PHENOTYPIC CHARACTERIZATION, HUSBANDRY PRACTICES, AND DEFINING BREEDING OBJECTIVE TRAITS OF INDIGENOUS SHEEP POPULATIONS IN MESKAN AND SODDO DISTRICTS, EAST GURAGE ZONE, ETHIOPIA

MSc Thesis

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HAWASSA UNIVERSITY

College of Agriculture

Hawassa, Ethiopia

April, 2024

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DEDICATION

This thesis is dedicated to all of my beloved family, especially my father **Shifa Temam** and my mother **Muhaba Awol,** for nursing me with unconditional love and great sacrifice. This piece of work is also dedicated to my elder sister **Mekiya Shifa** and my second mother **Betula Kersima,** for their ceaseless encouragement and for cherishing me with a devoted partnership in the success of my life.

STATEMENT OF THE AUTHOR

Through my signature below, I declare and confirm that this thesis is my genuine work and that all sources of materials used for this thesis have been profoundly acknowledged through citation. I have followed all ethical and technical principles of scholarship in the preparation, data collection, data analysis, and compilation of this thesis. This thesis has been submitted in partial fulfillment of the requirements for an advanced Master of Science (MSc) degree at Hawassa University, and it is deposited at the university library to be made available for users under the rule of the library.

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LIST OF ABBREVIATIONS AND ACRONYMS

AFL	Age at First Lambing
BHS	Black Head Somali
BL	Body Length
BW	Body Weight
CSA	Central Statistical Agency
DNA	Deoxyribonucleic Acid
EL	Ear Length
FGD	Focus Group Discussion
GLM	General Linear Model
HG	Heart Girth
HH	House Hold
HL	Horn Length
HW	Height at Wither
ICARDA	International Center for Agricultural Research in the Dairy Area
LBM’s	Linear Body Measurements
LI	Lambing Interval
LS	Litter Size
MSE	Mean Square Error
Ne	Effective Population Size
Nf	Number of Breeding Female
NL	Number of Lambing
NLB	Number of Lambs Born
NLW	Number of Lambs Weaned

Nm	Number of Breeding Male
PPI	Permanent Pair of Incisor
PW	Pelvic Width
RALH	Rank after Provision of Life History
RBLH	Rank before Provision of Life History
RH	Rump Height
SE	Standard Error
SC	Scrotum Circumference
spp.	Species
TL	Tail Length
UNESCO	United Nations Educational, Scientific and Cultural Organization
WH	Wither Height

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Phenotypic Characterization, Husbandry Practices, and Defining Breeding Objective Traits of Indigenous Sheep Populations in Meskan and Soddo Districts, East Gurage Zone, Ethiopia

By: Wolyu Shifa: Werabe University

Advisor: Haile Welearegay (PhD): Hawassa University

ABSTRACT

The study was conducted in the Meskan and Soddo districts of the East Gurage Zone of the Central Ethiopia Regional State with the objectives of identifying and generating comprehensive information on husbandry practices, breeding objectives, selection criteria, and phenotypic characterization of indigenous sheep populations under the smallholder management system. A total of 176 households were selected randomly from Meskan and Soddo districts (3 rural kebeles from each district), and 270 mature sheep (30 males and 240 females) were taken for morphometric data. A semi-structured questionnaire was developed to gather survey data focused on husbandry practices, breeding objectives, selection criteria, and breeding performance of indigenous sheep. Following the survey study, own flock animal ranking and group-animal ranking experiments were carried out, 15 breeding ewes and 15 breeding rams from each district were randomly selected and used for the group animal ranking experiment. The survey data were analysed using SPSS version 26, while indices were computed for the ranked data. The own flock and group ranking experiment data were analysed using SAS version 9.4. Based on the investigated results, the top two objectives of keeping sheep were income generation and ceremonies in the study area. The most prevalent feed source for sheep during the dry season was grazing aftermath (57%), while in the wet season, natural pasture (65.91%) was common in the study area. The major source of water during the dry season was pipe water (57.39%), whereas in the wet season, rivers (31.82%) were mostly used in the study area. The larger portion of the respondents in both districts practiced castration. The majority of sheep keepers (89.20%) in the study area practiced uncontrolled mating due to a lack of awareness (67.95%). The majority of the respondents (57.95%) do not have their own breeding ram; however, they use rams from communal grazing lands. The average weaning age of indigenous sheep lambs in the study area was 3.56 months. The proportion of breeding males to breeding females was 1:3.39. The mean age of male sheep at sexual maturity and female sheep at first service in the study area was 7.74 and 8.07 months, respectively. The mean values of age at first lambing, lambing interval, number of lamb crops per ewe life time, and reproductive lifespan of ewe were 13.75 months, 7.96 months, 11.99 lambs, and 8.23 years, respectively. The major selection criteria of the farmers for breeding rams was body size (index = 0.28), while twining ability for breeding ewes with an index value of 0.31. The most important health affecting problem for sheep was diarrhea (index = 0.30). The main constraint that hindered sheep productivity in the study area was disease incidence, with index values of 0.27. It was found that in the own-flock ranking experiment, sheep keepers focused on the animal's reproductive performance and mothering ability, while in the group-animal ranking experiment, they selected the animals based on observed physical appearances like coat colour and body size. Heart girth was the single best predictor of body weight ($P < 0.001$) in the study area. In general, frequent twinning, shorter lambing intervals, and higher adult body weight are the most desirable traits, which may also be used as selection criteria. Considering the producer's objective traits in the current study would help in designing sheep productive performance improvements in the study area.

Keywords: *Breeding objective, Feed sources, Husbandry practices, Inbreeding, Indigenous sheep, Reproductive performance, Selection criteria*

1. INTRODUCTION

Ethiopia is home to various indigenous sheep populations, which contribute to being the largest in Africa, corresponding to its diverse agro-ecologies, production systems, and ethnic communities. The estimated population number of sheep in Ethiopia is 42.9 million, of which about 99.52% are indigenous breeds (CSA, 2021). Most of the traditional sheep types in Ethiopia are named after specific communities. For instance, Black Head Somale sheep from Somale, Bonga sheep from Bonga, Horro sheep from Horro Guduru area communities, and so on. Ethiopia has about 14 known traditional sheep populations (Abegaz *et al*., 2008).

For smallholder farmers, sheep have multi-purpose roles such as generating income, meat, skin, wool, manure, ceremony purposes during festivals, risk alleviation during crop failures, and social function (Nigussie *et al*., 2015). Indigenous sheep can produce under unfavourable climatic conditions and use marginal land efficiently. Therefore, the adaptive ability of indigenous sheep with increased sheep productivity can be used to reduce poverty and improve the lives of smallholder farmers in many parts of Ethiopia (Geatachew and Ashenafi, 2020). The export and domestic markets for mutton and live animals have created more opportunity for sheep production in Ethiopia (Mohammed *et al*., 2015). Despite its multi-purpose role and large number, Ethiopian sheep production is comparatively poor (Mathewos *et al*., 2021).

Evidence on husbandry practices and phenotypic characterization of indigenous sheep types can serve as a foundation for long-term improvement and identifying productive performance variation between and within breeds (Asmare *et al*., 2023). Husbandry practices, such as management, feeding, and breeding aspects are among the factors that can affect the phenotypic characteristics of animals (Gatew *et al*., 2017). The issue of losing diversity and conservation of farm animal genetic resources has gained momentum in the last few decades. Correspondingly, there have been tremendous efforts globally to study genetic diversity in livestock species to address the needs of both the development and conservation of animal genetic resources in different parts of the world (Meseret, 2020). Most of the time, breeding ewes and rams are selected from the outstanding females and males, respectively, while the unwanted ones are disposed of mostly through sale and slaughter. Furthermore, the age of selection for breeding rams is different from that of breeding ewes; rams are selected at their youngest age, whereas ewes are selected mostly at their older age compared to rams (Nurilgn, 2020).

Even though Ethiopia has invested in institutionalised and centralised sheep genetic improvement efforts for some decades, the sheep have frequently failed to produce meaningful results at the farm level. The absence of structured breeding plans, the limited reliance on the imported technological packages, a severe lack of technical proficiency, and the limited involvement of relevant stakeholders were among the many reasons for such failure in the planning and implementation of sheep improvement efforts (Haile *et al*., 2020). Communal grazing lands and watering points are a customary and promising option for designing breeding schemes to consider the village population as one large flock or a breeding unit. In this case, breeding animals are being selected based on their phenotypes recorded within the village population.

The primary aim of a breeding program for smallholder conditions should be to minimize failure risks by using resource saving production methods while achieving acceptable genetic gain in important breeding traits (Sölkner *et al*., 1998). In developing countries where unfavourable environmental conditions are prevalent, there has been a dilemma in genetic improvement programs on how to effectively organize breeding schemes involving smallholder farmers at the village level and how to record such flocks' important information and monitor progress (Kosgey *et al*., 2006). The formulation of acceptable and viable breeding programs for low-input traditional and subsistence production systems requires the identification of breeding objectives through a participatory and comprehensive approach. The breeding objective includes all relevant characteristics of an animal, such as production, reproduction, fitness, and health characteristics (Kosgey, 2004).

The phenotype characterization forms the basis for the traditional breed descriptions (such as coat colour, horns, and tail type). Phenotypic characterization can be helpful in addition to the powerful biotechnological tools for evaluating genetic variation at the genome level. The mobility of pastoral flocks possess additional difficulties in recording and selection (Mirkena *et al*., 2012). Furthermore, the production system is affected by several factors, such as feed scarcity, lack of technical capacity of the farmer, disease and parasite prevalence, low genetic potential for useful traits of the animal, lack of appropriate breeding strategies, and limited understanding of the production systems (Gatew *et al*., 2017). The importance of identifying breeding objectives and selection criteria by involving farmers in the development of effective sheep breeding designs in order to implement sustainable productivity is crucial. Generally, sheep production in the mixed crop-livestock production system is vital to food security and economic development in Ethiopia (Mekuria and Mekonnen, 2018).

1.1. Statement of the Problem

The study area has an appropriate number of sheep, but both their genetic potential and the value they contribute to the farmers' livelihood have fallen below expectations. To increase the productivity and genetic potential of sheep, an understanding of their husbandry practices, breeding objectives, and selection criteria is necessary. Despite the fact that these factors taken together are essential for boosting sheep's genetic potential, research in the study area according to this is limited.

Sheep have a high genetic capacity for producing meat and skin. However, the productivity of sheep is often limited by various factors, such as feed and water shortages, diseases, rangeland reductions, and other related management practices (Obeidat *et al*., 2014). Descriptions of husbandry practices, knowing the breeding objectives, understanding selection criteria, and trait preferences are important issues to improve and conserve the indigenous sheep types in their natural production environment in the development of CBBPs (Yakubu *et al*., 2020). An approach to the producers' desired traits and selection criteria is required to assist breeders in effectively designing sustainable genetic improvement programs that would make possible the development of appropriate sheep genotypes that match the prevailing socio-economic and cultural environments. So, the author initiated collecting related information and gave the best recommendation for the future reproductive improvement of the indigenous sheep populations. Therefore, applying such approaches to the improvement of indigenous sheep populations in the study area is crucial. The study was carried out to address these issues with the following objectives:

1.2. Objective

1.2.1. General objective

- To determine the existing husbandry practices, breeding objectives, and selection criteria of indigenous sheep populations, including phenotypic characterization, in the study area.

1.2.2. Specific objectives

- To identify the husbandry practices of indigenous sheep populations in the study area.
- To identify the ultimate breeding objectives of indigenous sheep populations in the study area.
- To identify the ordinary selection criteria of indigenous sheep populations in the study area.
- To describe the phenotypic characteristics of indigenous sheep populations in the study area.

2. LITERATURE REVIEW

2.1. History of Sheep Domestication

The first step begins after the wild animal assumes that they are in a controlled environment, which is changing their behaviour. The change in the behaviour of the domesticated animal is directly related to the word "tame" and is considered a continuous process (Oldenbroek and van der Waaij, 2014). Sheep domestication is also related to a biological context in which the domesticated sheep benefit from successful reproduction while humans gain valuable products from them; this type of biological relationship between sheep and humans is known as mutualism, which is directly related to the term co-evolutionary process; this is the most appropriate perspective of domestication (Gifford-Gonzalez and Hanotte, 2011).

The current sheep types in Africa are classified into two groups based on their tail types: thin-tailed and fat-tailed or fat-rumped. Due to the wide range of adaptability of the introduced sheep, the existing sheep types in different parts of Africa not only differ in tail type but also differ in coat color, horn shape, face profile, and body conformation (Gifford-Gonzalez and Hanotte, 2011). In the present day, sub-Saharan African domestic sheep (*Ovis aries*) have substantial genetic resources, with an estimated 170 breeds (Meillour, 2022). In Africa, over 87% of sheep are classified as indigenous populations that are kept through traditional farming practices (Molotsi *et al*., 2017).

2.2. Adaptation Behavior of Sheep to Various Agro-ecologies Zones in Ethiopia

Ethiopia makes up the larger part of the “Horn of Africa,” which is thought to have been a gateway for the introduction of most livestock (especially both cattle and sheep) from the Middle East into Africa, resulting in extensive genetic diversity of native livestock (Edea *et al*., 2017). Sheep are greatly adaptable to a broad range of environments. They can utilize a wide variety of plant species and can be raised under mixed grazing conditions complementary to goats, cattle, and camels. They can efficiently utilize marginal and small plots of land as well. There is a faster turnover of capital because sheep sexually mature early and are young at their slaughter age. Smaller carcasses are also easier to market and consume in a short period of time (Geatachew and Ashenafi, 2020). The variation in tail type and shape relates to the ability of the local sheep to adapt to changes in feed supply. It might be true that local sheep are fat-tailed in feed scarcity areas with a developed mechanism for energy reserving and thin-tailed in feed excess areas (Agraw *et al*., 2023).

