.

The knowledge of improved feeding practices has also imposed a significant and positive influence on the likelihood of adopting but an insignificant impact on the intensity of adopting crossbred cows. As the farmers acquire more knowledge and experience in improved feeding techniques the likelihood of adopting crossbred cows increased by 3.4%, ceteris paribus. This result is in conformity with the findings of Fita *et al*. (2012) who reported a positive association between knowledge on improved dairy husbandry practices and improved dairy technology adoption in Ethiopia.

The main product in dairy farming is milk which is meant mainly for sale. The quantity of milk produced is an important variable for those who already adopted crossbred cows and it is usually higher for the adopters than non-adopters. Hence, it was included only in the intensity equation. The result shows that the quantity of milk produced was significantly and positively associated with the intensity of crossbred cows adoption while selling experience of households was significantly and positively associated with both the likelihood and intensity of adopting crossbred cows. A liter increase in milk production would increase the number of crossbred cows by 1.4%, holding all other variables constant. Likewise, as the experience of selling milk increases by one year, the likelihood of further adoption of crossbred cow increases by 2.3% while the number of cows owned increases by 7.1%, ceteris paribus. A previous finding by Fita *et al*. (2012) has also attested that experience in dairy farming plays a positive role in dairy technology adoption in Ethiopia.

The result further shows that households who have proximity to big cities had a 14.2% higher likelihood of adoption but 5.3% less likelihood to own additional crossbred cows. The explanation for this could be dairy farming requires larger farm size for its operation, but farmers near the capital city usually keep productive but small number of dairy cows. Surprisingly, institutional variables such as access to credit and extension services, and membership in dairy cooperatives had a significant impact neither on the likelihood of adoption nor on the intensity equation although more roles are expected from such institutes to modernize the dairy sector in the country. The implication is that the government and development partners have to redesign the service provision system of these institutes to bring the intended objectives.

CONCLUSION

This paper investigated the adoption of crossbred cows in Oromia National Regional State. The adoption rate of crossbred cows in the Oromia region was 28%, which is perceived to be an encouraging progress. Various factors have positively and significanlty influenced adoption of crossbred cows. These included increased education levels, male headed households, older household heads, using of grazing as a main feed source, perception of high feed cost, knowledge of improved feed practices and milk selling experiences had a higher probability of adopting crossbred cows. On the other hand, households who perceived that the price of crossbred cows is high had less likelihood of adopting crossbred cows. Furthermore, farm size, dairy related practical training, milk production and experiences in milk selling had positive influence on the intensity of crossbred cows adoption while gender (male) and age of household head, perceived price and unavailability of crossbred cow sources, high feed cost and distance from big cities had negative impact on the intensity of adoption of crossbred cows.

The finding of this research has a nummber of policy implications. First, strengthening access to training on improved dairy is important. Dairy related trainings were observed to have a positive influence on crossbred cows adoption. Strengthening the capacity of farmers' training centers and provision of skill based trainings on improved dairy production and management practices will enhance adoption rates and intensity of improved dairy technologies. Exposing dairy farmers to experience sharing visits to successful and exemplary smallholder dairy farms would largely help to facilitate adoption of crossbred cows technologies. Preparation of an easily understandable production manuals in all aspects of dairy production in local languages will be useful to increase crossbred dairy adoption.

Second, gender focused intervention is crucial. Dairy management fundamentally requires the involvement of women for various operations, such as feeding, milking, cleaning, and health care. Despite this, the participation of women in training, experience sharing visits and other capacity-building initiatives are very limited as compared to men. Mostly men are given priority advantages in training and expereicne sharing programs. Therefore, there should be fair consideration of men and women in capacity building programs, technology promotion and demonstration initiatives. Targeting of either men or women shall depend based on the type of task they are mainly responsible for dairy management. This could be identified through a gender analysis study disaggregating the various practices and activities as managed by men, women, and youths. Based on this, it is essential to design gender-responsive programs and development initiatives that eventually contribute to the enhancement of the dairy sector.

Third, the need to have formal and reliable sources of crossbred heifers at affordable prices is important. One of the problems fundamentally recognized during the study was the unavailability of reliable sources of crossbred cows and heifers at affordable prices. There are no formal heifer rearing centers in the country as there are seed multiplication enterprises for crops. Only limited private enterprises have started the initiative of crossbred heifers rearing even though they are not still able to meet the growing demands. As a result, the farmers tend to depend on markets to acquire crossbred cows, a source where they cannot get reliable information about reproductive and production traits of the cows, such as their parity, milk yield potential, age, and other essential merits. In addition, the price of crossbred cows is very high and unaffordable for smallholder farmers. Even those households who can afford could not get crossbred cows in the required supply with known records of reproductive traits. Therefore, addressing these problems requires not only development but also policy intervention to establish heifer rearing centers at regional levels to create easy and reliable access to farmers with affordable prices. Moreover, private enterprises need to be supported and strengthened to invest in this business venture. In the short term, additional options can be taken to produce crossbred calves from local cows through effective promotion of AI and purebred bull services including synchronization techniques. All other possible options need to be exhausted to ensure a reliable supply of crossbred heifers for the farming community. Beyond policy and institutional issues, enhancing the supply of crossbred heifers also requires a serious engagement in technical back up by harnessing the state of the art of reproductive biotechnology (multiple ovulation and embryo transfer, sexed semen technology, and *in vitro* fertilization).

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Joint Adoption Patterns of Dairy Production Technologies in SNNP and Amhara National Regional States of Ethiopia

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ABSTRACT

Increased use of improved dairy technology packages could bring improvements in dairy productivity, production, household income and poverty alleviation. In spite of this, the adoption of such technologies has remained low in Ethiopia. However, empirical evidence on factors influencing joint adoption of dairy technologies remains unclear. Determinants of joint adoption of dairy production technologies were investigated using primary data collected from a sample of 1242 dairy farmers in six selected zones of SNNP and Amara National Regional States. A multivariate probit model (MVP) was used to analyze the data. The results of the study revealed that adoption rates of crossbred dairy cows and improved forages were 21 and 29%, respectively. It was also noted that 21 and 50% of the households have adopted improved concentrates and veterinary services, respectively. The findings have also figured out that only 2% of the households have adopted all four technologies of crossbred cows, concentrates, improved forages and health services as a package. Instead, adopting only two technologies was commonly experienced by 57% of the households. The MVP model results showed the existence of correlation in the adoption decision of crossbred cows, concentrates, improved forage and veterinary services. The results also revealed that farmers' adoption of technologies varied significantly and explanatory variables had heterogeneous effects on the adoption of various technologies. Ceteris paribus, the study results further revealed that education, age, family size, training, membership in a dairy cooperative, off-farm participation, dairy income, perception, gender, access to credit, extension, experience in the use of improved crop varieties and farm size had a positive and significant effect on the choice decisions of adopting dairy technologies. From the study, it can be recommended that the adoption of dairy technology packages needs to be strongly promoted through effective extension services. Apart from this, the farmers need to be advised to adopt packages of technologies to ensure maximum benefits. Establishing crossbred heifer rearing ranches and commercializing feed resources in the regions could also largely enhance the adoption of dairy technologies.

Keywords: Dairy technologies, determinants, multivariate probit model, adoption

INTRODUCTION

Ethiopia has the largest livestock inventory compared to other African countries because of diverse and favorable agroecology for livestock and dairying (Yilma *et al.*, 2011; Tegegne *et al*., 2013). The Ethiopian Central Statistical Agency (CSA) estimated the cattle population to be 60.39 million and the dairy population (dry, pregnant and milking cows) to be more than 19 million (CSA, 2018). However, the dairy subsector in the country is underdeveloped and characterized mainly by traditional subsistent smallholder production systems with a few emerging commercial dairying in urban and peri-urban areas (Kebebe *et al.,* 2017).

The dairy production system in Ethiopia is categorized into three: (1) lowland pastoral and agro-pastoral grazing system, which is the major but the most neglected dairying system; (2) highland crop-livestock mixed farming system, and (3) urban and peri-urban system (Gizaw *et al*., 2016; Mihret *et al*., 2017). Smallholder dairy production constitutes 98 percent of milk production (Mihret *et al.,* 2017) where 3.32 billion liters of milk were produced in Ethiopia in 2017 (CSA, 2018).

However, the domestic production of dairy products was far lower than the demand, because Ethiopia is increasingly importing dairy products in terms of whole dried, skimmed dried and whole condensed to fill the gaps (Bachewe *et al.*, 2017; FAOSTAT, 2019).

Currently, the rising demand for animal source foods, in general, and dairy products such as milk and butter, in particular, is due to an ever-increasing population, urbanization and better-off (Minten *et al.*, 2020). This may offer smallholder farms to sustainably engage in dairy production as a pathway out of poverty and food insecurity (Yitayih *et al.*,2016; Kebebe *et al.*, 2017) and new employment opportunity (SNV, 2008; Mihret *et al.*, 2017). Despite its huge economic contributions and opportunities for development, the productivity of the dairy sub-sector remains low in Ethiopia. This resulted in the growing shortage of dairy products and increased expenditure of hard currency by the country in importing dairy products.

A growing body of empirical evidence suggests that shortage of cross-bred cows, feeds, grazing land, farm land, poor and inadequate veterinary services and inefficiency of artificial insemination and synchronization activities are contributing to the low productivity and performance of the dairy sub-sector (Ahmed *et al*., 2004; Kebebe *et al*., 2015; Gizaw *et al*., 2016; Diro *et al.*, 2019). With the support of development partners, the government of Ethiopia has been developing and introducing several dairy production technologies for decades ago to solve the aforementioned constraints to increase dairy productivity and household income and reduce poverty. More specifically, crossbred cows, high quality feeds (concentrates and improved forages), and veterinary services were introduced to improve the performance of the dairy sub-sector since the early 1960s. Despite the efforts by the government in the dairy sub-sector, the adoption level of dairy cattle technologies has remained low (Tesfaye *et al*., 2016; Kebebe *et al*., 2017). Apart from this, Kebebe *et al*. (2017) have also reported about less than 10% adoption rate of dairy technologies among the sample households in Ethiopia. Tesfaye *et al.* (2016) have also reported adoption rates of 28% for crossbred cows and 10% for improved forage in selected zones of Oromia Region.

The adoption of dairy technologies is affected by several interlinked factors. Farmers' decision to adopt dairy technologies is influenced by a lack of comprehensive policies, an unorganized crossbreeding system, poor institutions, extension services, and socioeconomic processes (Gebremedhin *et al*., 2003; Ahmed *et al*., 2004; Lemma *et al*., 2010; Berhanu and Poulton, 2014; Kebebe *et al*., 2015; Guadu and Abebaw, 2016). Smallholder farmers' decision to adopt dairy technologies is influenced by household demographics including age, education, family size (Basunathe *et al*., 2010; Tesfaye *et al.*, 2016; Martinez-Garcia *et al*., 2016; Yitayih *et al*., 2016), farm characteristics including farm and herd size; institutions including access to extension and credit services and infrastructures including access to roads, health centers and markets (Tesfaye *et al.*, 2016; Yitayih *et al*., 2016; Kebebe *et al*., 2017). For example, family size of the household was found to influence farmers' decision to adopt dairy technologies (Abdulai *et al*., 2008; Tesfaye *et al*., 2016; Kebebe *et al*., 2017). Education of the household head was also found to influence the decision to adopt dairy technologies (Abdulai *et al*., 2008; Fita *et al*., 2012). The age of the household head was also found to influence farmers' decision to adopt dairy technologies (Abdulai *et al*. 2008; Kebebe *et al.*, 2017). It was also reported that access to extension, training and credit services influence the decision to adopt dairy technologies (Fita *et al*., 2012; Yitayih *et al*., 2016; Tadese, 2020). Likewise, farm size was found to influence farmers' decisions to adopt dairy technologies (Rahelizatovo and Gillespie, 2004).

Nonetheless, most of the above prior studies focused on single dairy technology adoption despite the fact that farmers use a bundle of dairy technologies which often compute for capital and labor. They employed single logit and probit models to discrete choice; focused on single dairy technologies such as crossbred cow, artificial insemination, forage, or health service, independently;

and also relied on a small sample that may dearth adequate variability. Considering a single technology in the adoption analysis often ignores the interdependence and endogeneity of dairy package technologies and choice decisions (Deribe and Tesfaye, 2016). Failure to recognize interdependence of dairy technology choice decisions by smallholder farmers in examining resource allocation constraints results in biased and inefficient estimates. The exception of a study by Deribe and Tesfaye (2017) investigated the determinants of dairy technologies using a multivariate probit model, and the results showed a significant correlation between technologies. However, Deribe and Tesfaye (2017) used a small sample with limited area coverage and failed to consider veterinary service as a dairy technology.

This study, therefore, differs from these existing studies in three. First, our analysis considers four important dairy technology packages including crossbred cows, concentrate feeds, improved forage and health service. Second, the study relies on a large sample (1242 dairy households) and area coverage. Three, the study uses a multivariate probit model to figure out the interdependence between the adoption decisions of dairy technology packages. Therefore, this study attempts to investigate the joint adoption of dairy technologies and factors influencing adoption decisions.

METHODOLOGY

The Study Areas

The study was conducted in Southern Nations, Nationalities and People's (SNNP) and Amhara National Regional States with cattle populations of 11.8 and 16.1 million, respectively (CSA. 2015). A total of six zones (three from each of the regions) were selected in their representativeness of dairy production practices. From SNNP, Sidama, Welayita and Guraghe zones from SNNP while Awi, West Gojam and South Gondar zones from Amhara Region were included in the study.

Data Collection Procedures

Multi-stage sampling procedure was used to select sample zones, *woredas*[1] and *kebeles*[2] to collect the required data. While three zones were selected from each of the regions, two woredas were also selected from each of the study zones based on their representativeness in dairy production practices. Two *kebeles* were in turn selected from each of the target *woredas* based on their representativeness in dairy production. In the last stage, households were selected randomly from the identified sampling frame. To collect quantitative data, a per-tested structured questionnaire was developed and loaded on CSPro software. Data was collected using Computer Assisted Personal Interview (CAPI) by well-trained enumerators. The whole data collection process was monitored by a supervisor to ensure data quality.

Sampling Frame and Sample Size Determination

The sampling frame for this study was the population of Households who owned dairy cows either zebu or crossbred. The complete list of dairy households from where samples were drawn was obtained from records of kebele level Office of Agriculture. Sample households were drawn from the established dairy holders. Out of this sampling frame, the sample households were selected randomly using a systematic probabilistic sampling technique. To determine representative sample size, the sample size determination formula by Cochran (1977) was used:

$$N_s = \frac{Z^2 * pq}{e^2} \quad (1)$$

[1] Woreda is the third administrative division of Ethiopia
[2] Kebele is the lowest administrative unit of Ethiopia

Where N_s is the required sample size, Z is the confidence level of 99% (Z=2.58), p is the estimated proportion of an attribute of interest to be responded by the population (p=50%), q= 1-p and e = 0.037 (level of precision). Thus, using the statistical values of p =0.5, q = 0.5, and e= 0.037, the Cochran formula yields a total of 1242 sample dairy households (Table 1).

Table 1. Distribution of sample households by study regions and zones

Regions	*Zones*	*Male*	*Female*	*Overall*
SNNP	Sidama	136	64	200
	Welaita	144	56	200
	Guraghe	162	38	200
Amhara	Awi	117	72	189
	West Gojam	124	107	231
	South Gondar	140	82	222
Overall total		823	419	1242

Analytical Framework

According to classical economics, farmers are presumed to be utility maximizers (McFadden, 1974). Hence, the decision to adopt dairy technologies is made when the expected utility or net profit from adopting the technology is significantly better than would be the case without the technology (Greene, 2008). The basic assumption is the decision-maker (dairy households in this case) have perfect information to make adoption decisions. However, farm households have limited information and cognitive ability to make decisions to adopt technologies, bounded rationality of Simon (2000). The utility is often a latent variable (directly unobserved), whereas farmers' technology choice is observed. To place this utility theory in analytical form, suppose, that U_j and U_k represent a farmer's expected utility for alternative choices j and k, respectively; presume also that $\mathbf{X}_i$ and $\mathbf{X}_k$ are vectors of explanatory variables that influence the expected utility of alternative technologies j and k. Following Greene (2008) the random utility model could be specified as:

$$U_{ij}^{*} = \beta_j X_{ij} + \nu_{ij} \text{ and } U_{ik}^{*} = \beta_j X_{ik} + \nu_{ik} \tag{2}$$

Where β_j and β_k are parameters to be estimated and ν_i and ν_k are unobserved vector of error terms presumed to be independently and identically distributed, that is, ν_j and ν_k = MVN (0, Ω). It follows that the expected utility for the i^th farmer from alternative j is greater than the utility from option k shown as:

$$U_{ij}^{*}\ (\beta_j X_{ij} + \nu_{ij}) > U_{ik}^{*}\ (\beta_j X_{ik} + \nu_{ik})\ , j \neq k \tag{3}$$

Assuming that D is the decision to adopt technology j where D takes the value of 1 if adopted and 0 otherwise, the probability that a dairy farmer will adopt improved dairy technologies of the j^th alternative conditional on explanatory variables (X) can be presented as:

$$P_i = \prod_{j=1}^{J} \{D_{ji} P_{ji} - (1 - D_{ji})(1 - P_{ji}\} \tag{4}$$

This can also be expressed as follows:

$$\begin{aligned} P(D = 1|X) &= P\left(u_{ij}^{*} > 0\right) \\ &= P\left(\beta_j X_{ij} + \nu_{ij} > 0|X\right) \\ &= P(\beta^{*} X_i + \nu^{*} > 0|X) = F(\beta^{*} X_i, \rho) \end{aligned}$$

With F(.) is the cumulative distribution function of ν^* evaluated at $\beta^* X_i$ and the particular parameter values of $\beta_1^*, \dots, \beta_J^*$ that maximize the J individual function.

Empirical Estimation

The simultaneous adoption of dairy technologies defers between farmers due to their unique characteristics, social and economic factors. Investigation of farmers' technology adoption decision behavior requires the use of a multivariate modeling framework to take the multiple technologies and possibilities of simultaneity of the decision-making process into account. As a result, this study adopts multivariate probit (MVP) econometric method which simultaneously models the influence of the set of explanatory variables on each of the dairy technologies by allowing error terms to be systematically correlated (Belderbos *et al.*, 2004; Deribe and Tesfaye, 2017). These correlations may either be positive (showing complementarities) or negative (substitutabilities) between dairy technology types. In this study for MVP estimation, the choice of improved dairy technologies corresponds to a binary choice (1=yes/0=no) equation. Thus, a household uses M different dairy technologies and M equations each describing a latent dependent variable that corresponds to the observed binary outcome for each dairy technology that is required to be estimated simultaneously (equation 6).

A system of simultaneous multivariate probit model was built for dairy technologies following Cappellari and Jenkins (2003) which is depicted as:

$$D_{im}^* = \beta_j X_{im} + \varepsilon_{im} \qquad (6)$$

$$D_{im} = \begin{cases} 1 \; if \; D_{im}^* > 0 \;\; and \\ 0 \quad\;\; otherwise \end{cases} \qquad \text{(j= B, C, F, V)}$$

Where $\boldsymbol{\varepsilon}_m = (\varepsilon_{iB}, \varepsilon_{iC}, \varepsilon_{iF}, \varepsilon_{iV})$ is a vector of error terms assumed to exhibit a multivariate normal distribution of mean 0 and symmetric variance-covariance matrix **Ω,** and independently and identically distributed across i (i=1,…,N) but correlated across m (m=1,…,M, J≠M) for any i, on the leading diagonal and correlations $\rho_{ij} = \rho_{ji}$ as off-diagonal elements; B, C, F and V denote crossbred dairy cows, concentrates, improved forage and veterinary services, respectively. The correlation matrix of the error terms in the four equations is depicted as:

$$\Omega = \begin{pmatrix} 1 & \rho BC & \rho BF & \rho BV \\ \boldsymbol{\rho CB} & 1 & \rho CF & \rho CV \\ \boldsymbol{\rho FB} & \boldsymbol{\rho FC} & 1 & \rho FV \\ \boldsymbol{\rho VB} & \boldsymbol{\rho VC} & \boldsymbol{\rho VF} & 1 \end{pmatrix} + (-) \qquad (7)$$

The hypothesis that this study follows is that the off-diagonal correlation coefficients are non-zero while all the cross-equation correlation coefficients are equal to zero. This hypothesis is often validated with a Wald test used to test the null hypothesis (H_0) of no correlation across equations, that is, off-diagonal coefficients are all zero (Hausman, 1978). If H_0 is rejected, it proposes that MVP models are suitable to estimate the probability of joint dairy technology adoption.