2.3. Population Size of Sheep in Different Region of Ethiopia

The distribution of the sheep population in different regions of Ethiopia is displayed in Table 1. The statistics in CSA (2021) indicated that the Somali, Amhara, Oromia, Sidama, and Afar Regions together represent 94% of the total national sheep population. The remaining 6 percent of sheep are mainly distributed in Tigray, Southern Nations, Nationalities, and Peoples (former), Benishangul-Gumuz, Dire Dawa, Gambella, and Harari Regions (Diribi and Getiso, 2022).

Table 1. Geographical distribution of small ruminant populations in Ethiopia

Geographical area	Sheep distribution	Goat distribution
Tigray	2,097,619	4,838,969
Afar	4,476,845	8,843,082
Amhara	10,391,582	7,045,305
Oromia	9,752,385	8,425,727
Somale	11,013,491	16,464,505
Benishangul-Gumuz	61,335	446,323
Sidama	4,561,504	5,518,806
SNNP	467,858	308,903
Gambella	27,789	135,494
Harari	5,497	110,499
Dire Dawa	59,320	325,922
Total	42,915,225	52,463,535

Source: (CSA, 2021).

2.4. Sheep Breeds in Ethiopia

The sheep found in Ethiopia could fall into different breeds and types whose distribution ranges from midland to highland environments. Sheep were domesticated as dual-purpose animals to produce wool and meat; early peoples would have valued sheep milk as well (Diribi and Getiso, 2022). Like those of many other African countries, indigenous sheep in Ethiopia exhibit a wide variety of morphologic or genetic variability. Six breed groups and nine breeds of indigenous sheep are currently named in Ethiopia based on morphological traits, genetic differences at the DNA level, tail type, and hair type (Rekik *et al*., 2020).

Table 2. Indigenous sheep breed groups and breeds in Ethiopia

Breed group	Breed	Tail type/shape	Fiber type
Short-fat tailed	Simien, Sekota, Farta	Fatty and short	Fleece
	Tikur, Wollo, Menz	Fatty and short	Fleece
Washera	Washera	Fatty and short	Hair
Thin-tailed	Gumuz	Thin and long	Hair
Long-fat tailed	Horro	Fatty and long	Hair
	Arsi	Fatty and long	Hair
Bonga	Bonga	Fatty and long	Hair
Fat-rumped tail	Afar	Fat rump/fat tail	Hair
	BHS	Fat rump/tiny tail	Hair

Source: Gathered from (Gebremichael, 2008)

2.5. Socio-Economic Importance of Sheep Production in Ethiopia

Sheep are relatively cheap and often serve as the first asset obtained by a young family or a poor family to recover from disasters such as drought or war, whether by purchase or receiving as a gift. If sheep and goats are once acquired, they become an important asset, providing security as well as milk and dairy products to the household. Farmers and pastoralists in the subsistence sector depend on small ruminants for a large portion of their income, usually to a greater extent than cattle, because sheep are often owned by the poorer parts of the community (Bachano and Monenus, 2022).

Sheep have a short generation interval and a high frequency of multiple births, which leads to rapid increases in the number of animals. This raises financial capital and allows for the sale of surplus animals for cash, which can then be used for other household expenses, such as school tuition, medical costs, clothes, and so on (Welday *et al.*, 2022). There are no banking services in most rural areas as usual, so purchasing sheep and goats is a simple way to save money for future needs. Small ruminants have been referred to as the 'village bank' in certain areas. It should be emphasised that this is in addition to the cash merits of the animal. Small ruminants account for 40% of the cash income and 19% of the overall value of subsistence food derived from all livestock production, despite accounting for only 7% of the average total capital invested in livestock in the mixed crop-livestock production system in Ethiopia (Sisay *et al.*, 2021).

2.6. Sheep Production System in Ethiopia

The production environment, availability of resources (particularly land, feed, and water), long-standing tradition of agricultural production in the community, socio-economic circumstances (awareness and skill), and government support (access to inputs, services, and markets) resulting from agricultural policies all influence the choice of farmers/pastoralists for agricultural enterprises in Ethiopia. Sheep and goats are important in a subsistence-oriented traditional production system because they require little initial capital and maintenance expenses, can utilise marginal land and crop residues efficiently, generate milk, meat, and wool in readily usable quantities, and are easily cared for by most family members, including smaller children and elderly persons. Furthermore, sheep are critical in feeding the developing world's rapidly rising population under typical difficult environmental conditions (Jemberu *et al*., 2022).

Ethiopia is a country where a traditional sheep-producing system takes place largely. The traditional sheep production system in Ethiopia consists of mixed crop-livestock production systems, pastoral and agro-pastoral production systems, government ranches for breeding and multiplication centres, and peri-urban production systems; each has its own set of production goals and priorities, management strategies and practices, and production constraints (Gebreslase, 2021). The production systems of sheep in Ethiopia are grouped into five categories based on the degree of integration with crop production, contribution to livelihood, level of production input, intensity of production, type of agro-ecology, length of growing period, land usage, and type of commodity used in the production of sheep (Molla, 2020).

2.6.1. Highland sheep-barley system

The highland sheep-barley production system is practiced in most high-altitude areas of Ethiopia (3000 metres above sea level), where the major crops grown are barley and pulses such as fava beans, lentils, etc. Sheep are the dominant livestock species in the area compared to other livestock species. The main feed resource base in the area includes wasteland grazing, stubble feeding, and sometimes straw feeding. Sheep flock sizes range from 30 to several hundred heads in the area, which indicates that sheep rearing is highly practiced in the area. Sheep are reared mainly for meat, skins, and coarse wool production in the cottage industry, which are subsidiary products of sheep in the central Highlands of Ethiopia (Abegaz *et al*., 2008).

2.6.2. Mixed crop-livestock production system

The mixed crop-livestock production system is predominantly found in highland agro-ecological zones where the climatic factors are conducive to farming crops and raising livestock. This system is generally found in areas where the altitude ranges are between 1500 and 3000 meters above sea level. The area has adequate rainfall and a moderate temperature; therefore, it is suitable for grain and livestock production. In this production system, livestock and crops are maintained as complementary enterprises. The average land size per household is often less than two hectares. On the other hand, the sheep owners in mixed crop-livestock production agreed that they brought their sheep from different areas such as Somalia, Harerge High Land, Afar, and West Hararghe. Sheep owners in this production system believe that their sheep do not have a uniform coat color and tail type like those of the BHS sheep but rather are intermixed. This is because purchasing sheep from the pastoral and agro-pastoral systems and fattening/managing them in the mixed crop-livestock production system is common practice in the area (Abegaz *et al*., 2008).

Small ruminant production systems have been found to be associated with various agricultural production systems that vary in the potential intensity of the mixed farming operation and the natural resource base, including grazing and livestock resources. Furthermore, in highland agro-ecology, such as in central Ethiopia, the growing human population has resulted in smaller farm sizes and a gradual shift away from keeping large to small ruminants, particularly goats and sheep (Chufa *et al*., 2022).

2.6.3. Pastoral and agro-pastoral systems

The major sheep breed in pastoral and agro-pastoral areas is BHS, which is distributed within the Somali Regional State and in some parts of the Oromia Regional State. The population of sheep is on a decreasing trend, though there is significant variation between production systems (pastoral and agro-pastoral systems). The possible reasons for this decreasing trend are mainly due to drought (pastoral production system), feed shortage, and disease (Nigussie *et al*., 2015).

2.6.4. Ranching system

The ranching system is a range-based system of livestock production similar to the pastoral systems but with different production parameters, livestock functions, and management. The system can be considered a modern land-use system. The main function of this system is to generate cash income. Both highland and arid ranching can be undertaken in Ethiopia (Abegaz *et al*., 2008).

2.6.5. Urban and peri-urban production systems

Farming and trading are the most common occupations for sheep producers in peri-urban and urban areas, respectively. Additionally, sheep producers in urban areas work as technicians, teachers, civil servants, and retired individuals (Hakimi, 2021). In some peri-urban areas, natural pasture grazing, crop residue, and grass hay are the major feed resources, whereas in other areas, wheat bran and Niger seed cake are the major feed resources. By-products from local breweries and legume grain processing are also considerable feed resources in peri-urban areas (Tsega *et al*., 2014).

2.7. Husbandry Practice of Sheep

2.7.1. Feed resources and grazing managements of sheep

Green pastures and crop residues are the main feed types available in Ethiopia (CSA, 2021). Natural pasture is the primary feed source for livestock and is abundant during the rainy season. In some areas, it is harvested during wet seasons and conserved as hay for use during dry seasons when feed scarcity occurs (Duressa *et al*., 2014).

Feeding crop residues (maize and sorghum stovers and straws of barley, *teff*, and wheat), parts of root and tuber crops (cassava, sweet potato), sugar cane, grains, parts of *enset* and banana plants, weeds and tillers from crop fields, and leaves and browses from local trees are major feed resources for sheep in different seasons of the year (Admasu *et al*., 2017).

Human feed leftovers, local minerals (bole), and other agro-industrial by-products from the local beverages are supplemented to improve the utilization of crop residues and roughages. After crops are harvested, livestock freely graze on grazing and crop lands, and afterward, either they graze (tethered) or under the supervision of herdsmen (Admasu *et al*., 2017).

2.7.2. Watering practices of sheep

The major water sources for sheep are rivers, pipe water, local ponds, groundwater, springs, and rainwater. Watering sheep in different livestock production systems depends on the season, the production environment, and the moisture content of the sheep feed, which is common in different parts of Ethiopia. Farmers' sheep watering frequency is mainly classified as freely available, once a day, once every two days, and once every three days (Nigussie *et al*., 2015).

2.7.3. Milking practices of sheep

To improve milk production, a realistic alternative would be applied to select breeding rams directly based on their breeding values for milk yield coming from related daughters (Gebreslase, 2021). All Afar pastoralists milk their ewes twice per day and use the milk mostly for home consumption. The only exception that ewes are not milked is when they are in poor condition at lambing or when lambing occurs during the dry season. The pastoralists stated that the lactation length ranged from 1.5 to 6.0 months, depending on the parity and condition of the ewe and the availability of feed. Sheep milk is commonly used for the preparation of a local drink known as *'hashara'*, which is prepared by boiling sheep and/or goat milk in water and roasted coffee hulls. Pastoralists prefer sheep milk for butter making due to the perceived higher fat content (Getachew *et al*., 2010).

2.7.4. Shearing practices of sheep

Sheep shearing is the process by which the woollen fleece of a sheep is cut off. The person who removes the sheep's wool is called a shearer. In the Menz area, the shearing of sheep is common and is done twice per year. The first shearing usually occurs between August and October, and the second shearing occurs between April and June. The sheared wool is utilized by smallholder farmers for manufacturing local blankets and carpets or sold for income generation to fulfil different household expenses (Getachew *et al*., 2010).

2.7.5. Culling criteria for rams and ewes

Most smallholder farmers practice excluding both rams and ewes with small body sizes from their flocks that are not preferred for breeding purposes. Likewise, sheep with unwanted coat colors are not preferred for breeding purposes by the smallholder farmers who practice culling sheep due to the unwanted coat color. Furthermore, rams and ewes could be culled due to old age and different fertility problems. The average culling age for breeding ewes due to old age is 9.78 years, while rams are excluded from the flock much earlier than ewes in many parts of Ethiopia. Moreover, the poor mothering ability of indigenous female sheep, which is implicated largely in lamb growth performance and lamb survival, is one of the main culling reasons for female sheep. The smallholder farmers believed that the sheep body condition fluctuation occurs mostly due to seasonal variations in the availability of feed (Abebe *et al*., 2020).

2.8. Growth Performance of Sheep

To evaluate sheep meat and other production potentials, growth performance is an important character that determines the overall productivity of the flock and the economic return from the sheep production enterprise. Although heredity dictates the maximum amount of growth and development, along with other environmental factors, nutrition governs the actual rate of growth and extent to which development is attained (Solaiman, 2010).

2.9. Early Body Weight and Growth Rates of Sheep

Lambs with higher birth weights are expected to grow faster in life. The birth weight of a lamb is strongly influenced by breed. It is also affected by the sex of the lamb, birth type, age of the dam, feeding level, season of birth, and production system (Lakew *et al*., 2014).

2.10. Breeding Objectives and Trait Preferences of Sheep

The main preferred traits of sheep are income, meat, manure, hair, savings/assets, ceremonies, wealth, religious festivals, skin, and milk. Sheep rearing for income generation and household meat consumption is common and has many contributions to livelihood, especially as an alternative income source for the poor family. Given the breadth of purposes that farmers have for keeping sheep, much care is required in the choice of breeding objectives and breeding strategies, as the function of the animals is closely linked to the traits desired by the producers (Jimmy *et al*., 2010).

2.11. Selection Criteria and Breeding Practices of Sheep

The most important selection criteria for breeding ewes are mothering ability, body size, coat color, and horn for sheep keepers. Body size, followed by growth rate and coat color is the most important selection criteria for breeding rams. The preference for big body size and fast growth rate as the preferred traits since the main purpose of keeping sheep is for cash sources (Kerga, 2021). Animals with large body sizes are in high demand in the market and bring good local market prices (Abebe *et al*., 2020). For ram selection, the farmers' target is not only breeding purposes but also taking into account the traits that affect market value (Nigussie *et al*., 2015). Sheep producers further stated that rams with any defects or visible injuries on the testis are not selected for breeding. Sheep producers who do not have breeding rams stated that they tend to borrow rams from neighbours or mate their breeding ewes at random with rams present in the flocks on adjacent grazing land and watering points. Uncontrolled natural mating is a common practice for most sheep keepers (Kerga, 2021).

2.12. Level of Reproduction in Indigenous Ethiopian Sheep

Ewes are seasonally polyestrous, meaning they cycle through estrus (heat) every 16–17 days during the breeding season. The length of the estrus is influenced by factors such as breed, age, the presence of a ram, and the season. Age at puberty, age at first lambing/kidding, parturition interval, litter size, number of lamb crops per reproductive lifetime, and fertility indices are all common measures of reproduction in sheep and goats (Sisay *et al*., 2021).

2.12.1. Age at first lambing

Age at first lambing is calculated as the difference between the birth date of ewes and the first lambing date of ewes. Age at first lambing (AFL) is an important reproductive trait, as greater population turnover and more rapid genetic progress can be obtained when sheep produce their first offspring at an earlier rather than later age. Early-maturing females are known to have a relatively long and fruitful reproductive lifetime. Data on the average age at first lambing for most of the indigenous sheep in Ethiopia are between 11 and 16 months, which means most sheep breeds tend to have their first offspring before they are two years old (Ayele and Urge, 2019).

2.12.2. Lambing interval

The duration between two successive parturitions is known as lambing the interval (LI). Under traditional management, the lambing interval for most Ethiopian indigenous sheep ranges between 7 and 10 months. These variations might occur due to differences in breed, season, lamb sex, type of delivery (single or twin), parity, post-partum body weight, and management practice for the given ewe in many parts of Ethiopia (Hussein, 2018).

2.12.3. Litter size

Litter size is defined as the number of progenies born per parturition of an animal. Litter size is one of the most important reproductive parameters, affecting the productivity of a dam and thereby the sustainable profitability of a given farm. Litter size is a trait that depends on ovulation rate and is affected by the number of fertilized oocytes in the reproductive tract of the female animal. The higher the ovulation rate, the more oocytes will be available for fertilization during the estrous and increase the possibility of producing a larger litter per parturition (Drouilhet *et al*., 2013).

Table 3. On-farm reproductive performance of some indigenous sheep breeds in Ethiopia

Sheep breed	AFL (month)	LI (month)	LS	Productive lifetime	Lamb crop in lifetime	Sources
Gumuz	12.5	10.4	1.7	6.7	9.8	Asmare *et al*. (2021)
Menz	15.22	8.5	1.13	-	-	Mekoya (1999)
Washera	11.6	9.2	2.4	6.6	12.2	Asmare *et al*. (2021)
BHS	24.07	11	1.04	13.11	9.53	Abdilahi *et al*. (2023)
Bonga	13.9	8.5	1.46	-	-	Abate *et al*. (2020)
Horro	13.3	7.8	1.36	7.4	15.3	Edea (2008)
Arsi-bale	15	8.06	1.7	-	11	Diriba (2020)
Adilo	14.6	-	1.42	-	-	Getahun (2008)
Afar	-	9	1.03	-	-	Getachew (2008)

AFL= Age at first lambing; LI = Lambing interval; LS = Litter size

2.13. Farm Animal Genetic Resources

The most common domestic farm animal genetic resources in Ethiopia can be categorized into mammalian, avian, and honeybee species (Assefa *et al*., 2021). Ethiopian farm animal genetic resources comprise tropical livestock units of cattle, sheep, goats, chickens, horses, mules, donkeys, and camels, while the number and distribution area of these various farm animals are different according to a recent estimation of CSA (2021).

Animal genetic resources are important subsets of biological diversity that are composed of the breeds and strains of domesticated animals that humankind has developed out of some 40 wild species over the last 10,000 years (Valle Zárate *et al*., 2005). A previous attempt that has been used for the last 5 decades to increase productivity in Ethiopia is by crossbreeding locally adapted breeds with imported exotic animals. The approaches failed in most cases due to the poor adaptability of exotic breeds, which resulted in the dilution of genetic resources in urban and peri-urban production systems. The new approach gaining global interest is small ruminant community-based breeding program (CBBP) and conservation-based utilization in all livestock species that have been run by confirmed substantial genetic gain and economic benefit (Haile *et al*., 2018).

2.14. Phenotypic Characterization

Body Weight and Linear Body Measurements

The agro-ecological zone, age, and sexual variations had a substantial impact on the majority of the physical traits when morphometric measurements were done in different parts of Ethiopia for various farm animals. For instance, the impact of the agro-ecological zone on a number of quantitative traits, such as ear length, rump length, tail length, and heart girth, was greater in ewes than in rams (Hailu *et al*., 2020). Body measurements in sheep have a high value in predicting live body weights in animals. In most cases, subjective assessments (such as visual judgement and loin area palpation) are typically used to set market prices. Estimating the market price using live weight is critical for fair and better bargaining practices (Lakew *et al*., 2018).

It is very difficult to obtain an exact measurement for this highly important feature (live weight) due to the lack of a weighing scale, especially in distant rural areas. Estimating small ruminant live weight is critical for farmers' good animal management, which includes understanding medicine doses, regulating feed supply, monitoring growth, and selecting replacement males and females based on their body weight (Birteeb and Lomo, 2014).

2.15. Sheep Production Constraints

The major constraints affecting sheep production are feed and grazing land shortages, lack of money, disease occurrence, water scarcity, and the loss of sheep by predators. Among these constraints, feed shortage, lack of money, and diseases are the top three sheep production constraints (Welday *et al*., 2019). All species of animals graze together in communal grazing lands and fallow lands; in this type of grazing system, lambs are usually more vulnerable to the effects of feed shortage and malnutrition, and as a result, the mortality of lambs increases (Kerga, 2021).

2.16. Major Diseases and Parasites of Sheep

The most frequently mentioned diseases that cause productivity losses for small ruminants in Ethiopia are ectoparasites, including ticks, fleas, lice, and mites. Gastrointestinal parasites and their intermediate stages (including *Haemonchus spp*., *Trichostrongylus spp*., and *Cysticercus tenuicollis*) and sheep/goat pox are the second and third most frequently mentioned diseases in Ethiopia, respectively (Armson *et al*., 2020).

2.17. Community-Based Breeding Programs

Community-based breeding programs (CBBPs) are owned and run by small-scale farmers who undertake animal identification, performance and pedigree recording, and systematic selection in their flocks (Mueller *et al*., 2015). Typically, the farmers prioritize breeding objectives and selection criteria as a community, which they then pursue in small-scale one-tier or two-tier breeding structures (Haile *et al*., 2020). CBBPs have been implemented in Africa (Burkina Faso, Ethiopia, Malawi, Sudan, Tanzania, Uganda), South and Central America (Argentina, Bolivia, Mexico, Peru), and Asia (Iran) for different livestock species (Kaumbata *et al*., 2021). Several aspects of CBBPs have been investigated, including livestock keepers' selection criteria and breeding goals and simulation modelling of potential genetic gains for diverse traits. However, what has yet to be investigated is the possible effects of farmer-driven selection on the genomes of CBBP animals (Wurzinger *et al*., 2021).

2.18. Conservation Methods of Animals

2.18.1. Ex-situ conservation:

Ex-situ conservation is done through cryo-preservation of animal germplasm by storing sperm, oocytes, and embryos, and also through the preservation of live animals that are endangered breeds out of the area where they were originally kept. The facilities in Ethiopia for this technique are not well developed. The germplasm can be collected in Ethiopia and may be stored in countries where facilities are available (Abdurehman, 2019).

2.18.2. In-situ conservation:

In-situ conservation is the preservation, multiplication, and utilization of indigenous breeds in their native habitats and the maintenance of pure breeds. The minimum number of animals recommended for sheep is 60, and the maximum is 1500 ewes (Abdurehman, 2019).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted in the Meskan and Soddo districts of the East Gurage Zone in the central part of Ethiopia on indigenous sheep populations. The map of the study area is indicated in Figure 1.

Meskan District

Meskan is one of the four districts in East Gurage Zone, Central Ethiopia Region, and the district is located 135 km away from Addis Ababa via the southwest direction in the Central Ethiopia Regional State of Ethiopia. Meskan district is bordered on the south by the Siltie Zone, on the west by Muhor Na Aklil district, on the northwest by Kokir Gedebano district, on the north by the Oromia Region, on the northeast by Soddo district, and on the southeast by Mareko special district. The capital town of the Meskan district is Butajira. Meskan was part of the former Meskan-Mareko district. The Meskan community is settled in the Meskan district and Butajira town administration. The current population number of Meskan district is 139,270; of this 87,933 are men and 91,786 are women (Meskan District Health Bureau in 2023), of which the Meskan ethnic group constitutes the majority. Compared to the Sebat Bet Gurage ethnic groups, migration to other parts of Ethiopia is less common among the Meskan people. Less than 5% (which is 6,963.5) of the total population is believed to have migrated from rural to urban towns in Meskan. Meskanigna is an Afro-Asiatic language spoken by the Gurage people in the East Gurage Zone of Ethiopia; it belongs to the family of Ethiopian Semitic languages.

Meskan district is located in the altitude range of 1501-3500 m.a.s.l. The mean annual rainfall of the area is between 1001mm and 1200mm. The topographical aspect of the area is 10% highland, 55% plain, and 35% sloppy. The agro-ecology in the district are 20% Dega and 80% Weyna Dega. The total area covered by the district is 50,177 ha, of which the land used for cultivation is 13,579 ha; the land covered with grazing pasture, forest, and shrubs is 25.22 ha; and the remaining land is covered with others (such as building houses, mountains, and rivers). Topographically, the area is characterized by massive mountainous terrain (such as Zebidar Mountain) on the western border of the district, whereas the eastern part is dominated by plain land. The maximum annual temperature does not exceed 26^{o}C and the minimum annual temperature varies from 11.2 to 19.2^{o}C. The living style of the majority of dwellers is similar and depends on agriculture, using mixed livestock-crop production. The main crops cultivated in the district are maize, wheat, *teff*, chat, and barely.

Soddo District

Soddo is one of the four districts in the East Gurage Zone, Central Ethiopia Region, and is 100.6 km far from Addis Ababa in the southwest direction in the East Gurage Zone of the Central Ethiopia Regional State of Ethiopia. Soddo district is bordered on the south by Meskan district and on the west, north, and east by the Oromia Region. The administrative center of Soddo is Buei; In addition, there are other towns in Soddo district, such as Tiya and Suten. The Soddo Gurage people primarily inhabit in Soddo district, East Gurage Zone, but large amounts also live in various parts of Ethiopia, particularly in Addis Ababa, Nazret, Butajira, and Dire Dawa.

The Soddo Gurage language, traditionally and locally known as *Kistanigna*, is one of the Gurage languages from the north-eastern group, which is classified as one of the clusters of the South Ethio-Semitic language family. *Kistanigna* is generally considered closer to the Amharic language than the other Gurage languages. Some *Kistane* oral sources claim that they descended from the northern parts of Ethiopia, in places such as Axum, Gojjam, Gonder, and Bulga. The system of traditional governance of the Soddo *Kistane* people is known as *Ye Gordena Sera*, which was thought to have been founded in a place called Enjeri in the present Nurena area and is often referred to interchangeably as *Ye Enjeri Sera*.

Landmarks in this district: Soddo is sometimes referred to as the site of numerous historical places, such as the *Medrekebd Abo* monastery, which is located 22 kilometres apart from Buei, and the monolithic church *Adadi Mariam*, which is a testament to the area's strong and long links with Christianity. Another local landmark is the *Geyet Gereno* Stelae, which is a complex of about 100 stones located 14 kilometres apart from Buei with similarities to the monolithic UNESCO World Heritage Site Tiya Stelae, which is also located in this district. The Soddo district has a total population of 56,673, of which 28,248 are men and 28,425 are women; 15.19% of its population are urban dwellers (Soddo District Health Bureau, 2023). Soddo district, located at an altitude of 2,300 meters above sea level. The annual rainfall in this region ranges from 1,000 to 2,200 millimetres. The maximum annual temperature does not exceed 27^{o}C and the minimum annual temperature is not less than 10^{o}C. The three main ethnic groups settled in Soddo district were the Soddo Gurage (85.25%), the Oromo (11.58%), and the Amhara (1.47%); all other ethnic groups made up 1.7% of the total population. Their living style is mostly similar and depends on agriculture, using mixed livestock-crop production. The main crops cultivated in the district are *teff*, maize, wheat, and barley.