Definition of Variables and Hypotheses

Dependent variables

The study identified four dairy technologies as a dependent variable namely crossbred dairy cows, concentrate feeds, improved forage, and veterinary services (Table 1). The term crossbred dairy cow in this study refers to the improved dairy cow of any blood level of indigenous zebu crossed with either Holstein Friesians or Jersey breeds. It is modeled as a dummy variable that takes the value of one if a household adopts at least one crossbreed cow, or zero otherwise. Concentrate feed refers to the use of purchased industrial by-products such as oilseed cakes, wheat bran, molasses, a multi-nutrient block (MNB), and homemade grain by-products. This variable is modeled as a dummy variable that takes the value of one if a household adopts at least one of the concentrate feed types, or zero otherwise. Improved forage refers to the use of high-quality forage including oat vetch, elephant grass, pigeon pea, alfalfa, fodder beet, desmodium, desho grass, sesbania, and tree lucerne. The variable takes the value of one if a household adopts at least one of the improved forages mentioned above, or zero otherwise. Veterinary service refers to the use of improved health care to cure sick animals (dairy cattle). This variable is modeled as a dummy variable that takes one if a household took his/her sick dairy cattle to the nearest vet clinic and got the service, or zero otherwise.

Independent variables

Based on the literature review, the independent variables considered in modeling the adoption of dairy technology packages include sex, age, education, family size, training on improved breed management and health, credit, membership to dairy cooperative, off-farm participation, experience of improved crop varieties adoption, visits of commercial dairy farm, extension contact, perception of feed shortage, income from dairying and own land size.

Sex of the respondent is a proxy variable for resource endowments of the household to represent gender. This variable is modeled as a dummy variable and takes the value of one if the household head is male, or zero otherwise. Male farmers had more access to resources and information about technologies than their counterparts. Thus, sex of household head is expected to affect the probability of adopting dairy technologies. Age of the household head is a continuous variable measured in years. It is a proxy variable for farm experience and expected to influence the probability of adopting dairy technologies. Educational level of the household head is also a continuous variable measured in completed years. More years of education is believed to be associated with the ability to gather and utilize new information. It is hypothesized that a household with more years of education positively influences the probability of adopting dairy technologies regardless of their quality. Family size also refers to the number of family members within the economic working age groups (15-64 years). It is believed to have a profound influence on the adoption of dairy technologies as dairying is a labor-intensive activity. Accordingly, a household with a large family size is expected to influence the probability of adopting dairy technologies.

Training on improved dairy breed management such as heat detection in cows, synchronization, artificial insemination, and record keeping are expected to influence dairy adoption and performance. It is modeled as a dummy variable and takes the value of one if a household took training in one of these topics, or zero otherwise. Thus, it is hypothesized that training on breed management influences the probability of adopting dairy technologies. Training is a dummy variable that takes the value of one if a household has taken training on improved health management practices, or zero otherwise. This variable is also expected to influence the probability of adopting dairy technologies. Credit access is modeled as a dummy variable that takes the value of one if a household got credit in relation to dairying, or zero otherwise. Credit relaxes the liquidity constraints of the household to invest in dairy technologies. This variable is also expected to influence the probability of adopting dairy technologies. Membership in dairy cooperatives reflects farmers' intensity of interactions with other more experienced farmers, helping them to learn new dairy technologies. It is a dummy variable that takes one if one of the household members has participated in dairy cooperatives, or zero otherwise. Thus, this variable is expected to influence the probability of adopting dairy technologies.

Off-farm refers to the activity in which a household participated outside of his/her farm to earn supplementary income. It is modeled as a dummy variable that takes one if one of the household members participated in at least one off-farm activity, or zero otherwise. Income from off-farm activities in turn provides capital to finance dairy technologies. Thus, it is expected to influence the probability of adopting of dairy technologies. Experience refers to the number of years a household adopted improved crop varieties. It is a continuous variable and is expected to influence the probability of adopting dairy technologies. Visit refers to an official visit to commercial dairy farms in order to share or gain knowledge about improved dairy management. This variable is also expected to influence the probability of adopting dairy technologies. It is modeled as a dummy variable taking one if the farmer has participated in visits, or zero otherwise. Extension contact refers to the interaction made between extension personnel and farmer in relation to dairy production. It is a continuous variable measured in the number of frequencies of contacts made per month. It is expected to influence the probability of adopting dairy technologies.

Perception refers to the understating of farmers about feed shortage as a problem for dairying. This is a dummy variable and takes a value of one if a household has perceived feed shortage as a problem, or zero otherwise. It is expected to influence the probability of adopting dairy technologies. Income refers to the income earned annually from sale of dairy products (milk, butter and cow dung). It is a continuous variable measured in Birr and is expected to influence the probability of adopting dairy technologies. Land holding refers to the land owned by a household. It is a continuous variable measured in hectares. Land is important for investment in dairy production and hence expected to influence the probability of adopting dairy technologies. Detailed description and posited relationship with the outcome variables of these factors is presented in Table 2.

Table 2. Summary of definition and hypotheses of variables

Variable	*Description and values*	*Posited relationship*
Dependent variables		
D1 (crossbred dairy cows)	1= if the household had crossbred dairy cows, 0 otherwise	
D2 (Concentrates)	1= if the household used concentrates, 0 otherwise	
D3 (Improved forages)	1= if the household used improved forages, 0 otherwise	
D4 (Veterinary service)	1= if the household used veterinary service, 0 otherwise	
Independent variables		
Sex	1= if the household head is male, 0 otherwise	+/-
Age	Age of the household head in years	+/-
Education	Education level of the household head in completed years	+
Family size	Number of family members within working age groups (15-64)	+
Training on improved dairy	1= if the household took training, 0 otherwise	+
Training on health	1= if the household took training on improved health management practices, 0 otherwise	+
Credit	1= if the household ever got credit to strengthen his/her dairying, 0 otherwise	+
Membership	1= if one of the household members was a member of dairy cooperatives, 0 otherwise	+
Off-farm	1= if one of the household members participated in off-farm activities, 0 otherwise	+/-
Experience	Number of years a household adopted improved crop varieties	+/-
Visit	1= if the household visited a dairy farm for experience sharing, 0 otherwise	+
Extension	The frequency of extension visits performed per month in relation to dairying	+
Perception	1= if the household perceived feed shortage is a problem, 0 otherwise	-
Income	Income (revenue) from sale of dairy products Birr/year	+
Land holding	The size of land owned by the household in ha	+

RESULTS AND DISCUSSION

Results of Descriptive Analysis

Summary statistics of the 15 independent and four dependent variables used in the MVP model are presented in Table 3. The average age of farmers was 41 years with an average of 1.7 years of schooling and family size in the active working age group of three. It was also noted that 17.6 and 18% of the sample households took training on breeding and improved health management, respectively. The findings also indicate that 12, 2.2, 19, and 5% of the sample households, respectively, received credit for dairying, had membership in a dairy cooperative, participated in various off-farm activities, and visited the nearby commercial dairy farms for experience sharing. Averagely, dairy farmers in the study areas had 8.2 years of experience in adopting improved crop varieties, and the average contact days spent with the extension agent were low at 0.29 in a month. The proportion of dairy farmers who perceived feed shortage as a critical problem for dairying was 32%, and the average annual income (revenue) earned from the sale of milk, butter and cow dung was estimated at 703 Birr.

Table 3. Results of descriptive statistics

Variable	*Mean*	*Std.Dev.*	*Min.*	*Max.*
Dependent variables				
D1 (crossbred dairy cows)	0.21	0.40	0	1
D2 (Concentrates)	0.21	0.41	0	1
D3 (Improved forages)	0.29	0.45	0	1
D4 (Veterinary service)	0.50	0.50	0	1
Independent variables				
Sex	0.66	0.47	0	1
Age	41.5	13.85	18	80
Education	1.7	2.8	0	13
Family size	3	2	1	9
Training on improved dairy	0.17	0.38	0	1
Training on health	0.18	0.38	0	1
Credit	0.12	0.32	0	1
Membership	0.02	0.15	0	1
Off-farm	0.19	0.39	0	1
Experience	8.2	6.37	0	27
Visit	0.05	0.22	0	1
Extension	0.29	0.65	0	6
Perception	0.32	0.46	0	1
Income	703	2824	0	50000
Land holding	1.07	0.89	0	12

The average land holding of the household was low standing at 1.07 hectares. The variables, such as income from dairy products and land holding, were transformed into logarithms for MVP model estimation. In the study areas, 21% of the sample households in SNNP and Amhara regions have adopted crossbred cows. It was also observed that the same proportion of households (21%) have adopted concentrate feeding. The proportion of households who adopted improved forages was 29%. Apart from this, 50% of the households have experienced using improved veterinary services. Other studies, such as the ones by Tesfaye *et al.* (2016) have also reported 28% adoption rate of crossbred cows in Oromia region, while Deribe and Tesfaye (2017) and Kebebe *et al* (2017), respectively, reported 20 and 21%

adoption rate of improved forages. Kebebe *et al* (2017) and Tesfaye *et al.* (2016), respectively, have also reported 72 and 94% adoption rates of improved health services.

Dairy technology adoption patterns

In this study, adoption involves three interrelated decisions at the micro-level. First, farm households decide to choose packages of dairy technologies to adopt, and then they decide on the combination of the technologies and finally decide on how much resources to allocate to each combination of the dairy technologies.