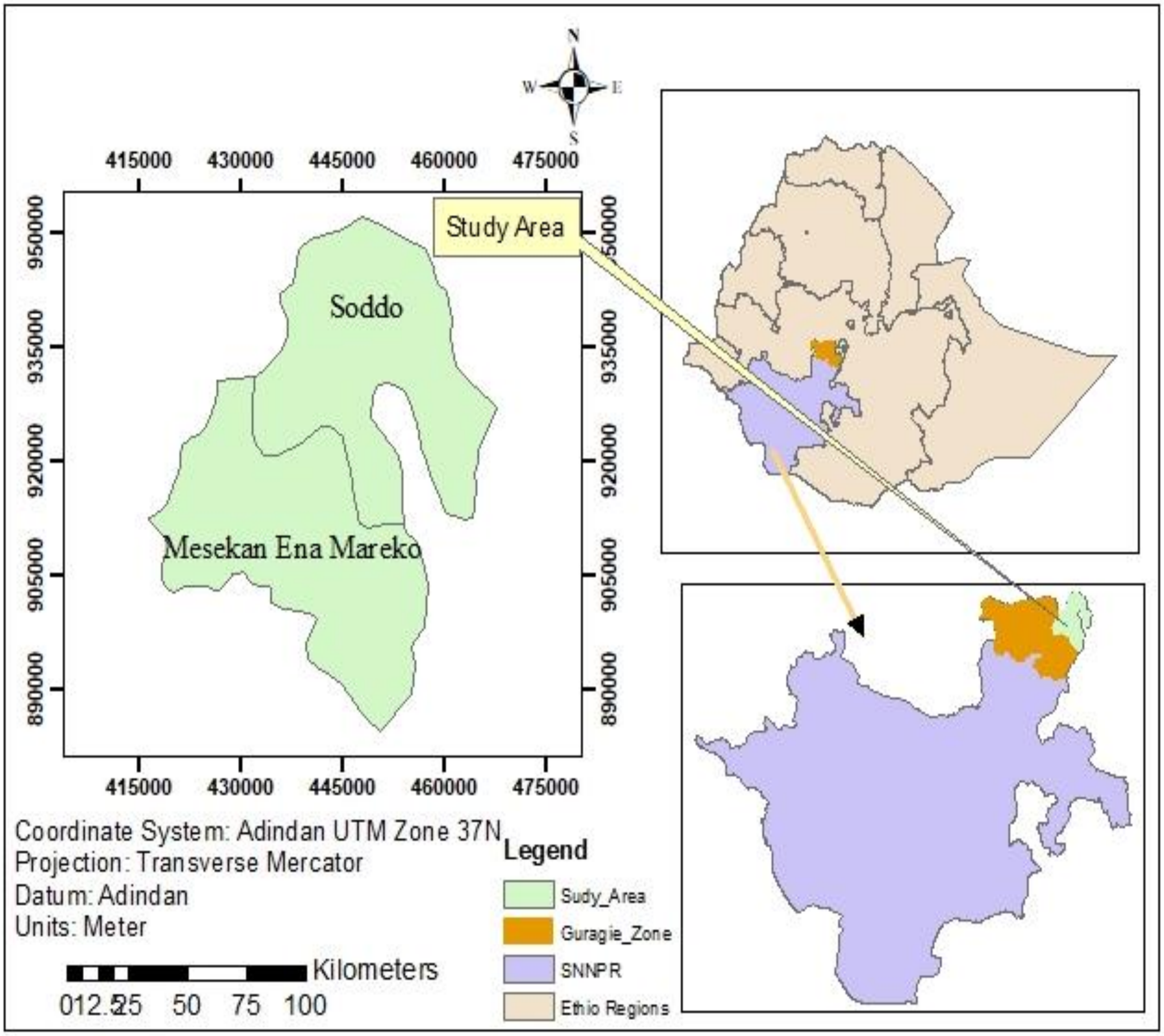


Figure 1. Location of study area on map

3.2. Sampling Techniques and Sample Size

Meskan and Soddo districts were selected purposively based on their sheep production potential. Before deciding on the target kebeles (smallest administrative units within a district), discussions were held with the district experts, development agents, and farmer representatives about the indigenous sheep breeding objectives and the current production systems in the study area. Based on their potential for sheep production and road accessibility to transport, three kebeles were selected from each district. Households having a minimum of three sheep and having a minimum of two years' experience in sheep production practice were identified from the residents' list obtained from the recent statistical data of the respective kebeles. Then by using a simple random sampling method, the author selected a total of 176 households from both districts for the current study.

For the morphological characterization study, both qualitative and quantitative traits of indigenous sheep were measured. Measurements were made on individual animals from 240 randomly selected non-pregnant females and 30 randomly selected males in the study area. Every animal to be measured was identified by sex and dentition. Morphological measurements were taken from each individual animal (1PPI to 4PPI) that was available in the sampled sheep population in the study area. All sampled sheep were individually handled and dentition characters were used to determine the age correlation in each case based on the owner's information.

To get a total sample size relevant to the targeted study, the author applied the formula (Yamane, 1967). Before using the formula, the total population found in each kebele and the target population were identified, and the sample size was calculated from the target population. After determining the sample size, the respondents of each kebele were selected by the proportion of the target population of kebele to the sample size. To increase the reality of the result, a sample was taken from the target population following ICARDA (2018) guidelines from each kebele proportionally. The target populations found were 173 and 141 for the Meskan and Soddo districts, respectively.

$$n = \frac{N}{1+N(e)^2} \qquad n = \frac{173\ +141}{1+314(0.05)^2} \qquad n = 176$$

Where: n = The total sample size of households

N = The target population (the total number of households having a minimum of three sheep including at least one breeding ewe in each selected kebele)

e = The margin of error

Table 4. The proportion of samples to each kebele in both study districts

Descriptions	**Targeted population (Meskan)**				**Targeted population (Soddo)**			
Kebeles	**K_1**	**K_2**	**K_3**	**Total**	**K_1**	**K_2**	**K_3**	**Total**
Targeted population	66	59	48	173	54	46	41	141
HH was selected	37	33	27	97	30	26	23	79

HH = House hold; K = Kebele

3.3. Data Collection Methods

Both primary and secondary information sources were collected and used in this study. The primary data was collected by administering a semi-structured questionnaire via individual interviews, focus group discussions, and key informants, and the secondary data, like climatic data (temperature and rainfall), geographical location, and human and livestock demography, was obtained from the district Livestock and Fishery Office. A modified questionnaire was prepared by adopting a questionnaire organised by ILRI (International Livestock Research Institute).

The questionnaire was pre-tested before the start of the actual study, and some re-arrangements and corrections were made to ensure the respondents perception. To make the questionnaire language easily understandable by the respondents, it was translated into the local (Guragigna) language. Enumerators were recruited and trained on the questionnaires to administer the household with the help of the author.

Objectives of keeping sheep, sheep flock size and structure, practices of breeding in sheep, and criteria of selection for sheep were collected by the author with the aid of trained enumerators. Additionally, data was collected from the focus group discussion. The group was formed by sheep farmers, elders, local leaders, socially respected individuals, women, and livestock experts. The history of sheep, sheep utility patterns, the main constraints of sheep production, and unique characteristics of the sheep production system, like social laws and communal land utilization, were the major points of the focus group discussion.

3.3.1. Individual interview

For the individual interview, a semi-structured questionnaire was used for the randomly selected 176 sheep owners whose age was more than 18 years old (97 from Meskan and 79 from Soddo districts), aiming to cover the following topics: general household characteristics, farming activities, livestock ownership, sheep flock structure, sheep production objectives, sources of available breeding rams and ewes, selection criteria for breeding sheep, breeding management, herding mechanism, mating system, fattening strategy, castration method, culling mode, reproductive performance, housing system, and production constraints of sheep. Before conducting the survey, enumerators who knew the community better and the local (Guragigna) language were trained.

In addition to this, a focus group discussion (FGD) was held to discuss husbandry practices, farmers' opinions on breeding objectives, and selection criteria for sheep in the study area. Eight (8) focus group discussion participants from each kebele were collected, and then it was allowed for each participant to express his/her idea freely and equally to avoid unwanted bias in the group. Again, in addition, randomly selected sheep owners were asked to list the different breeding objectives of sheep and criteria for selecting breeding rams and ewes in the stocks.

A comprehensive list of traits was provided to each sheep owner, and each farmer was asked to confirm the importance of the traits they preferred and the direction of the improvement they wanted, such as meat, skin, a combination of them, or other improvements. They were also asked to rank the preferred traits and give the reasons for ranking them accordingly.

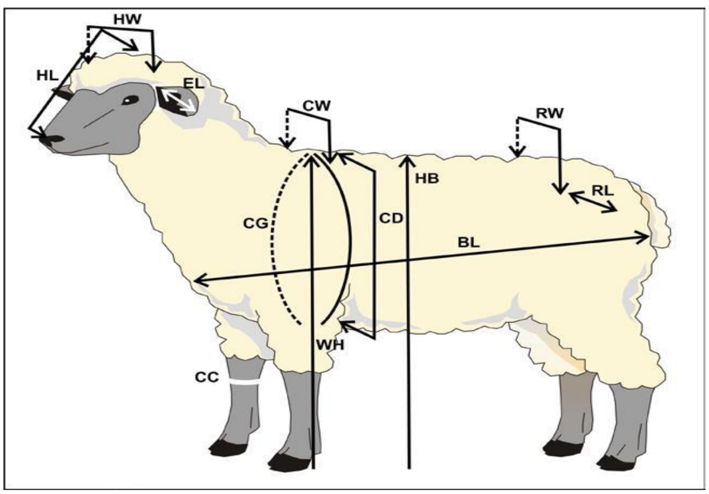
3.3.2. Own-flock ranking experiments

Thirty sheep owners from each selected district were visited early in the morning at their homesteads before the sheep were let out for grazing. The household members were asked to choose the first-best, second-best, third-best, and inferior ewe within their flock. In addition, data on morphological traits like coat color type and pattern, presence of wattle, and others were recorded for each ewe and ram. Size and growth traits like body weight, body length, heart girth, height at wither, ear length, and horn length. Pre-weaning lamb survival was calculated for each ewe as a proportion of lambs that survived to weaning age to the total number of lambs born in her lifetime. The twinning rate was also calculated for each ewe as a proportion of the number of lambs born per ewe's lifetime to the total number of ewe's parity.

Dentation and previous life histories of the ranked female animals were also recorded for reproductive performances like the number of times the ewe lambed, twinning rate, lambing interval, the number of lambs born per ewe lifetime, and the number of lambs that survived; and for male animals, dentation, libido, and temperament were recorded.

Body weight (BW) and linear body measurements (LBM's) such as body length (BL), heart girth (HG), height at wither (WH), ear length (EL), horn length (HL), and others were also recorded for ranked animals. Body weight was measured for each ewe and ram using a suspended spring balance with a 50 kg capacity and 0.2 kg precision. A weighing sack was used to lift sheep during the body weight measurements. The height measurements (cm) were taken using a graduated measuring stick, while the length, width, and circumference measurements (cm) were measured with a plastic measuring tape (1.50 m long with a precision of 2 cm). All measurements were taken before the sheep released for grazing to avoid the effect of feeding and watering on the animals.

The reasons given by farmers for ranking sheep were grouped into five trait categories, which included size and growth traits, survival (like lamb survival and disease resistance) traits, reproductive (like good mothering ability and short lambing interval) traits, coat color (like grey, red, white, and black) traits, and behavioral (like good temperament) traits.



Source, FAO (2012)

Figure 2. Body parts for linear body measurements in sheep

3.3.3. Group-animal ranking experiments

Fifteen breeding ewes and rams from each Meskan and Soddo district were randomly selected. For each selected ewe, information previously obtained from the owners on her dentation, parity, twinning rate, number of lambs born and survived, and lamb growth was used as the ewe's life history. Similarly, dentation, libido, and temperament were used as the ram's life histories.

The selected animals were brought to the central place and randomly assigned into five groups per district (i.e. three animals per group) for each sex. Fifteen farmers who are not familiar with the experimental sheep were invited to rank the animals from each district (Meskan and Soddo). The invited farmers were asked to rank the animals in each group as first, second, and third, with reasons for the ranking of those animals. The procedure was repeated 10 times (i.e. five times for each sex) until respondents covered all animals in the groups.

3.4. Data Management and Analysis

The necessary information obtained from household interviews, field observations, and morphometric measurements was coded and recorded in Microsoft Excel software. The survey data was analysed and presented in the form of descriptive statistics (mean, standard error, frequency, and percentage) by using SPSS software (SPSS version 26). The index for ranking sheep production constraints, common sheep health problems, causes of sheep mortality, sheep breeding objectives, and ram and ewe selection criteria by the smallholder farmers was computed for the first four ranks following the formula: index = sum of (4 for rank 1 + 3 for rank 2 + 2 for rank 3 + 1 for rank 4) given for an individual attribute divided by the sum of (4 for rank 1 + 3 for rank 2 + 2 for rank 3 + 1 for rank 4) for overall attributes.

$$\text{Index} = \frac{[\, R_n * C_1 + R_n - 1 * C_2 \ldots + R_1 * C_n]}{[\Sigma\, R_n * C_1 + R_n - 1 * C_2 \ldots + R_1 * C_n]}$$

Where: R_n = value given for the least ranked level (example, if the least rank is 4^{th}, then $R_n = 4$, $R_n - 1 = 3$, and $R_1 = 1$). C_n = Counts of the least ranked level (in the above formula, the count of the 4^{th} rank = C_n, and the count of the 1^{st} rank = C_1).

Descriptive statistics were employed and organized to summarize and describe the variables that have categorical behaviour. A chi-square was employed when required to test the independence of categories or to assess statistical significance.

Data from focus group discussions was held for their completion before the conclusion of each academic term. Data collected from focus group discussions was summarized, synthesized, and used to better understand the household survey results.

The effective population size for a randomly mated population was calculated as below:

$\text{Ne} = (4\text{Nm} * \text{Nf})/(\text{Nm} + \text{Nf})$

Where: Ne = Effective population size

Nm = Number of breeding males

Nf = Number of breeding females

The rate of inbreeding coefficient (ΔF) was calculated from Ne as ΔF = 1/2Ne (Falconer and Mackay, 1996). Statistical software SAS version 9.4 was used to analyze the data from the own flock and group-animal ranking experiments. The frequency and proportion of breeding ewe and ram traits preferred by farmers in their own-flock ranking and group-animal ranking experiments were also analyzed by the SAS version 9.4 frequency procedure.

3.4.1. Qualitative and body measurement data

Data from the body weight, linear body measurements, and qualitative data for morphological observation were analyzed using the Statistical Analysis System (SAS version 9.4). Qualitative data from the morphological observation was analyzed separately for both sexes in each district using frequency procedures. A general linear model (GLM) of the same statistical analysis system was used to analyze body weight and other linear body measurements (LBMs). The effect of class variables was expressed as means ± standard error (SE).