Table 4 presents the actual and possible combinations of the four dairy technologies. It is expected to have six, four, and one combination (possible combinations indicated in the denominator) of two, three, and four dairy technologies, respectively. Subsequently, the results revealed that six, four, and one combination (actual combination indicated in the numerator) of two, three, and four dairy technologies, respectively, used by smallholder farmers with different proportion. Complementary technology bundles here are composed of at least two technologies. Most (57%) of the sample farmers used two dairy technologies while only 2% of the sample households used four dairy technology bundles. Complementary packages most typically included 2-4 adopted dairy technologies indicating that all the possible combinations of technologies were adopted. As the number of bundled dairy technologies increases, they are most likely to be complementary with one another, although subsets of these technologies are substitutes when seen disjointedly.

Table 4. Complementary dairy technology bundles (N=1242)

Number in bundles (n)	*Observed outcomes of technology combinations/possible combinations of technologies*	*Percent*
2 dairy technologies	6/6	57
3 dairy technologies	4/4	16.4
4 dairy technologies	1/1	2

Table 5 presents the probability distribution of the joint adoption probabilities of crossbred cows, concentrates, improved forages and veterinary services. The adoption of none of the technologies is ignored as there was no household who did not adopt at least one dairy technology. The results revealed eleven combinations of adopted dairy technologies. It was recognized that 2% of the sample households adopted all four technologies while 11.8% of the sample households jointly adopted two dairy technologies (crossbred cows and veterinary service). The findings also indicate that 11.7% the households jointly adopted concentrates and improved forages. The results showed that the unconditional probability of adopting some dairy technologies was higher than the joint probabilities. For instance, the unconditional probability of adopting veterinary service was 49.7% while the probability of adopting crossbred and veterinary service (joint probability) was 11.8%, implying health service is important for all the sick dairy cattle (cows, calves, heifers, bulls and oxen).

Table 5. Probability distribution for joint & individual adoption of dairy technologies

Technologies (B, C, F, V)	*Frequency*	*Percent*
1, 1, 1, 1	26	2.1
1, 1, 1, 0	61	4.9
1, 1, 0, 1	46	3.7
1, 0, 1, 1	45	3.7
0, 1, 1, 1	52	4.2
1, 1, 0, 0	95	7.7
1, 0, 1, 0	114	9.2
1, 0, 0, 1	146	11.8
0, 1, 1, 0	145	11.7
0, 1, 0, 1	95	7.7
0, 0, 1, 1	113	9.1
1, 0, 0, 0	255	20.5
0, 1, 0, 0	259	20.9
0, 0, 1, 0	359	28.9
0, 0, 0, 1	617	49.7

Note: B= crossbred cows, C= concentrates, F= improved forage, V= veterinary service; 1=adopt, 0=no adopt

The conditional probability of adopting four dairy technologies of interest is presented in Table 6. The conditional probabilities are computed from Table 5. The conditional probability of adopting dairy technologies of one or more combinations is generally higher suggesting the existence of possible interdependence (synergy) across the four dairy technologies. For instance, the probability of adopting crossbred cows increased from 21 to 37, 45 and 57% conditional on the adoption of concentrates, improved forage and veterinary services, respectively. The likelihood of adopting crossbred cows also increased from 21 to 24% conditional on adopting improved forage and concentrate. The result is in conformity to the significance test of correlations of the disturbance terms in MVP model (Table 7).

Table 6. Conditional probabilities for the adoption of four dairy technologies in the study area

Conditions	*Technologies*			
	Crossbred (B)	Concentrates (C)	Improved forage (F)	Veterinary service (V)
P ($\boldsymbol{D_j^M}$=1)	0.205	0.209	0.289	0.497
P ($\boldsymbol{D_j^M}$=1|B=1)	1.00	0.367	0.318	0. 237
P ($\boldsymbol{D_j^M}$=1|C=1)	0.373	1.00	0.404	0.154
P ($\boldsymbol{D_j^M}$=1|F=1)	0.447	0.56	1	0.183
P ($\boldsymbol{D_j^M}$=1|V=1)	0.572	0.367	0.315	1.00
P ($\boldsymbol{D_j^M}$=1|B=1, C=1)	1.00	1.00	0.17	0.074
P ($\boldsymbol{D_j^M}$=1|B=1, F=1)	1.00	0.174	1.00	0.073
P ($\boldsymbol{D_j^M}$=1|B=1, V=1)	1.00	0.178	0.125	1.00
P ($\boldsymbol{D_j^M}$=1|C=1, F=1)	0.239	1.00	1.00	0.084
P ($\boldsymbol{D_j^M}$=1|C=1, V=1)	0.18	1.00	0.145	1.00
P ($\boldsymbol{D_j^M}$=1|F=1, V=1)	0.176	0.201	1.00	1.00
P ($\boldsymbol{D_j^M}$=1|B=1, C=1, F==1)	1.00	1.00	1.00	0.042
P ($\boldsymbol{D_j^M}$=1|B=1, C=1, V=1)	1.00	1.00	0.072	1.00
P ($\boldsymbol{D_j^M}$=1|B=1, F=1, V=1)	1.00	0.1	1.00	1.00
P ($\boldsymbol{D_j^M}$=1|C=1, F=1, V=1)	0.102	1.00	1.00	1.00
P ($\boldsymbol{D_j^M}$=1|B=1, C=1, F=1, V=1)	1.00	1.00	1.00	1.00

Note**:** D_j is a binary variable representing the likelihood of adopting j dairy technologies (Crossbred cows (B), concentrates (C), Improved forages (F) and veterinary service (V) in M combinations.

Determinants of probability for joint adoption of dairy technologies

Table 7 presents the estimates of pairwise correlation coefficients of the error terms in the four simultaneous equations. The correlation coefficients are all significant implying the MVP is a better specification than separate four univariate probit models. A non-zero correlation coefficient implies that there are unobservable factors influencing the choice of technologies and the decision to adopt them. The result showed a significant positive association (showing complementarities and synergies) between crossbred cow and concentrates, improved forages and veterinary service; and a significant positive association between concentrates and improved forage as expected, suggesting the adoption of one technology would enhance the chance of adopting another. Unexpectedly, among the posited variables veterinary service and concentrates, and veterinary service and improved forages showed a negative association (showing substitutabilities and trade-off). One intuitive explanation would be that the use of improved concentrates and forages enhanced the health condition of dairy cattle.

Table 7. Estimates of correlation coefficient for the error terms from MVP regression

Parameter	*Coefficient*	*Standard error*	*P-value*	*95% confidence interval*	
rho21	0.172	0.060***	0.004	0.053	0.287
rho31	0.096	0.057*	0.095	-0.017	0.206
rho41	0.174	0.055***	0.001	0.054	0.288
rho32	0.384	0.045***	0.000	0.292	0.469
rho42	-0.231	0.049***	0.000	-0.324	-0.133
rho43	-0.329	0.044***	0.000	-0.412	-0.240

Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0: $\chi^2(6) = 123.66$ Prob > $\chi^2 = 0.0000$; *, *** indicates level of significance at 10% and 1% respectively

Note: 1= crossbred cow, 2= concentrate, 3= improved forage, 4= veterinary service

Table 8 presents the results of the MVP model regression. The Wald test for the hypothesis that all coefficients in each adoption equation are jointly equal to zero is rejected (χ^2 (60) = 792.60; P-value=0.0000), suggesting the variables included in the model explain important portions of variations in the dairy technologies. Regarding the determinants, the results revealed that a number of hypothesized households, institutional, resource endowment and economic variables have a significant and differential effect on the probability of adopting improved dairy technologies.

Regarding the determinants of dairy technologies adoption, the results showed that a number of variables have a significant and differential effect on the four dairy technology pillars. Sex of the respondent positively and significantly affected the choice decisions of adopting concentrates, improved forages and veterinary services. This implies that male headed households had more chances of adopting dairy technologies. This differential adoption by gender could be attributed to variations in resource endowments. Prior studies reported that men had more endowments of land, inputs and training services than their female counterparts and hence had higher adoption rates of improved forages (Kebebe *et al*., 2017). Age of the household head positively and significantly affected the choice decisions of adopting crossbred cows as a priori expectation, but negatively affected the adoption of veterinary services. Older farmers had more chances of adopting crossbred cows while younger households had more chances of adopting veterinary services. This result is consistent with Abdulai *et al.* (2008) and Kebebe *et al*. (2017)

who reported that older farmers had higher adoption rates of crossbred cows than their female counterparts.