The statistical model used for the least squares mean analysis was as below:

$Y_{ijk} = \mu + B_i + A_j + S_k + (AS)_{jk} + e_{ijk}$

Where: Y_{ijk} = The observed quantitative measurements on the trait of interest

μ = The overall mean

B_i = The fixed effect of i^{th} district (i = Meskan, Soddo)

A_j = The effects of j^{th} age/dentation class (j = 1PPI, 2PPI, 3PPI, 4PPI)

S_k = The effect of k^{th} sex (k = male, female)

$(AS)_{jk}$ = Interaction effect of j^{th} dentition class and k^{th} sex

e_{ijk} = Effect of random residual error associated with quantitative measurements

The morphometric trait measurements between districts, sex, age, and sex × age were determined to provide evidence on the existing association between live body weight and other linear body measurements. District, sex, and age were the main sources of variation or fixed effects; additionally, sex and age were the interactions for live body weight and other linear body measurements.

The Pearson correlation of both sexes with other different characteristics was employed using SAS (version 9.4). The maximum adjusted R^2 and stepwise multiple regression procedures of the SAS (version 9.4) were implemented to estimate body weight from other linear body measurements (LBMs). In the first step, all variables (LBMs) were entered together into the model for the study sheep population by sexes, and then a group of variables having the maximum adjusted R^2 and minimum error mean square (MSE) was selected to develop the best-fitted regression model. In the second step, the variables that were selected by maximum adjusted R^2 and minimum MSE were entered together into the model to find the best-fitted regression equation.

The following regression model was used to estimate body weight from the linear body measurements

For adult males:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + e_j$$

Where: Y_i = The dependent variable (body weight)

β_0 = Intercept

$X_1, X_2 \ldots X_9$ = Independent variables (HG, BL, PW, HW, RH, HL, EL, TL, and SC)

$\beta_1, \beta_2 \ldots \beta_9$ = Regression coefficients of the variables for $X_1, X_2 \ldots X_9$

e_j = Random error

For adult females:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + e_j$$

Where: Y_i = The dependent variable (body weight)

β_0 = Intercept

$X_1, X_2 \ldots X_8$ = Independent variables (HG, BL, PW, HW, RH, HL, EL, and TL)

$\beta_1, \beta_2 \ldots \beta_8$ = Regression coefficients of the variables of $X_1, X_2 \ldots X_8$

e_j = Random error

4. RESULTS AND DISCUSSIONS

4.1. Household Characteristics of the Study Area

The value of information about the gender, age, marital status, and education level of respondents in the study area is illustrated in Table 5. The majority of the investigated samples in the study area were households with a male head. Thus, 87.63% of households in Meskan and 81.01% of households in Soddo had a male as the head of the household, while the proportion of female heads was lower in Meskan (12.37%) than in Soddo (18.99%). The current finding is congruent with Tulu (2021), who investigated that the majority of household heads were male in the Mid Rift Valley of Ethiopia.

The majority of respondents were in the age range of 41 to 50 years, followed by 31 to 40 years. Regarding the age range of 41 to 50 years, Meskan and Soddo represented 37.11% and 44.30%, respectively. This indicates that the majority of respondents were in a productive age range. The current result is in line with the investigation, which found that the highest percentage of sheep keepers were between the ages of 41 and 50 in the Aroresa and Loka Abaya (Tariku *et al*., 2021). In Meskan and Soddo, the majority of respondents were married (86.60% and 78.48%, respectively). The present finding is consistent with Bachano and Monenus (2022), who reported that the majority of respondents were married in Adiyo district, Keffa Zone.

Regarding the educational level of respondents in Meskan and Soddo, 55.67% and 53.16% had attended primary school; however, 18.56% and 16.46% were able to write and read; 16.49% and 7.59% were illiterate; 6.19% and 20.25% had attended secondary school; and 3.09% and 2.53% were university or college degree holders, respectively. The respondents, who attended elementary school, were actively involved in sheep production, particularly in the study area; they have considerable experience in sheep production. The current result is congruent with the report that the average educational level was grade 4 in Kembata Tembaro Zone (Mathewos *et al*., 2021). The illiteracy rate was higher in Meskan (16.49%) than in Soddo (7.59%). This might imply that the willingness of farmers to accept new technology for the productive and reproductive improvement of sheep is rare. According to the key informants report, the relatively higher illiteracy rate in the Meskan district might be due to the problem of access to schools far from residential areas, the lack of stationary materials for schools (text books, supportive guide books), and the lack of computers, with no immediate solution in the last decades.

Table 5. Respondents' characteristics and profiles in the study area

Parameters	Districts							
	Meskan		Soddo		Overall			
	N	%	N	%	N	%	X^2	P-Value
Gender							1.47	0.226
Male	85	87.63	64	81.01	149	84.66		
Female	12	12.37	15	18.99	27	15.34		
Age (year)							6.23	0.183
18-30	9	9.28	11	13.92	20	11.36		
31-40	25	25.77	21	26.58	46	26.14		
41-50	36	37.11	35	44.30	71	40.34		
51-60	26	26.80	10	12.66	36	20.45		
>60	1	1.03	2	2.53	3	1.70		
Marital status							2.26	0.520
Single	9	9.28	12	15.19	21	11.93		
Married	84	86.60	62	78.48	146	82.95		
Divorced	3	3.09	3	3.80	6	3.41		
Widowed	1	1.03	2	2.53	3	1.70		
Education level							9.86	0.043
Illiterate	16	16.49	6	7.59	22	12.50		
Write and read	18	18.56	13	16.46	31	17.61		
Primary school	54	55.67	42	53.16	96	54.55		
Secondary school	6	6.19	16	20.25	22	12.50		
University or college	3	3.09	2	2.53	5	2.84		

N = Number respondent, X^2 = Chi-square

4.2. Family Size and Land Size of Households in the Study Area

The average family size was 5.55 in the overall study area. Meskan accounts for 5.74 and Soddo for 5.30. The current finding is to some extent similar to the average family size (6.26) per household reported in the Dodota district of Arsi Zone (Abera *et al*., 2022).

The mean land owned per household was 1.20 hectares in the overall study area. The difference in landholding size between the two districts was statistically significant ($P < 0.05$), which suggests that smaller landholdings were more common in Meskan than in Soddo districts. The reason might be that in Meskan, there was land degradation as a result of flooding and increased population density due to high settlement opportunities, which were contributing factors. Therefore, as a consequence of this, when the population grew, the land owned per household decreased, and the amount of private grazing land for sheep and other livestock also decreased. The current investigation resembles the finding of Mathewos *et al.* (2021), who indicated that the average landholding per farmer was 1.12 hectares in the Doyogena district of the Kembata Tembaro Zone. However, the present study is more or less in contradiction with Teffera *et al*. (2018), who reported that the majority of households owned less than one hectare of land in the former South Nations, Nationalities, and Peoples Region.

Focus group reports demonstrated that the majority of smallholder farmers in the study area use their own lands for different activities such as growing food and cash crops, building houses, tethering animals during the wet season, and planting trees. Renting land from other farmers is not common in the current study area.

Table 6. Average family size and land holding per household in the study area

Parameters	Districts			P-Value
	Meskan	Soddo	Overall	
	Mean±SE	Mean±SE	Mean±SE	
Family size	5.74±0.12	5.30±0.13	5.55±0.09	0.02
Land holding (in hectare)	1.12±0.06	1.29±0.04	1.20±0.04	0.02

SE = Standard error

4.3. Household Incomes and Farming Activities in the Study Area

4.3.1 Major Sources of income in the study area

The major sources of income for farmers in Meskan during the dry season were crops (80.41%), mixed livestock and crops (8.25%), trade (6.19%), and livestock (5.15%). In Soddo, the major sources of income in the dry season for about 64.56%, 24.05%, 6.33%, and 5.06% of respondents were crops, both livestock and crops, trade, and livestock, respectively. The source of income from livestock was very low in the dry season; this might be due to the absence of natural pasture, which the majority of farmers used for fattening in the study area. Overall, the major source of income during the dry season was crops, accounting for 73.30% in the study area. The present study's result is consistent with the investigation of Tariku *et al*. (2021), who reported that in the dry season, the main source of income was crops in the Aroresa and Loca Abaya districts of the Sidama Region.

The majority of respondents' sources of income during the wet season were in Meskan, mixed livestock and crops (57.73%), crops (22.68%), livestock (12.37%), and trade (7.22%). In Soddo, the sources of income in the wet season for about 50.63%, 24.05%, 15.19%, and 10.13% of respondents were mixed livestock and crops, livestock, trade, and crops, respectively. Overall, the first-most source of income during the wet season was both livestock and crops (54.55%). The current result is more or less similar to the finding of Gedefaw and Gebremariam (2019), who investigated that the main sources of income for most households were crops in Habru district, North Wollo Zone. This might indicate that smallholder farmers in the study area depend more on crops and livestock for income than on other forms of income. Additionally, the reason for some respondents, who practice both livestock rearing and crop cultivation (a mixed livestock and crop farming system), might be to reduce the risk associated with either crops or animals alone.

4.3.2. Major farming activities in the study area

The main farming system in the study area was a mixed crop-livestock farming system (55.11%). This indicates that livestock farming is an essential aspect that is closely associated with crop production. Additionally, this mixed farming system is used for sheep production in terms of storing feed from different crop residues. The farmers raise cattle, sheep, goats, chickens, and donkeys as their major livestock in the study area. Similar to the current study, Tilahun (2023) reported that the majority of respondents practice a mixed crop-livestock farming system in North Shewa Zone, Amhara Region.

Table 7. The major sources of income and farming activities in the study area

Parameters	Districts							
	Meskan		Soddo		Overall			
	N	%	N	%	N	%	X^2	P-Value
Income (dry season)							8.58	0.035
Crop	78	80.41	51	64.56	129	73.30		
Livestock	5	5.15	4	5.06	9	5.11		
Both livestock and crops	8	8.25	19	24.05	27	15.34		
Trade	6	6.19	5	6.33	11	6.25		
Income (wet season)							10.36	0.016
Crop	22	22.68	8	10.13	30	17.05		
Livestock	12	12.37	19	24.05	31	17.61		
Both livestock and crops	56	57.73	40	50.63	96	54.55		
Trade	7	7.22	12	15.19	19	10.80		
Major farming activity							11.25	0.011
livestock production	9	9.28	3	3.80	12	6.82		
Crop production	23	23.71	30	37.97	53	30.11		
Mixed farming	61	62.89	36	45.57	97	55.11		
Trade	4	4.12	10	12.66	14	7.95		

N = Number respondent, X^2 = Chi-square

4.4. Major Crop Grown and Crop Residues Used for Sheep in the Study Area

The main crop grown in Meskan district was maize (55.67%), while in Soddo, the main crop grown was *teff* (54.43%). Maize was the main crop grown (38.64%) in the overall study area. Contrary to the current study, wheat was the major crop grown around Midre-Kebid Abo Monastery, Gurage Zone (Yilmato and Takele, 2019). The crop grown had a statistically significant difference ($P < 0.05$) between the Meskan and Soddo districts. The reason for this difference might be the variation in soil type between the two districts. During the dry season, in the Meskan district maize straw (68.04%), *teff* straw (12.37%), sorghum straw (11.34%), and wheat straw (8.25%) were the main crop residues used as sheep feed. While *teff* straw (53.16%), maize straw (25.32%), wheat straw (13.92%), and sorghum straw (7.59%) were the top four crop residues in Soddo district.

The ample source of crop residue in the dry season might be used to increase the income gained from sheep during the dry season through proper feed conservation methods. The present study is consistent with the investigation of Diriba (2020), who reported that during the dry season, sheep owners used crop residue as a feed source among those available in the Arsi and Bale Zones of Oromia, Ethiopia. During the wet season, in the study area, maize husk (63.64%) was the main crop residue used as sheep feed. The sheep feeding system in the study area had limitations in terms of growing improved forage.

Table 8. Major crops grown and crop residues used for sheep in the study area

Variables	Districts						X^2	P-Value
	Meskan		Soddo		Overall			
	N	%	N	%	N	%		
Major crop grown							34.27	0.000
Barley	4	4.12	6	7.59	10	5.68		
Wheat	15	15.46	9	11.39	24	13.64		
Teff	18	18.56	43	54.43	61	34.66		
Sorghum	6	6.19	7	8.86	13	7.39		
Maize	54	55.67	14	17.72	68	38.64		
Crop residues (dry season)							41.81	0.000
Wheat straw	8	8.25	11	13.92	19	10.80		
Sorghum straw	11	11.34	6	7.59	17	9.66		
Teff straw	12	12.37	42	53.16	54	30.68		
Maize straw	66	68.04	20	25.32	86	48.86		
Crop residues (wet season)							4.33	0.228
Wheat straw	5	5.15	4	5.06	9	5.11		
Sorghum straw	14	14.43	8	10.13	22	12.50		
Teff straw	13	13.40	20	25.32	33	18.75		
Maize straw	65	67.01	47	59.49	112	63.64		

N = Number respondent, X^2 = Chi-square

4.5. Livestock Holding Per-household in the Study Area

The most important livestock species observed in the study area were cattle, sheep, goats, donkeys, and chickens. The average number of livestock species in the study area is described in Table 9. The overall mean of livestock holdings per household was 4.84 sheep, 4.10 poultry, 3.24 cattle, 1.61 goats, and 1.18 donkeys. The current result showed a statistically significant difference ($P < 0.05$) between the two districts for sheep holding. The possible cause of the higher sheep number in Meskan might be due to management and feed sources. In comparison to the Soddo district, there were fewer cattle, goats, and poultry in Meskan. As a result, there was a statistically significant difference ($P < 0.05$) in the number of animals between the Meskan and Soddo districts, except for donkey holding.