Table 8. MVP model estimates for the simultaneous adoption of four dairy technologies and determinants

Independent variables	*Dependent variables (coefficients and standard errors)*			
	Crossbred cow	Concentrate	Improved forage	Veterinary service
Sex	-0.032 (0.121)	0.230 (0.095)**	0.143 (0.087)*	0.246 (0.084)***
Age	0.010 (0.004)**	-0.004 (0.003)	0.005 (0.003)	-0.017 (0.003)***
Education	0.092 (0.019)***	0.002 (0.016)	0.018 (0.015)	0.022 (0.015)
Family size	0.046 (0.026)*	-0.011 (0.021)	-0.004 (0.020)	0.104 (0.021)***
Training on breed	0.616 (0.152)***	0.162 (0.136)	-0.085 (0.133)	0.443 (0.134)***
Training on health	0.196 (0.155)	-0.053 (0.130)	0.003 (0.125)	0.507 (0.127)***
Credit	0.218 (0.157)	0.257 (0.123)**	0.116 (0.121)	-0.115 (0.120)
Membership	0.659 (0.282)**	0.386 (0.246)	1.311 (0.299)***	-0.804 (0.295)***
Off-farm	0.319 (0.136**)	0.005 (0.109)	-0.218 (0.106)**	0.138 (0.100)
Experience in crop adoption	-0.013 (0.009)	0.011 (0.007)	0.020 (0.006)***	-0.054 (0.007)***
Experience sharing	-0.136 (0.224)	-0.026 (0.194)	-0.545 (0.207)***	0.129 (0.202)
Extension	0.015 (0.084)	.332 (0.060)***	0.347 (0.058)***	-0.356 (0.059)***
Perception	0.445 (0.113)***	0.161 (0.091)*	-0.032 (0.086)	-0.103 (0.085)
Income	0.157 (0.010)***	0.026 (0.009)***	0.044 (0.009)***	0.003 (0.009)
Land holding	0.056 (0.039)	0.089 (0.030)***	-0.021 (0.023)	0.105 (0.025)***
Constant	-1.678 (0.237)***	-1.018 (0.177)***	-1.027 (0.166)	0.635 (0.162)***
Number of observations	1242			
Log likelihood	2253			
Wald $\chi^2(60)$	792.60, Prob > χ^2 =0.0000			

*, *** indicates level of significance at 10% and 1% respectively

The results showed that educational level of the household head had positively and significantly affected the probability of adopting crossbred cows as per a priori expectation. The finding is in line with the work by Abdulai *et al.* (2008) and Deribe and Tesfaye (2017) who reported that education of the household head had positively and significantly affected the probability of crossbred cows' adoption. It is presumed that farmers with exposure to formal education have increased knowledge that helped for informed decision making and adopt packages of dairy technologies. Family size in terms of active working age groups (15-64 years) and training on breeding had positively and significantly affected the chances of adopting crossbred cows and veterinary services, implying that dairy breeding and health management practices are labor-intensive activities. This finding is in line with Kebebe *et al.* (2017) who reported that large family size in active working age group had positively and significantly affected adoption of crossbred cows and veterinary services. Abdulai *et al.* (2008) also reported that household size had positively and significantly affected the probability of adopting crossbred technologies. Deribe and Tesfaye (2017) have also reported that training on breeding had increased the probability of adopting crossbred cows. Access to training on improved health management (veterinary service) had also positively and significantly affected the probability of adopting veterinary services tandem with a priori expectation. This finding is consistent with Yitayih *et al.* (2016) who reported that continuous trainings had a positive and significant impact in adopting increased number of dairy technologies. Moreover, dairy farmers reported that availability of crossbred heifers and feeds hindered the decision to adopt crossbred cows.

Household access to credit had positively and significantly affected the choice decisions of adopting concentrates in the study areas in tandem with a priori expectation, implying that households facing liquidity constraints are less likely to buy concentrates. The provision of agricultural credit is one of the most important stages in dealing with adoption constraints. Households' membership in dairy cooperatives was positively and significantly associated with the probability of adopting crossbred dairy cows and improved forages as expected but negatively and significantly affected the probability of adopting veterinary services contrary to expectation. Households who are members of dairy cooperatives have better access to dairy inputs, information and credit which enhance their bargaining capacity in the markets. This finding is consistent with Yitayih *et al*. (2016) who reported that membership in livestock related cooperatives had positively and significantly affected the probability of intensifying livestock feed technologies. Households' participation in off-farm activities had positively and significantly affected the choice decisions of adopting crossbred cows but negatively affected the probability of adopting improved forages. These relationships may partly be explained by the fact that off-farm income might provide financial resources to buy crossbred cows, but may compete for family labor in managing improved forages. This finding is consistent with Abdulai *et al.* (2008) who reported that off-farm participation had positively and significantly affected the probability of adopting crossbred cows.

Household's experience in adopting improved crop varieties had positively and significantly impacted the probability of adopting improved forages but negatively affected the chance of adopting veterinary services. This finding is consistent with Tesfaye *et al.* (2016) who reported that experiences of a household in the adoption of improved crop varieties had positively and significantly affected the probability of adopting improved forages. One explanation for this is that crops and most of the forages are related in nature (Martinez-Garcia *et al*., 2016). Contrary to a priori expectation, experience sharing among dairy farms had negatively influenced the probability of adopting improved forages. One explanation for this might be lack of demonstrating improved forages for visitors.

Extension contacts positively and significantly affected the probability of adopting concentrates and improved forages as a priori expectation. Extension is the major source of agricultural information for many rural farmers through contacts with extension experts. This finding is in line with Deribe and Tesfaye (2017) who reported that frequent contacts with extension agents resulted in increased probability of adopting concentrates. Tadese (2020) also reported that extension service had positively and significantly affected both the probability and intensity of adopting improved dairy technologies. Household's perception about feed shortage as a major problem influenced the probability of adopting crossbred cows and concentrates, implying famers could take risks in dairying.

Income (gross income from milk, butter and cow dung sale per year) had positively and significantly impacted the choice decisions of adopting crossbred cows, concentrates and improved forages. This finding is consistent with a priori expectation and that of Paudel *et al*. (2008) who reported that net income had positively affected the chance of adopting best dairy management practices. Gunaseelan *et al*. (2017) also reported that family income had positively and significantly affected the probability of adopting improved dairy farming technologies.

Land holding size had positively and significantly affected the probability of adopting concentrates and veterinary services. This finding is in line with Rahelizatovo and Gillespie (2004) who reported that farm size had positively affected the probability of adopting best dairy management practices. Martinez-Garcia (2016) also reported that size of land holding had positively and significantly affected the choice decisions of adopting improved forage related technologies.

CONCLUSION AND POLICY IMPLICATIONS

This study provides useful insights to investigate the determinants of adoption of dairy technologies in Amahara and SSNP regional states The adoption rates of crossbred cows, concentrate, improved forage and veterinary services were 21% , 21%, 29% and 50%, respectively in the study area. Several factors have positively and significantly influenced adoption of bundles of dairy technologies. Gender, age, education, family size in terms of active labor force, access to credit, membership to dairy cooperative, participation in off-farm activities, extension contact, perception (awareness) of feed shortage as a problem for dairying, income from dairying and land holding size were found to influence the choice decisions of of dairy technologies by farm households.

Our results suggest that there is a need for improved setup of and supportive policies (research, extension, health, marketing, value chain and commercialization) for effective dairy technology promotion that is working together to enhance smallholder dairy productivity and alleviate poverty. Promotion of packages of technologies was observed to be very less in this study. It is essential to promote the importance of adopting packages of dairy production technologies, such as improved breeds, feeds, and health management practices. The adoption rate of crossbred cows is also very less in SNNP and Amhara regions. One of the reasons was attributed to the unavailability of reliable formal sources of crossbred bred cows/heifers and consequent high prices. It is strongly suggested for regional states establish formal crossbred heifer rearing ranches to ensure sustainable supplies of crossbred heifers at affordable prices.

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The Roles of Indigenous Knowledge in Managing Natural Pasture Land and Key Socio-Economic Drivers for Diminishing Grazing Land Holding

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ABSTRACT

This study was conducted in Kofele district, West Arsi Zone of Oromia Regional State, Ethiopia. It was aimed at describing the traditional livestock feed sourcing practices and highlight the roles of indigenous knowledge in managing natural pasture land and identifying the key socio-economic drivers for diminishing holding of grazing lands. The district was stratified in to highland (2500-3200 m.a.s.l) and midland (2200-2500 m.a.s.l) agro-ecologies. Household (HH) survey using semi-structured questionnaires, focus group discussions and key informant interviews were used to collect qualitative and quantitative data, which were analyzed using descriptive statistics and regression analysis. The results showed that majority of the farmers practice mixed crop-livestock farming. Average land holding per household was reported to be 2.24 hectares (ha) of which 1.27 and 0.92 ha are allocated for crop cultivation and natural pasture, respectively. Natural pasture, crop residues, enset by-products, agro-industrial by-products and improved forage represent about 56.5%, 29%, 9.5%, 2.3% and 1.1% of the available feed resource. About 93.3% of the respondents reported that the landholding per HH is declining through time. The area of grazing land is affected ($p<0.01$) by total land holding and the size of crop and forest land. The study revealed that the farmers in Kofele district have the tradition and many years of experience in livestock keeping and grassland management practices. Private enclosure, standing hay or kaloo, wet-land drainage and fencing of grazing land were found to be the traditional method of grassland management in Kofele district. Appropriate land allocation, grassland management practice such as controlled grazing and cut and carry feeding, proper feed conservation and empowering traditional grassland management practices should be considered. Future studies may show the grassland compositions, diversity and its impact on livestock production and productivity.

Keywords: Feed resources; mixed crop-livestock; indigenous knowledge; grazing systems

INTRODUCTION

The highlands of Ethiopia with altitudes of above 2000 m.a.s.l, cover 37% of the total land area of the country, but carried the majority of human and livestock population (CSA, 2018), where rain-fed mixed crop-livestock agriculture is the mainstay of smallholder farmers. Grasslands provide various ecosystem services in addition to serving as a cheap source of animal feed, and thus proper management and maintenance of grasslands is essential for the sustainable intensification of the smallholder mixed agricultural production system in the highlands of Ethiopia. The mixed farming system in the highlands of Ethiopia is characterized by high integrations and competitions between crop and livestock production systems. Livestock serve as source of farm inputs, food, cash income and capital savings, while crop cultivation provides animal fodder in the form of crop residues (IBC, 2012; Amedie and Kirkby, 2004).

Natural pasture is the major feed resource in Ethiopia. However, its contribution has been declining from as high as 80-90% of the total feed supply in the 1980s (Mengistu et al, 2017) to about 56% (CSA, 2018). The increasing population pressure, and hence the need for more food crops forced the expansion of arable lands at the expense of grassland and forestlands. Coupled with the diminishing pasture area, the productivity of the available grasslands continued to decline due to land degradation, over grazing and climate change (Dejene, 2003; Mengistu, 2004; 2006; Bezabih, 2013). Currently, the country is facing critical feed shortage and hence depend on seasonally available feed resources and heavily relies on poor quality crop residues as animal feed (Tolera *et al.* 2012; Lemma, 2016).

Grasslands are important and cheap sources of livestock feeds. Therefore, keeping the grassland diversity and biomass is vital for sustainable growth. Sustainable use of grassland demands a context specific management strategy that takes into account traditional knowledge/practices (Mengistu et al., 2017). Indigenous knowledge plays paramount role in the sustainable use of grassland and other natural resources and builds on the existing knowledge towards improved management practices (Angassa *et al*., 2012; Otte and Chilonda, 2002). The current study aims to investigate the indigenous knowledge and practices of farmers in the study area as well as the trends and drivers of change in pasture land availability and livestock productivity.

MATERIALS AND METHODS

Description of Study Site

This study was carried out in Kofele district, West Arsi Zone of the Oromia Regional State, located at $7^0$9'60.00''N and $38^0$49'59.99''E (Fig 1). The district has a typical highland agro-ecology, with an altitude ranging from 2200 to 3200 m.a.s.l (Kofele Agriculture and Natural Resources Management Office, 2017; unpublished report). The area receives an average rainfall of 1800 mm per annum and has bi-modal rainfall distribution with small rains extending from March up to May and the main rainy season extending from June to September/October. The agricultural landscape in the district is dominated by two types of land use systems, small farmland around homestead usually dedicated for vegetable and Enset production and a relatively larger/main portion of the land away from the homestead in most cases, sometimes at distances as far as 20 km where cereal crops (notably wheat and barley) are grown in the midland villages, and also pastureland which is reserved for cattle.

Study Design

The study involved individual interviews on randomly selected farm households, focus group discussions and key informant interviews. To identify representative farm households, the district's rural *kebeles* (smallest administrative units) were grouped into two altitude groups, namely mid-land and highlands. The district has a total of 38 rural *kebeles,* of which 74% are located in highland (2500 to 3200 3200 m.a.s.l) and 26% in midland (2200 to 2500 m.a.s.l). Proportional to the size of the two agro-ecologies of the district, four *kebeles* from high altitude and two from midland altitudes were selected randomly from the list. The participating household sample size of the selected *kebele* was determined using the formula suggested by Yamane (1967).

$$n = \frac{N}{1 + N(e)^2}$$

Where n= is the sample size; N= total HH size; e= marginal error.

Accordingly, the total sample size was 150 households, randomly selected from the two major agro-ecologies.

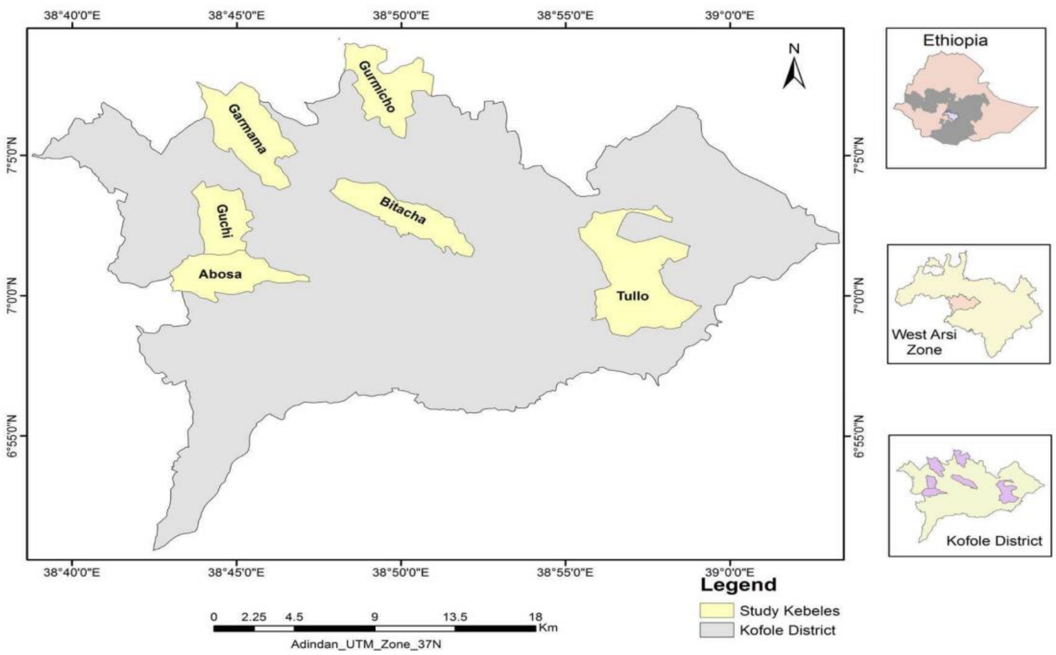

Figure 1.Map of the study area

Data Collection

A reconnaissance survey was conducted in the district and key informant interviews conducted with elderly farmers, development agents and district officials. This was followed by separate focus group discussions for each of the two agro-ecologies using a checklist of questions. For the individual interview, a semi-structured questionnaire was developed, pretested and refined before the tool was employed to generate primary data on household characteristics, farming practices, use patterns, traditional grassland management practices, access to services, and challenges in relation to feed sourcing and livestock production. For assessment of feed resources, feed assessment tool (FEAST) developed by Duncan et al (2012) was used to assess local feed resource availability and to estimate it's contribution/by proportion.

Data Analysis

A descriptive analysis was conducted to describe farm household socio-economic characteristics and traditional grassland management practices using SPSS. A Multiple Linear Regression Model (MLRM) was used to explore relationships between socio-economic characteristics of the participating households and proportion of pastureland at household levels.

Variables selection and hypothesis

The conceptual framework of the study and variables for MLRM were identified thorough literature reviews. The response variable was grazing land size (ha) at HH level and it was taken as continuous variable while seven independent variables namely crop land size (ha), livestock holding (TLU), total land holding (ha), family size, forest land size (ha), proximity to urban center (km) and amount of unsuitable land for agriculture (ha) were identified.

Grazing land size (Y): Grassland is assumed to be associated with the socio-economic factors, means of livelihood of farmers and interests of farmers to focus on livestock farming over other farm activities. The hypothetical associations between the response variables and independent variables are outlined as follows:

Livestock holding (X_1): is the total livestock holding (TLU) that was owned by the HH. According to the national livestock census, the total livestock population (cattle and small ruminants particularly) in the country is increasing while the per capita holding is declining. Famers reduce the stock size when they have small farmland holding (Emana *et al.*, 2015). It was hypothesized that more livestock holding at household level means farmers have more pasture land allocated for their livestock as important source of feeds.

Crop Land Size (X_2): was the second explanatory variable expressed by a size of a land in hectare used for crop cultivation by each sampled HH in the area. It was hypothesized negative relationship between grazing land size and crop land size for this model, which implies that farmers increase the size of the cropland at the expense of pastureland (Tadesse *et al*. (2017).

Total Land Holding Size (X_3): According to Teshome (2014) in the highlands of Ethiopia household land per capita is decreasing over time and it affected grazing land size. Similarly, it is hypothesized that the total land holding per household and grazing land size are positively correlated.

Family Size (X_4): The IBC (2012) reported that an increase in family size has resulted in declining land holding as parents redistribute farmland for their children when they leave at maturity age.

Forest Land Size (X_5): Area of land (ha) used for private forest plantation for commercial purposes by each sample household. We hypothesized negative relationship between forest land size and land allocated for pasture.

Distance to Urban Center (km) (X_6): is the distance in kilometers by which each sampled households are settled from urban center. We hypothesized a negative relationship between grazing land sizes and proximity to urban center for this model.

Degraded Land Size (ha) (X_7): is the land size in hectare that is not suitable for agricultural activities in each sampled HH in the area. We hypothesized that the more unsuitable land a farmer owns he might allocate the land for livestock farming rather than for crop activities.

Model specification

According to Gujarati (2004) regression model used when the study involves more than two variables and the following MLRM equation was used:

$Yi = \beta0 + \beta1X1 + \beta2X2 + \beta3X3 + \beta4X4 + \beta5X5 + \beta6X6 + \beta7X7 + \varepsilon i$.

Where Yi = Grazing land size as a dependent variable

$\beta0$ = constant

Livestock holding (X1), crop land size (X2), total land holding (X3), family size (X4), forest land size (X5), distance to urban center (X6) and size of land unsuitable for farming (X7) were independent variables. The β1, β2, β3, β4, β5 β6 and β7 represents coefficients of the respective independent variables, whereas εi = the residual variance in Y after taking into consideration the effects of the Xi variables included in the model. Before fitting variables into the regression models for analysis, multicollinearity problem among variables was tested, to identify the separate effect of independent variables on the dependent variable because of existing strong relationship among them.

RESULTS

Land holding of the participating households

The land holding and land allocations for various farming practices of the participating households are shown in Table 1. The land holding in the study area ranged between 0.06 and 6 ha. However, most farmers own farmland in the rages of 1 and 2.5 ha per household, whereas the overall average land size in the study area was 2.24 (±1.41) (Table 2)

Table 1. Land holding per household in the study area

Land size categories (ha)	Agro-ecology (%)		Overall mean n=150
	High altitude n=93	Midland altitude n=57	
0.06-0.25	2.15	0.00	1.08
0.26-0.99	16.13	7.02	11.57
1-2.5	56.99	66.67	61.83
2.6-6	24.73	26.32	25.52

From the total land holding, farmland allocated for cropping activities was the highest followed by natural pasture. The average farmland holding varied between the two agro-ecologies; farmers in the highland had lower farmland size than their counterpart in the mid-altitude (Table 2).

Table 2. Mean (± SE) farmland holding (ha) and land allocations (ha) by farm households

Variables	Agro-ecology		
	Highland (n=93)	Midland (n=57)	Overall (n=150)
Grazing land	0.81±0.66	1.03 ±0.89	0.92±0.78
Crop land	1.18±0.73	1.35±0.86	1.27±0.80
Forest land	0.05±0.11	0.03±0.06	0.04±0.08
Overall land size	2.04±1.28	2.43±1.53	2.24±1.41

Table 3 shows how farmers first received farmland and their perceptions on the trends of farmland ownerships in the area. Majority of the farmers inherited their farmland from their parents and benefitted from farmland redistribution programs by the government. Over years, farmers realized/perceived that farmland holding is shrinking from generations after generations when inherited from their parents and even by the redistribution programs.