Sheep were the predominant species in the study area, accounting for 5.04 and 4.59 average numbers of the individual households in Meskan and Soddo districts, respectively, with flock sizes ranging from 3 to 8 animals. The current survey's 4.84 overall mean number of sheep per household was comparable to Kerga (2021), who reported that sheep were the most common species (4.80) in the Gurage Zone. The current result is quite higher than the finding of Lakew *et al*. (2021), who reported that sheep were raised at a subsistence level in the districts of Kalu (0.64) and Gubalafto (0.42). On the contrary, the current result is lower than the report of Goshu (2021), who investigated that the average number of sheep kept per household was 10.99 sheep in selected districts of Central and West Gondar Zone. The imaginable reasons that influenced the farmers to rear sheep might be the use of sheep as an immediate source of family income, ease of management, short generation intervals, low initial investment need, and ease of marketability.

Table 9. Species composition and livestock holdings per household in the study area

Livestock Species	**Districts**			**P-Value**
	Meskan	**Soddo**	**Overall**	
	Mean±SE	**Mean±SE**	**Mean±SE**	
Cattle	3.01±0.10	3.52±0.13	3.24±0.08	0.002
Goat	1.30±0.14	1.99±0.21	1.61±0.13	0.006
Sheep	5.04±0.13	4.59±0.11	4.84±0.09	0.010
Donkey	1.13±0.06	1.24±0.06	1.18±0.04	0.205
Chickens	3.88±0.18	4.38±0.13	4.10±0.12	0.035

SE = Standard error

4.6. Sheep Flock Size and Composition in the Study Area

The mean flock structure for each category of sheep flock by age and sex in both districts is illustrated in Table 10. The overall mean values per household were 1.90, 0.74, 0.62, and 0.56 for breeding ewes, female lambs, male lambs, and breeding rams, respectively. Similar to the current result, Taye *et al*. (2021) reported that the mean number of breeding ewes per household was 1.97 in the Genji district of West Wollega, Oromia Regional State.

The breeding ewes had the largest proportion in the flocks of both districts, with a mean of 2.05 in Meskan and 1.72 in Soddo districts, followed by ewe lambs and ram lambs. Ewe and ram lambs were known to be used as replacements for breeding flocks in the present study area. This might be attributed to the prevalent practice of keeping ewes for breeding purposes, which contributes to a greater portion of the newly born animals.

The mean number of breeding ewes, male lambs under six months old, and males between the ages of six months and one year in Meskan district was higher than in Soddo, with a statistically significant difference ($P < 0.05$) between the two districts. However, there was no statistically significant difference ($P > 0.05$) between the two districts for the number of breeding rams, female lambs under six months, and castrated males. The present result is in line with the breeding ewes representing a higher number than any other category of sheep in Hadiya Zone (Hemacha *et al*., 2022). On the other hand, compared to breeding ewes, the average value for breeding rams was lower (0.59 in Meskan and 0.53 in Soddo district). The current finding is similar to the report that the majority of farmers owned more breeding ewes than breeding rams for the Gedeo Zone (Tezera and Engidashet, 2022).

Almost all farmers kept mature ewes in the study area. Generally, the investigated average flock size of sheep per farmer in the study area was small compared to most other areas in Ethiopia. For instance, the current result is less than the findings of Abebe *et al.* (2020), who found that the average size of a sheep flock per household was 10.21 in the northwest highlands of Ethiopia. The small flock size of sheep in the current study might be related to a difference in the production system compared to the report cited above. This also might be because higher-quality rams are rarely used for breeding; instead, they were intended for sale at a younger age for free traditional marketing in the study area. If not sold, they were castrated and fattened to be sold later. The breeding ram-to-ewe ratio in the Meskan and Soddo districts was 1:3.47 and 1:3.25, respectively.

The breeding ram-to-breeding ewe ratio was 1:3.39 in the overall present study area, which implies that there were enough rams to mat the existing breeding ewes. The current result is consistent with the result of Teramaj (2020), who reported that the ratio of breeding rams to breeding ewes in the Legambu district of South Wollo Zone was 1:3 in the midlands.

Table 10. Categorical composition of sheep possessed by respondents in the study area

Sex and Age Categories	Districts			P-Value
	Meskan	Soddo	Overall	
	Mean±SE	Mean±SE	Mean±SE	
Male lamb < 6 months	0.74±0.07	0.48±0.07	0.62±0.05	0.012
Female lamb < 6 months	0.71±0.07	0.78±0.07	0.74±0.05	0.466
Male 6 months to 1 year old	0.55±0.07	0.28±0.06	0.43±0.05	0.005
Female 6 months to 1 year old	0.39±0.07	0.62±0.08	0.49±0.05	0.025
Male >1 year (Breeding rams)	0.59±0.07	0.53±0.07	0.56±0.05	0.564
Female >1 year (Breeding ewes)	2.05±0.08	1.72±0.08	1.90±0.06	0.004
Castrated males	0.08±0.03	0.08±0.03	0.08±0.02	0.883

SE = Standard error

4.7. Trends of Livestock Population in the Study Area (in the Last 10 Years)

According to the perception of respondents in the study area, the number of goats decreased by a large amount (81.25%), followed by cattle (67.61%), chickens (46.59%), and sheep (15.91%). The present result corresponds with the finding of Berhe *et al.* (2019), who investigated that the number of goats decreased by larger amounts than other livestock. Respondents claimed that the main causes of this higher decreasing tendency of livestock were rangeland degradation, increased agricultural cultivation, a lack of feed and water, the growth of the human population, frequent disease occurrences, the presence of predators, the cost of living, and drought. On the other hand, the number of sheep was increasing (52.84%) as a result of the district livestock and fishery offices cooperating with different non-governmental organizations to give some breeding sheep and inform the farmers about the rearing system and benefits of sheep production at the level of kebele. The current finding is similar to the result that the number of sheep was increasing better than other livestock species in North Shewa Zone, Amhara Region (Tilahun, 2023).

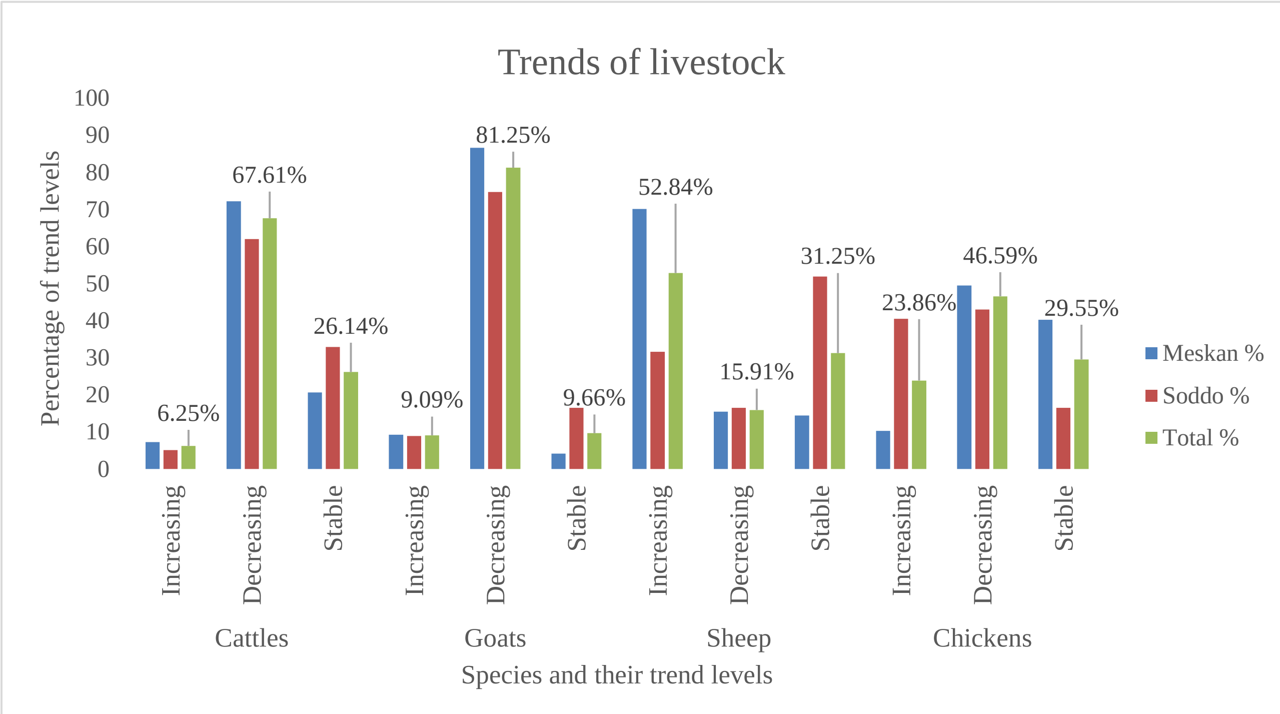


Figure 3. The trend of livestock in the study area (in the last 10 years)

4.8. Husbandry Practices of Indigenous Sheep in the Study Area

4.8.1. Sheep production systems and herding practices

Sheep production systems were classified as semi-intensive and extensive, depending on the advancement of inputs and the intensity of production, according to the current study (as illustrated in Table 11). In the current study area, the majority of respondents reported that the semi-intensive sheep production system, which accounts for about 69.32%, and the extensive sheep production system accounted for 30.68% of the total. Under the extensive sheep production system, low management, poor housing, a lack of feed, and poor sanitation were common features. The current result contradicts the report that the majority of households practice an extensive sheep production system in Harawa (Mahamed and Ali, 2023). The current result is also in contrast with the finding that the primary sheep production system in the Habru district was extensive (Gedefaw and Gebremariam, 2019).

Almost all of the respondents in Meskan (97.94%) and Soddo (98.73%) indicated all classes of sheep herded together. Few of the respondents managed the new-born lambs independently from the herd for some days near the house. The current investigation corresponds with the result that in the Central and West Gondar Zones, all classes of sheep were herded together (Goshu, 2021).

On the other hand, the majority of respondents in Meskan (53.61%) and Soddo (51.90%) said that they kept their sheep mixed with other animals. This might be due to a lack of labour and grazing land in the current study area. In the districts of Meskan and Soddo, about 62.89% and 62.03% of respondents mixed their sheep flocks with other sheep flocks when herding at communal grazing land and watering areas, respectively. The current study is consistent with the result that farmers in Semien Mountain prefer to keep their sheep together with all other livestock, and the majority of sheep owners herded more than one flock of sheep together as a single flock (Mulat *et al*., 2022).

Table 11. Production systems and herding practices of indigenous sheep in the study area

Descriptors	Districts							
	Meskan		Soddo		Overall			
	N	%	N	%	N	%	X^2	P-Value
Production systems							12.51	0.000
Semi-intensive	78	80.41	44	55.70	122	69.32		
Extensive	19	19.59	35	44.30	54	30.68		
Herded in the day time							0.17	0.685
Lambs are separated	2	2.06	1	1.27	3	1.70		
All classes are herded together	95	97.94	78	98.73	173	98.30		
Sheep flock is herded							14.89	0.005
Together with cattle	8	8.25	9	11.39	17	9.66		
Together with goat	7	7.22	17	21.52	24	13.64		
Together with donkeys	4	4.12	5	6.33	9	5.11		
All herded together	52	53.61	41	51.90	93	52.84		
Sheep herded separately	26	26.80	7	8.86	33	18.75		
Way of herding sheep							0.01	0.907
A household run as a flock	36	37.11	30	37.97	66	37.50		
More households run as a flock	61	62.89	49	62.03	110	62.50		

N = Number respondent, X^2 = Chi-square

4.8.2. Sheep housing in the study area

The three different types of sheep housing systems that were observed in the present study area (which means in a family house, a separate house for livestock, and an adjoining house on the side of the main family house) are illustrated in Table 12. In Meskan (71.13%) and Soddo (46.84%), respondents housed their sheep in houses adjoining the main family house; the remaining proportion of respondents in both Meskan and Soddo districts housed their sheep in the main family house and in a separate house constructed for livestock. Almost all sheep owners in the current study area kept their sheep indoors at night. The reason behind this might be to protect the sheep from predators, thefts, and unfavorable weather. The current result is in line with the outcome of Gebregziabhear *et al.* (2019), who reported that the majority of households in Central and Eastern Ethiopia housed their sheep in adjoining main family houses.

The majority of farmers in the current study area built their sheep houses by using locally accessible and marketable materials like wood, iron sheets, plastic sheets, grass/bush, stone/bricks, mud, and concrete to protect the animals from the sun, rain, wind, and thefts. The majority of respondents (67.05%) used iron sheets, followed by grass/bush (26.70%) and plastic sheets (6.25%) for constructing the roofs of their sheep houses. Most of the farmers' sheep house walls (94.32%) were constructed by using wood, and the remaining small proportion of sheep owners constructed their sheep house walls by using iron sheets and stone/bricks. The sheep house floors were mainly (62.50%) made up of stone/bricks, followed by concrete (30.11%) and mud (7.39%). The current study's floor construction material is in contrast with the result that most sheep houses were made up of wooden floors in Genji district (Taye *et al*., 2021).

Almost all farmers (97.73%) housed their newly born lambs with adult sheep in the current study area. This might be due to a lack of money and the difficulty of accessing local construction materials to build a separate house for the newly born lambs. On the other hand, the majority (78.41%) of farmers housed their sheep together with other animals in the study area. The housing system in which all animal species are housed together might highly expose the sheep to mechanical injuries by other large animals in the house. According to the suggestions of respondents, good housing may have a positive influence on sheep productivity by reducing stress, lowering the risk of disease, and simplifying management.