Table 3: Land source for both crop and grazing land in the study area (N=150)

Variables	Parameters	By agro ecology (%)		Overall (n=150)
		Highland (n=93)	Midland (n=57)	
Source of land	Land redistribution	41.94	24.56	33.25
	Inherited from parents	53.76	68.42	61.09
	Shared from relatives	4.30	7.02	5.66
Land holding trend	Decreasing	93.55	92.98	93.27
	No change	6.45	7.02	6.73

Feeding practices

Table 4 shows the common livestock feeding practices in the study area. The findings show that free grazing is the most common method of feeding ruminant livestock followed by tethering whereas the practice of stall feeding is very rare in the area. Feed availability and quality is low during the long dry and long rainy seasons. On the other hand, the incidence of feed shortage is much lower during the short rainy season.

Table 4. Feeding practices followed by farmers and main seasons feed scarcity in study area

Variables	Parameters	Agro-ecology (%) Highland (n=93)	Midland (n=57)	Overall (n=150)
Method of animal feeding	Free grazing	63.40	57.90	60.65
	Tethering	24.80	29.80	27.30
	Herded grazing	7.50	8.80	8.15
	Stall feeding	4.30	3.50	3.90
Feed shortage season	Long dry season	44.00	52.60	48.30
	Long rainy season	33.30	26.30	29.80
	Short dry season	16.20	17.50	16.85
	Short rainy season	6.50	3.60	5.05

The major feed resources and its importance by month of the year are shown as Figures 2 and 3, respectively. Rotational grazing is practiced by only 8% of the households, in which the farmers allocate portion of pastureland (blocks), for 1-2 months particularly maintained for selected livestock species, like oxen and young stocks, which is locally termed as *Kaloo* (standing hay). As shown in Figure 3, natural pasture remains the dominant source of feeds for livestock, especially from June to November.

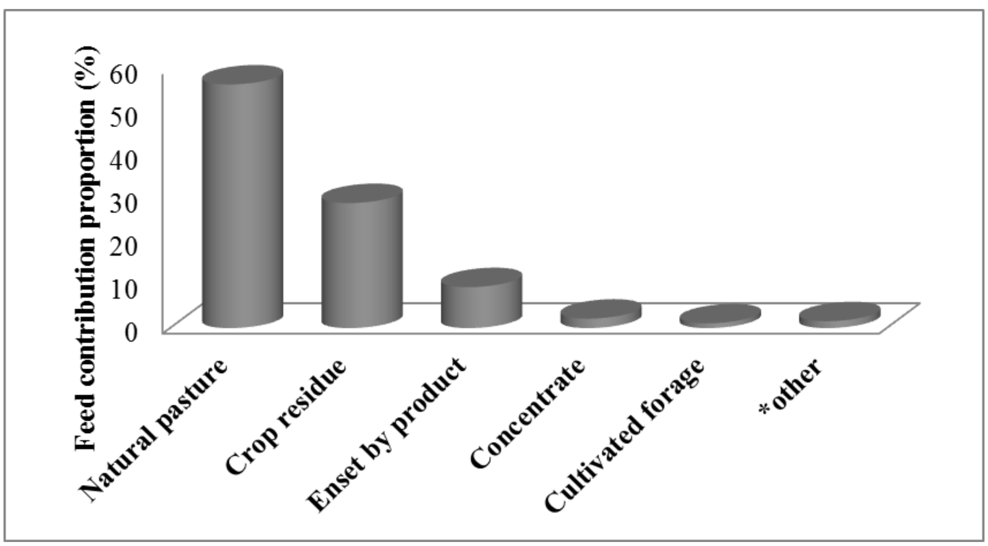

Figure 2: Major feed resources in the study area

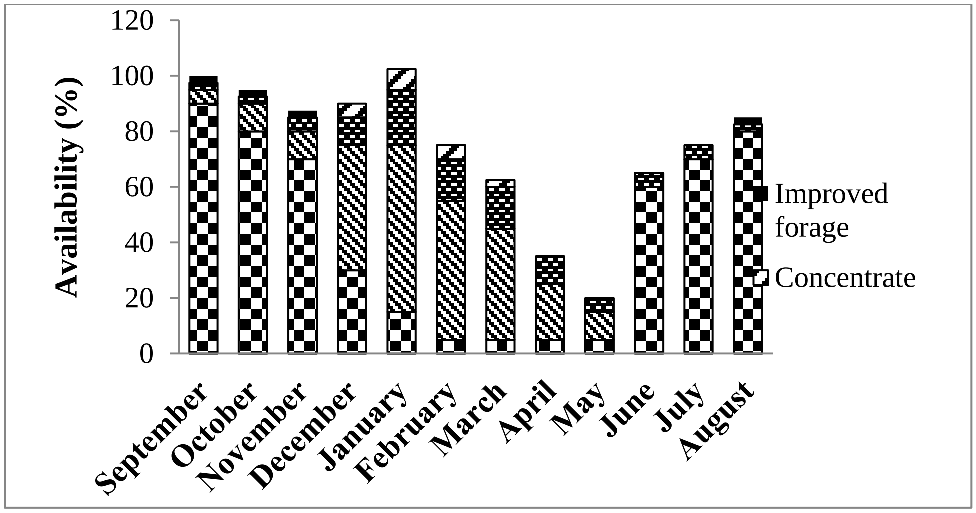

Figure 3: Major feed resources in the study area, its importance by months of the year

Feed conservation practices

Table 5 shows the feed conservation practices in the study area. Conservation of crop residues was the main strategy used to alleviate feed shortage during scarce seasons in the study area. Study result shows that crop residues are mainly conserved from own farmland. Farmers mainly judge the straw quality by qualitative organoleptic characteristics including color, type of straw itself, appearance and level of maturity. Among the cereals, barley straw is the most widely accepted crop residues preferred by most farmers, compared to teff (*Eragrostis tef*) and wheat straws.

Table 5. Crop residue conservation practices in the study area

Variables	Parameters	By agro ecology (%) Highland (n=93)	Midland (n=57)	Overall (n=150)
Farmers' engagement in feed conservation	Yes	77.40	82.50	79.95
	No	22.60	17.50	20.05
Method of storage	Stacked out side	83.30	78.70	81.00
	Stacked under shade	13.90	6.40	10.15
	Baled out side	2.80	4.30	3.55
	Baled under shade	0.00	10.60	5.30
Indicators used by farmers to evaluate feed quality	Residue type	46.20	15.80	31.00
	Color	24.70	36.80	30.75
	Smell	10.80	33.30	22.05
	Appearance	15.10	10.50	12.80
	Maturity	3.20	3.60	3.40

Traditional Grassland Management

To maximize grassland productivity, the farmers traditionally use different management practices (Table 6). Fencing of private grazing land or enclosure is the main means of pastureland management strategy practiced by most of the farmers in the study area, which is more common in the midland than in the highland agro-ecology. Draining of swampy areas is the second most important management practice, which is more prevalent in the highland agro-ecology. About 60% of all the respondents perceive the purpose of enclosures as a means of overcoming feed shortage whereas the remaining about 40% of the respondents value it as a means of rehabilitating the pastureland.

Table 6. Traditional management practices in the study area

Variables	Parameters	By agro-ecology (%) Highland (n=93)	Midland (n=57)	Overall (n=150)
Management strategies	Fencing	64.7	74	69.35
	Draining of swampy land	23.3	16	19.65
	Fire application	9.3	10	9.65
	Bush clearing	2.7	0	1.35
Do you use enclosure	Yes	69.9	82.5	76.20
	No	30.1	17.5	23.80
Farmer opinion on purpose of enclosure	Overcome feed shortage	58.06	63.16	60.61
	Rehabilitation	41.94	36.84	39.39

Table 7 shows the perceptions of farmers on the current condition of grazing land as compared with the condition of the grazing land about 30 years ago. Farmers rated the pasture conditions as poor, fair and good. In addition, the farmers strongly perceived that the current condition of the natural pasture is poor, mainly due to the weakening of customary management practices as compared to the previous years.

Table 7. Farmers perceptions on current grassland condition in the study area

Parameters	Criteria	By agro-ecology (%) Highland	Midland	Overall (%)
Condition of grassland	Poor	90.30	87.70	89.00
	Fair	7.50	7.00	7.25
	Good	2.20	5.30	3.75
Traditional management trend	Weak	93.50	87.70	90.60
	Strong	5.40	7.10	6.25
	The same	1.10	5.20	3.15

Factors affecting grazing land size: a regression analysis

The adjusted R^2 value of for the regression analysis employed was found to be 0.98, showing that 98% of the variation in grazing land size at household level can be explained by the selected household socio-economic variables. Table 8 shows the significance test for regression among different variables. The result shows that total farmland size, land allocated for cropping activities as well as forest area have significant relationship ($p<0.011$) with pasture land size owned farm households.

Table 8.Regression coefficients and their significance for the variables used in the analysis

Variables	Unstandardized Coefficients (B)	Sig.	VIF
(constant)	0.001		
Livestock holding (TLU)	0.001	0.808	2.095
Crop land	-0.963*	0.000	5.709
Land holding size	0.982*	0.000	6.256
Forest land	-0.971*	0.000	1.116
Family size	-0.001	0.818	1.053
Urbanization	-0.001	0.524	1.160
Land degradation	-0.127	0.556	1.103

* indicates regression relationship is significant at 1%

DISCUSSION

Farm and Grazing Land Holding

The results of the current study showed that mean land holding of 2.24 ha per household is higher than the Ethiopian national average farmland size. According to Headey et al. (2014) the national average farmland size was reported to be 0.96 ha per household with variations among regions. Oromia Region has the largest 1.15 ha per household, while Amhara Region has 1.09 ha, whereas Tigray and Southern Peoples Regions having relatively smaller values each having 0.49 ha. Over 72.1% of the households are operating agricultural practices on smaller than 1 ha land. Therefore, study area is endowed with relatively larger land holding. However, farmers believe that as farm size is declining and larger portion of land is dedicated to the recently growing trends of cropland expansions, hence farmers are switching to crop residue feeding to their animals. The farmland dedicated for pasture development/grazing is declining and the productivity of existing grazing land is declining. The result of this study is in agreement with other findings such as Österle *et al.* (2012), who reported a higher tendency of converting a grazing land into cropland in the high lands of Ethiopia. The shrinkage of grazing land, due to expansion of cropland, leads to overgrazing and causes significant reduction in the availability and diversity grass biomass, favoring less productive grass species. For example, dominance of *Pennisetum sphacelatum* is a common indicator of overgrazed areas (Sylvia, 2014).