Table 12. Sheep housing and constructing materials for sheep houses in the study area

Descriptors	Districts						X^2	P-Value
	Meskan		Soddo		Overall			
	N	%	N	%	N	%		
Housing adult sheep							10.82	0.004
In family house	15	15.46	24	30.38	39	22.16		
Separate house for livestock	13	13.40	18	22.78	31	17.61		
Adjoining family house	69	71.13	37	46.84	106	60.23		
Material (house roof)							0.67	0.717
Iron sheet	66	68.04	52	65.82	118	67.05		
Grass/bush	24	24.74	23	29.11	47	26.70		
Plastic sheet	7	7.22	4	5.06	11	6.25		
Material (house wall)							0.59	0.743
Wood	92	94.85	74	93.67	166	94.32		
Stone /bricks	1	1.03	2	2.53	3	1.70		
Iron sheet	4	4.12	3	3.80	7	3.98		
Material (house floor)							0.68	0.712
Stone /bricks	60	61.86	50	63.29	110	62.50		
Concrete	31	31.96	22	27.85	53	30.11		
Mud	6	6.19	7	8.86	13	7.39		
Lambs housed							1.50	0.221
With adults	96	98.97	76	96.2	172	97.73		
Separately	1	1.03	3	3.80	4	2.27		
Sheep are housed with							4.79	0.029
With other livestock	82	84.54	56	70.89	138	78.41		
Separately	15	15.46	23	29.11	38	21.59		

N = Number respondent, X^2 = Chi-square

4.8.3. Sheep feed resources and availability in the study area

The various feed sources and their seasonal usage in the study area are illustrated in Table 13. Natural pastures, grazing aftermath, crop residues, shrubs and bushes, by-products of human food, concentrates, established pastures, improved forages, and hay were the various feed sources reported in the study area. The usage of these feed types differed from season to season.

Grazing aftermath (57.39%) and cereal crop residues (18.18%) were the crucial sheep feed sources during the dry season, soon after crops were harvested in the study area. The usage of aftermath starts in November and declines around the end of February due to the beginning of the short rainy season, when farmers prepare their croplands for the next cropping season, and then its importance stops. The current finding is to some extent similar to the result of Abera *et al*. (2022), who reported that in the dry season after harvesting the crops, grazing aftermath was mostly practiced in Arsi Zone.

Feeding of crop residue during the dry season was also a significant source of feed for sheep, which is mostly used in periods of insufficient rainfall. While its usage starts to decrease around the beginning of the short rainy season, when natural pasture begins growing for the next wet season as well, and then its importance stops. Therefore, the conservation of various crop leftovers was a widespread practice in the study districts. Due to the adequate amount of rainfall during the wet season, it was observed that the majority of farmlands were covered with crops, and feeding on natural pasture at grazing land or cutting it in crop lands (65.91%) served as the primary source of sheep feed for farmers in the study area. The current result is congruent with the finding of Abdilahi *et al*. (2022), who reported that the main feed resource for sheep during the wet season in Awbarre district was communal natural pasture.

The main traditional feed sources for sheep were human food leftovers *('rigafoche')* and local brewery and/or coffee by-products *('chombo')*, which are almost always accessible in all seasons, and farmers used them as additional feed sources. The majority of respondents (84.66%) reported being exposed to a seasonal shortage of sheep feed. In the study area, the months of February, March, and April had the greatest animal feed shortage. The current investigation corresponds with the finding that the majority of respondents reported seasonal feed shortages for the South and North Wollo Zones (Tesema *et al*., 2023). The conversion of grazing lands into cultivated lands due to the increase in human population, lack of rain, drought, and low experience of gathering and conserving feed for the dry season might be the main obstacles that cause the shortage of sheep feed in the study area.

Table 13. Major feed sources and a seasonal feed shortage for sheep in the study area

Feed Sources	Districts						X^2	P-Value
	Meskan		Soddo		Overall			
	N	%	N	%	N	%		
Feed sources (dry season)							13.81	0.017
Grazing aftermath	62	63.92	39	49.37	101	57.39		
Shrubs and bushes	5	5.15	3	3.80	8	4.55		
Crop residues	9	9.28	23	29.11	32	18.18		
By product of human food	6	6.19	4	5.06	10	5.68		
Concentrate	13	13.40	6	7.59	19	10.80		
Hay(standing hay)	2	2.06	4	5.06	6	3.41		
Feed sources (wet season)							14.30	0.026
Natural pasture	73	75.26	43	54.43	116	65.91		
Shrubs and bushes	4	4.12	14	17.72	18	10.23		
Crop residues	5	5.15	7	8.86	12	6.82		
Established pasture	2	2.06	3	3.80	5	2.84		
By-product of human food	3	3.09	6	7.59	9	5.11		
Concentrate	6	6.19	3	3.80	9	5.11		
Improved forages	4	4.12	3	3.80	7	3.98		
Is there a feed shortage							4.64	0.031
Yes	77	79.38	72	91.14	149	84.66		
No	20	20.62	7	8.86	27	15.34		

N = Number respondent, X^2 = Chi-square

4.8.4. Grazing land types and grazing methods in the study area

The common types of grazing land, grazing systems used for sheep, and the perception of farmers on the trends of communal grazing land (in the last 10 years) in both study districts are shown in Table 14. The current outcome showed that the majority of respondents were able to get communal grazing pastures (68.18%), followed by tree-covered grasslands (19.32%), and the remaining small proportion of farmers used stone-covered grasslands and their own grazing lands. The small amount of private grazing land per household might indicate that the average total land holding size of the farmers is smaller in the present study area.

According to the group discussion and key informant interviews, grazing on communal grazing pastures was more practical during the wet season before the main crop was harvested in the current study area. In contrast to the present result, the majority of households established their own grazing land in Habru district (Gedefaw and Gebremariam, 2019). The current result is also contrary to the finding that the majority of households had no access to communal grazing land in the districts of Aroresa and Loka Abaya, Sidama Region (Tariku *et al*., 2021). In the current study area, the majority of respondents (73.86%) used herding as their primary sheep grazing system, followed by tethering (13.07%) and free grazing (9.09%) during the dry season, while about 65.34% of respondents used tethered grazing, followed by herding (25.00%) and free grazing (5.68%) during the wet season for their sheep. Similar to the current study, the majority of respondents in Arsi Zone practiced tethered grazing for their sheep during the wet season (Abera *et al*., 2022).

The main reason for tethering sheep during the wet season was to protect crops from damage by animals, but during the dry season, it was rarely done to minimize the use of high labour for managing the sheep and to protect the sheep from thefts and predators, according to the information from respondents. There was a statistically significant difference ($P < 0.05$) between the two districts for the grazing system during the wet season. The possible reason for this difference might be due to the fact that, comparatively, a larger proportion of farmers in Meskan applied tethered grazing systems than the farmers in Soddo, while a larger proportion of farmers in Soddo used herded grazing systems than the farmers in Meskan. According to the perception of farmers in the current study area, the communal grazing lands were declining and getting smaller (88.07%). This might be due to the growing human population and extensive land usage for annual and perennial crop cultivation.

Table 14. Grazing lands and grazing methods for sheep in the study area

Descriptors	Districts						X^2	P-Value
	Meskan		Soddo		Overall			
	N	%	N	%	N	%		
Type of grazing land							18.26	0.000
Communal grazing pasture	61	62.89	59	74.68	120	68.18		
Tree covered grassland	29	29.90	5	6.33	34	19.32		
Private grazing land	3	3.09	7	8.86	10	5.68		
Stone covered grassland	4	4.12	8	10.13	12	6.82		
Grazing (dry season)							6.11	0.107
Free grazing /Browsing	5	5.15	11	13.92	16	9.09		
Herded	73	75.26	57	72.15	130	73.86		
Tethering	16	16.49	7	8.86	23	13.07		
Zero- grazing	3	3.09	4	5.06	7	3.98		
Grazing (wet season)							17.70	0.001
Free grazing /Browsing	3	3.09	7	8.86	10	5.68		
Herded	14	14.43	30	37.97	44	25.00		
Tethering	75	77.32	40	50.63	115	65.34		
Zero- grazing	5	5.15	2	2.53	7	3.98		
Trend of grazing lands							2.80	0.246
Increasing	2	2.06	3	3.80	5	2.84		
Decreasing	89	91.75	66	83.54	155	88.07		
Stable	6	6.19	10	12.66	16	9.09		

N = Number respondent, X^2 = Chi-square

4.8.5. Sheep water sources and watering frequencies in the study area

The water intake of sheep is influenced by the temperature of their surroundings, the temperature of the water they drink, the activity of the animal, and the moisture content of their feed. The main water sources in the study area during both the dry and wet seasons of the year are illustrated in Table 15. In the dry season, the majority of respondents in Meskan (63.92%) and Soddo (49.37%) mentioned that pipe water was the primary source of water for their sheep. Similar to the present study, pipe water was the major source of water for small ruminants in the Arsi Zone throughout the dry seasons (Abera *et al*., 2022).

During the wet season, the majority of respondents in Meskan (34.02%) mentioned that rain water was the primary source of water for indigenous sheep, while the majority of respondents in Soddo (48.10%) mentioned that river water was the primary source of water for indigenous sheep in the wet season. The river was the largest (31.82%) source of water during the wet season in the overall study area. Similarly, rivers served as the primary source of water in the Jimma Zone throughout the wet season (Yemane *et al*., 2020). Contrary to the current study, the majority of farmers reported that well water was the primary source of water for shoat in both the dry and wet seasons in Harawa, Somali Region (Mahamed and Ali, 2023).

The watering frequency of sheep in the study area varied from season to season. During the dry seasons, 70.45% of the farmers offered water once per day, 15.34% freely available, 9.66% once every two days, and 4.55% once every three days for their sheep. Some of the respondents in the present study reported that, to some extent there was a water limitation in their locality during the dry season. The possible reason for this might be the drying of water sources and distances to water sources from the farmer's home during the dry season.

The watering frequency of sheep in the wet season was once every two days for the farmers in the Meskan (57.73%) and Soddo (67.09%) districts, respectively. However, the remaining percentages of respondents were provided water freely, just once per day, and once every three days during the wet season. The provision of water once every two days rather than once per day might be a result of feeding high-moisture content pastures and humid surrounding air conditions during the wet season. In contrast to the current study, most of the households provided water for sheep twice per day in Angollelana Tera district (Bezabh, 2022).

Table 15. Water sources and watering frequencies for sheep in the study area

Descriptors	Districts							
	Meskan		Soddo		Overall			
	N	%	N	%	N	%	X^2	P-Value
Water (dry season)							17.99	0.001
Borehole/water well	21	21.65	9	11.39	30	17.05		
Dam/Pond	3	3.09	4	5.06	7	3.98		
River	7	7.22	24	30.38	31	17.61		
Spring	4	4.12	3	3.80	7	3.98		
Pipe water	62	63.92	39	49.37	101	57.39		
Water (wet season)							22.84	0.000
Water well	16	16.49	9	11.39	25	14.20		
Dam/Pond	4	4.12	5	6.33	9	5.11		
River	18	18.56	38	48.10	56	31.82		
Spring	5	5.15	4	5.06	9	5.11		
Pipe water	21	21.65	14	17.72	35	19.89		
Rainwater	33	34.02	9	11.39	42	23.86		
Watering (dry season)							3.16	0.367
Freely available	14	14.43	13	16.46	27	15.34		
Once a day	73	75.26	51	64.56	124	70.45		
Once in two days	7	7.22	10	12.66	17	9.66		
Once in three days	3	3.09	5	6.33	8	4.55		
Watering (wet season)							4.41	0.221
Freely available	29	29.90	14	17.72	43	24.43		
Once a day	8	8.25	10	12.66	18	10.23		
Once in two days	56	57.73	53	67.09	109	61.93		
Once in three days	4	4.12	2	2.53	6	3.41		

N = Number respondent, X^2 = Chi-square

4.8.6. Sheep castration practices in the study area

The sheep castration practices, such as methods of castration, age of castration, season of castration, and reasons for castration in the study area are shown in Table 16. The majority of the respondents in Meskan (93.81%) and in Soddo (91.14%) reported that they practiced castrating male sheep. The unfamiliarity of some farmers with castration might be caused by the delivery of ram lambs to the local market, which is why they do not practice castration. The result of the current study is in agreement with Hemacha *et al.* (2022), who stated that the majority of respondents in Duna and Misha districts had engaged in ram castration. The majority of respondents castrated sheep mainly to improve fattening (84.62% in Meskan and 80.56% in Soddo), while the remaining did so to reduce the aggressive behaviour of the male sheep and control breeding in both districts. The current finding is similar to the result that the majority of respondents castrated their male sheep to improve fattening in the Arsi and Bale Zones (Diriba, 2020).

In the Meskan (85.71%) and Soddo (90.28%) districts, the respondents practiced the modern method of castration. Professionals of the government veterinary extension program (87.73%) offer this modern castration service at various stations by using the castration procedure of burdizzo. The remaining small proportion of respondents reported that they used the traditional castration method, which is painful and may even cause animal infections and death. The current study's investigation corresponds to the result that the majority of farmers practiced modern castration in the Dodota district of Arsi Zone (Abera *et al*., 2022). However, the present study is in contrast with the investigation of Tariku *et al*. (2021), who reported that smallholder farmers in selected districts of the Sidama Region practiced castration by using the traditional castration method.

More than half of the farmers in Meskan (83.52%) and Soddo (62.50%) castrated their ram at the age of more than 12 months old. The same age of castration was reported for majority farmers in Western Amhara, who castrated their rams at 1.5 to 2 years old (Adimasu *et al*., 2019). Here, castrating ram at a young age might become more difficult and painful, and the chances of a complicated health situation occurring on the castrated ram increase greatly. This also led to a delay in the growth and fattening time of the ram, which contradicts the belief of farmers that castrated rams usually fatten faster than intact males if suitably managed with proper feeding and care.