Feed Resources Availability and Livestock Feeding Systems

Natural pasture was reported to be the major feed resources in the study area, accounting for about 56.5% of the available feed resource. This is consistent with other findings in Ethiopia (Tolera *et al.* 2012; Mengistu et al, 2017; CSA, 2018) showing that natural pasture is still the dominant feed resources in the highlands of Ethiopia, although its contribution is declining over years. Crop residues are the second most important feed resources in the area, and play a pivotal role during the dry season. Their availability is closely related with type of farming system, types of crops produced and intensity of cultivation. The dominant crop residues used as livestock feed in the study area include wheat and barley straws and as well as *enset* by-products.

Feed availability and livestock feeding practices in the study area are greatly dependent on the growing season. There are also variations among households due to differences in land ownership, which also determines livestock holding. Key informants explained that feed shortage commonly occurs during the long dry season (December-February) and during the long rainy season (June-August). During the long dry season, there is no growth of pasture and the available pasture and other feed resources are depleted whereas during the long rainy season most of the available land is covered with crops and crop residues are depleted. However, the degree of the problem varies with agro ecologies; the problem being more serious in the highland agro-ecological zone. There are also variations among households, due to differences in farmland sizes, those farmers who have larger farmland could dedicate more land for pasture/grazing and hence can better sustain even during dry season by conserving standing hay. SIn the study area, communal land is converted to private land. Unlike in the past decades, communal grazing is on the verge of disappearing. In terms of pastureland management and use, farmers have priorities to cattle, particularly to calves, draft oxen and lactating cows in in that order.

The prevailing livestock feeding systems in the study area include communal grazing, herded grazing, tethering and cut-and carry indoor feeding (zero grazing). Unlike in the past decades, the area dedicated for communal grazing in various parts of the district is declining, hence farmers are relying more on privately owned grazing areas. The feeding method used varies with season i.e. free grazing was the main feeding strategy during dry season. Tethering was mainly practiced during heavy rainy season, which also overlaps with crop season and farmers restrict the movement of their animals to avoid trumping on their crop fields. In terms of pastureland management and use, farmers give priority for cattle, particularly for calves, draft oxen and lactating cows in in that order. Uncontrolled free grazing could lead to the depletion of feed resources through overgrazing which could contribute to low productivity of livestock (Mengistu, 2002; Gebremedhin *et al.*, 2004).

Traditional Grassland Management

To maximize grassland productivity, farmers traditionally uses different management strategies such as the use of private enclosure (*Kalo*), fencing and draining of marshy area The pastureland conserved as standing hay (Kalo) is particularly and preferentially used for draft oxen during peak cropping seasons, lactating cows, and weak animals during long rainy seasons. Excess accumulation of water on natural pasture land was one of the major challenges for livestock owners in the wetlands of the highland agro-ecological zone. Unless such excess water is drained, it affects forage availability and vegetation growth rate (Funte *et al*, 2010).

Factors Affecting Grazing Land Holding

The study area is known to supply a large volume of rain fed crop products, notably vegetables as important cash crops, such as potato, round cabbage, beet roots and onions. According to key informant interviews, over decades farmers in the study area have been allocating the major portions of their farmland for such cropping activities, usually diminishing the proportions of natural pasture land, while leaving smaller propositions of land as natural pasture/grazing areas.

CONCLUSION

The study highlighted that gradual expansion of crop cultivation is changing the agricultural landscape of the study area causing shrinkage of grazing areas and declining contribution of grassland as importance sources of feeds for livestock although the area was once a typical grassland and livestock production used to be a major means of livelihood. The area of pastureland per household is determined by the size of total land holding and the area of land allocated for crop production and tree plantation by the family. Future studies should focus on evaluation of grassland compositions, diversity and its impact on livestock production and productivity.

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EJAP PUBLICATION POLICY

Focus and Scope of the Journal

The Ethiopian Journal of Animal Production (EJAP) is a peer reviewed journal published annually by the Ethiopian Society of Animal Production (ESAP). The Journal is publishing original basic and applied research articles, short communications, technical notes, and review articles dealing with livestock and livestock related issues. Critical reviews may also be published. Although the journal focuses on livestock production in Ethiopia, papers from similar agro-ecological regions from different parts of the world are welcomed.

Only new and original manuscripts that have not been previously published can be accepted. When submitting a paper to EJAP, the authors must declare, in an accompanying cover letter, that the manuscript is new and original and not under consideration for publication elsewhere. All papers published in EJAP, whether invited or volunteered, are subject to a peer review process.

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Papers submitted to Ethiopian Journal of Animal Production will be peer reviewed by at least two referees to ensure both accuracy and relevance. The Section Editors and Editor-in-Chief will base their decision on the report of the referees whether to accept or reject the paper. Most papers undergo different levels of revision (major, moderate or minor) before final acceptance.

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The Ethiopian Journal of Animal Production (EJAP) publishes original articles of high scientific standard dealing with livestock and livestock related issues. Reviews on selected topics on livestock research and development appropriate to Ethiopia and other similar countries in the tropics and subtropics will also be considered for publication. Short communication and technical notes are also welcome.

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Discussion: The reliability of evidence (result), comparison with already recorded observations and the possible practical implication is discussed.

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Examples

Journal article:

Zerbini, E., Gemeda, T., Tegegne, A., Gebrewold, A. and Franceschini, R. 1993. The effects of work and nutritional supplementation on postpartum reproductive activities and progesterone secretion in F1 crossbred dairy cows in Ethiopia. Theriogenology 40(3):571-584.

Crosse, S., Umunna, N.N., Osuji, P.O., Tegegne, A., Khalili, H. and Tedla, A.. 1998. Comparative yield and nutritive value of forages from two cereal-legume based cropping systems: 2. Milk production and reproductive performance of crossbred (Bos taurus x Bos indicus) cows. Tropical Agriculture 75 (4):415-421.

Article by DOI

Negewo, T., Melaku, S., Asmare, B. and Tolera, A. 2018. Performance of Arsi-Bale sheep fed urea treated maize cob as basal dietand supplemented with graded levels of concentrate mixture. *Tropical Animal Health and Production*. 50: 1209-1217. https://doi.org/10.1007/s11250-018-1544-4

Book

Steel, R.G.D. and Torrie, J.H. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co., Inc., New York.

Chapter in a Book

Zerbini, E., Gemeda, T., Gebre Wold, A. and Tegegne, A. 1995. Effect of draught work on the metabolism and reproduction of dairy cows. In: Philips, C.J.C. (ed.), Progress in Dairy Science. Chapter 8. CAB International. pp. 145-168.

Paper in Proceedings

Gebre Wold, A., Alemayhu, M., Tegegne, A., Zerbini,E. and Larsen, C. 1998. On-farm performance of crossbred cows used as dairy-draught in Holetta area. Proceedings of the 6th National

Conference of the Ethiopian Society of Animal Production (ESAP), May 14-15, 1998, Addis Ababa, Ethiopia, pp. 232-240.

Thesis/Dissertation

Trent, J.W. 1975. Experimental acute renal failure. Dissertation, University of California

Online document

Tekle, D., Gebru, G. and Redae, M. 2018. Growth performance of Abergelle goats fed grass hay supplemented with pigeon pea (*Cajanus cajun* (L.) Millsp) leaves. *Livestock Research for Rural Development. Volume 30, Article #149.* Retrieved August 2, 2018, from http://www.lrrd.org/lrrd30/8/desta30149.html

Cartwright, J. 2007. Big stars have weather too. IOP Publishing PhysicsWeb. http://physicsweb.org/articles/news/11/6/16/1. Accessed 26 June 2007

Abbreviations

Follow standard procedures.

Units

All measurements should be reported in SI units. (e.g., g, kg, m, cm)

Table 1. The following are examples of SI units for use in *EJAP*

Quantity	Application	Unit	Symbol or expression of unit
Absorption	Balance trials	Grams per day	g d^{-1}
Activity	Enzyme	Micromoles per minute per gram	μmol min^{-1} g^{-1}
Area	Land	Hectare	ha
	Carcass	Square centimetre	cm^2
Backfat	Carcass	Millimetres	mm
Concentration	Diet	Percent	%
	Blood	Gram per kilogram	g kg^{-1}
		International unites per	IU kg^{-1}
		kilogram	mg dL-^{1}
		Milligram per 100 mL	Mequiv L^{-1}
		Milliequivalents per litre	
Density	Feeds	Kilogram per hectolitre	kg hL^{-1}
Flow	Digesta	Grams per day	g d^{-1}
	Blood	Milligrams per minute	mg min^{-1}
Growth rate	Animal	Kilogram per day	kg d^{-1}

		Grams per day	g d^{-1}
Intake	Animal	Kilograms per day	Kg d^{-1}
		Grams per day	g d^{-1}
		Grams per day per kg bodyweight0.75	g d^{-1} $kg^{-0.75}$
Metabolic rate	Animal	Megajoules per day	MJ d^{-1}
		Watts per kg bodyweight	W kg^{-1}
Pressure	Atmosphere	Kilopascal	KPa
Temperature	Animal	Kelvin or degree Celsius	K or ^{o}C
Volume	Solutions	Litre	L
		Millilitre	ML
Yield	Milk production	Litres per day	L d^{-1}
Radioactivity	Metabolism	Curie or Becquerel	Ci (=37 GBq)

Units with two divisors should be written with negative indices (e.g., kg ha^{-1} yr^{-1}). The use of solidus (/) should be reserved for units written in full (e.g., mole/kilogram) or to separate a physical quantity and unit (e.g., yield/ha). Units should be chosen so that the numeric component falls between 1 and 10 or 1 and 100 when using one or two significant figures, respectively (e.g., use 31.2 mg than 0.0312 g).

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Application form for Membership

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