Table 16. Sheep castration practices and their methods in the study area

Descriptors	Districts						X^2	P-Value
	Meskan		Soddo		Overall			
	N	%	N	%	N	%		
Castrate male sheep							0.46	0.500
Yes	91	93.81	72	91.14	163	92.61		
No	6	6.19	7	8.86	13	7.39		
Reason to castrate ram							0.63	0.729
Control breeding	4	4.40	5	6.94	9	5.52		
Improve fattening	77	84.62	58	80.56	135	82.82		
Better temperament	10	10.99	9	12.50	19	11.66		
Age of male castration							11.43	0.003
3-6 months	6	6.59	5	6.94	11	6.75		
6-12 months	9	9.89	22	30.56	31	19.02		
> 12 months	76	83.52	45	62.50	121	74.23		
Season of castration							10.51	0.001
Dry	47	51.65	55	76.39	102	62.58		
Wet	44	48.35	17	23.61	61	37.42		
Who castrate for you?							0.81	0.666
My self	5	5.49	3	4.17	8	4.91		
Service of extension	78	85.71	65	90.28	143	87.73		
Traditional castrating man	8	8.79	4	5.56	12	7.36		
Castration methods							0.78	0.378
Modern	78	85.71	65	90.28	143	87.73		
Traditional	13	14.29	7	9.72	20	12.27		
Give supplementary feed							6.21	0.013
Yes	57	62.64	31	43.06	88	53.99		
No	34	37.36	41	56.94	75	46.01		

N = Number respondent, X^2 = Chi-square

4.8.7. Sheep culling practices in the study area

The majority of farmers (89.77%) practiced sheep culling in the current study area. The current result corresponds with Tezera and Engidashet (2022), who reported that the majority of respondents in the Gedeb district had sheep culling experience. The most often mentioned reason for culling sheep was poor physical appearance (47.47%) in the overall study area. The present finding is similar to the result of Abebe *et al*. (2020), who reported that the majority of respondents culled small-bodied sheep from their flock in the Northwest Highlands of Ethiopia. In cases of small flock sizes, culling was rarely practiced in the study area. In the current study, the most familiar culling techniques for male sheep were slaughtering (52.53%) and selling (47.47%), and for female sheep, selling (89.24%) and slaughtering (10.76%). The present result is similar to that of Berhe *et al*. (2019), who investigated that the most common sheep culling techniques were slaughtering and selling for Begait sheep.

Table 17. Sheep culling practices and modes of culling sheep in the study area

Descriptors	Districts						X^2	P-Value
	Meskan		Soddo		Overall			
	N	%	N	%	N	%		
Practice culling for sheep							2.13	0.144
Yes	90	92.78	68	86.08	158	89.77		
No	7	7.22	11	13.92	18	10.23		
Reasons for culling sheep							9.18	0.027
Old age	5	5.56	7	10.29	12	7.59		
Sickness	2	2.22	6	8.82	8	5.06		
Reproductive problem	32	35.56	31	45.59	63	39.87		
Unwanted Appearance	51	56.67	24	35.29	75	47.47		
Culling modes for male							9.79	0.002
Sold	33	36.67	42	61.76	75	47.47		
Slaughtered	57	63.33	26	38.24	83	52.53		
Culling modes female							0.47	0.495
Sold	79	87.78	62	91.18	141	89.24		
Slaughtered	11	12.22	6	8.82	17	10.76		

N = Number respondent, X^2 = Chi-square

4.8.8. Sheep fattening practices in the study area

Sheep fattening was a common practice in the current study area, although the degree, manner of fattening, and available resources were widely varied. The majority of respondents in Meskan (88.66%) and Soddo (93.67%) practiced sheep fattening. The present result does not correspond with the finding of Taye *et al*. (2021), who investigated that sheep fattening was a less common practice in the Genji district of West Wollega Zone. The current study is also contrary to the result of Goshu (2021), who reported that most of the farmers did not engage in sheep fattening practices in the Central and West Gondar Zones. The possible reason for this might be that in the current study area, there was better availability of feed used for sheep fattening compared to the Genji district and the Central and West Gonder Zones.

The castrated rams (51.88%) were the most preferred category of sheep for fattening, followed by young rams (21.25%) and mature intact males (16.88%) in the present study area. The current finding is in line with the result of Bezabh (2022), who investigated that castrated rams were the most common types of sheep selected for fattening in the Angollelana Tera district. Similarly, Abdilah *et al*. (2023) stated that castrates were the first category of sheep selected for fattening in Awbarre district. Natural pasture (51.25%) was the primary component of the feeding system for fattening sheep, followed by concentrates (38.13%) in the current study area. The present result is comparable with the report that the most common feed source for fattening sheep was natural pasture in the Kaffa Zone (Bachano and Monenus, 2022). Most of the respondents in both districts provide special management to the sheep that were selected for fattening.

According to the report of the most farmers (70.63%) in the present study area, fattening took, on average, three to four months for adult sheep. Similar to the present result, the majority of respondents completed small ruminant fattening in three to four months in the Dodota district Arsi Zone (Sime *et al*., 2023). The current study is also similar to the findings of Assefa and Asrat (2020), who reported that mature sheep required three months on average to fatten in the Duna district of Hadiya Zone. According to the focus group discussion report, the period of castration was from September to November. The main reason farmers select this period to fatten sheep might be to prevent the risk of infection that occurs during the wet season and due to the availability of surplus feeds from fallow lands and crop residues in the study area.

Table 18. Sheep fattening practices in the study area

Fattening Practices	Districts							
	Meskan		Soddo		Overall			
	N	%	N	%	N	%	X^2	P-Value
Practice fattening sheep							1.32	0.250
Yes	86	88.66	74	93.67	160	90.91		
No	11	11.34	5	6.33	16	9.09		
Categories of fattening							14.17	0.007
Culled young female	5	5.81	3	4.05	8	5.00		
Young male	21	24.42	13	17.57	34	21.25		
Castrated males	51	59.30	32	43.24	83	51.88		
Older intact males	7	8.14	20	27.03	27	16.88		
Older female	2	2.33	6	8.11	8	5.00		
Season of fattening							0.25	0.621
Dry season	19	22.09	14	18.92	33	20.63		
Wet season	67	77.91	60	81.08	127	79.38		
Length of fattening							8.42	0.015
3 - 4 months	69	80.23	44	59.46	113	70.63		
4 - 6 Months	14	16.28	26	35.14	40	25.00		
> 6 months	3	3.49	4	5.41	7	4.38		
Types of feed for fattening							15.04	0.002
Natural pasture	56	65.12	26	35.14	82	51.25		
Concentrates	22	25.58	39	52.70	61	38.13		
Crop residue	5	5.81	5	6.76	10	6.25		
Improved forage	3	3.49	4	5.41	7	4.38		

N = Number respondent, X^2 = Chi-square

4.9. The Purposes of Sheep Keeping in the Study Area

The purposes of keeping sheep in the study area are illustrated in Table 19. Sheep was kept for various objectives, and sheep were versatile animals that served for different purposes, which corresponded to farmers' long or short-term needs in the study area. Sheep were also the first animals to be sold when crop harvests in the area were inefficient for household consumption and other necessities.

The top three purposes of keeping sheep in Meskan district were income generation (index = 0.33), ceremonies (index = 0.25), and manure sources (index =0.14), while for Soddo, income generation (index = 0.34), ceremonies (index = 0.23), and saving (index = 0.15) were mentioned in order of their importance. The index values of each purpose for keeping sheep varied slightly in both study districts. The possible reasons for farmers in both study districts to raise sheep primarily for earning income through the sale of live animals (as sources of money) might be that they are used to pay for emergency expenses, medication, school fees, clothing, food items, fertilizer, and other household needs. The current study is comparable with the investigation in Eastern Amhara, where generating income was the first purpose for the farmers who kept sheep (Lakew *et al*., 2021).

Table 19. Major purpose of sheep keeping in the study area

	Districts										
	Meskan					Soddo					Overall
Keeping Purposes	Rank					Rank					
	1st	2nd	3rd	4th	Index	1st	2nd	3rd	4th	Index	Index
Income generation	59	22	8	3	0.33	53	14	6	3	0.34	0.34
Ceremonies	25	32	19	10	0.25	17	26	15	5	0.23	0.24
Saving/asset	8	13	13	7	0.11	4	21	14	8	0.15	0.13
Manure source	1	16	38	7	0.14	1	3	27	17	0.11	0.13
Meat consumption	3	9	11	13	0.08	1	6	8	21	0.07	0.08
Wealth status	0	3	4	33	0.05	2	5	4	9	0.05	0.05
Skin	1	1	2	20	0.03	1	3	2	9	0.03	0.03
Dowry	0	1	2	4	0.01	0	1	3	7	0.02	0.02

4.10. Sheep Breeding Practices in the Study Area

The common breeding practices and mating systems of indigenous sheep in the study area are displayed in Table 20. Uncontrolled types of mating were the most common in the study area, and this type of mating was practiced by 91.75% of sheep owners in the Meskan, which is greater than the 86.08% in the Soddo district. This uncontrolled mating system might be used to prevent inbreeding in the current study area. The current finding is congruent with Hemacha *et al*. (2022), who reported that the majority of sheep owners in the Duna and Misha districts of Hadiya Zone practiced uncontrolled types of mating. The main reason that respondents practiced uncontrolled mating in the study area was due to a lack of awareness (67.95%), the grazing of more than one household sheep flock together on the same grazing land (26.92%), and the insufficient number of rams (5.13%). In contrast to the present study, the usage of communal grazing land was the main cause of unrestricted mating in the Simien Mountains of Ethiopia (Mulat *et al*., 2022).

The majority of sheep farmers who have breeding ram in the Meskan (95.35%) and Soddo (87.10%) districts reported that their breeding ram was mated with both their own ewes and those of other ewes, without any restriction. The possible reason for this might be that smallholder farmers in the study area graze their ram on the extensive communal grazing lands with their and other flock ewes. The current result is similar to the finding that the majority of sheep farmers in the Yirgachefe and Gedeb areas reported that their breeding rams mate both with their own ewes and with their neighbours (Tezera and Engidashet, 2022).

The main source of breeding ewe in Meskan (90.72%) and in Soddo (75.95%) was born in the farmers own flock, followed by purchases from local markets. The majority of households (89.20%) in the current study area allowed free service of any available ram on communal grazing land and watering points to their ewes, which may be a result of the family's lack of information about inbreeding and its effects on the ewes' reproductive performance. Similar to the current study, the majority of households in Lagambo district of South Wollo Zone permit their ewes free service to any available ram (Teramaj, 2020). The majority of farmers in the districts of Meskan (91.75%) and Soddo (78.48%) reported that they were able to identify the sire of the lambs by comparing the newly born lambs to the color and appearance of rams. In contrast to the present study, Teramaj (2020) reported that most of the farmers who practiced uncontrolled mating did not identify the sire of a lamb in the Lagambu district of South Wollo Zone.

Table 20. Mating systems and sources of breeding ewe in the study area

Mating Systems	Districts						X^2	P-Value
	Meskan		Soddo		Overall			
	N	%	N	%	N	%		
Use control mating							1.46	0.227
Yes	8	8.25	11	13.92	19	10.80		
No	89	91.75	68	86.08	157	89.20		
Reason for uncontrolled							10.14	0.006
Sheep graze together	16	18.18	26	38.24	42	26.92		
Lack of awareness	69	78.41	37	54.41	106	67.95		
Insufficient number of ram	3	3.41	5	7.35	8	5.13		
Ram serves any ewes							1.65	0.199
Yes	41	95.35	27	87.10	68	91.89		
No	2	4.65	4	12.90	6	8.11		
Ewes served by any ram							1.46	0.227
Yes	89	91.75	68	86.08	157	89.20		
No	8	8.25	11	13.92	19	10.80		
Know the impact of mating-relatives							4.21	0.040
Yes	10	10.31	17	21.52	27	15.34		
No	87	89.69	62	78.48	149	84.66		
Identify the sire of a lamb							6.29	0.012
Yes	89	91.75	62	78.48	151	85.80		
No	8	8.25	17	21.52	25	14.20		
Source of breeding ewe							7.25	0.027
Born in flock	88	90.72	60	75.95	148	84.09		
Inherited as gift	2	2.06	3	3.80	5	2.84		
Purchased from markets	7	7.22	16	20.25	23	13.07		

N = Number respondent, X^2 = Chi-square

4.10.1. Breeding ram ownership and mating systems in the study area

The majority of respondents in Meskan (55.67%) and Soddo (60.76%) did not have their own breeding ram. This might be due to the ram lambs greatly sold in the local market. Similar to the current finding, most of the respondents in Western Amhara did not have their own breeding ram (Adimasu *et al*., 2019). For farmers who did not have a breeding ram, there were two ways to access rams: the most prominent approach was using rams at communal grazing areas where a large number of households graze together and ewes mate at random with available rams, and the other approach was using rams from the neighbouring flock for mating ewes that were on heat. Consequently, in Meskan district, farmers who did not have a breeding ram mated their ewes using rams at communal grazing land (61.11%) and using neighbouring rams (38.89%). However, for Soddo district, the percentages of mating the ewes using rams in communal grazing areas and using neighbour rams were 85.42% and 14.58%, respectively.

The current result indicated that social values play a key role in the sharing of breeding rams and herd mixing, and this traditional custom is crucial to breed improvement and organizing the best breeding ram usage. The current study is in contrast with Adimasu *et al*. (2019), who reported that most of the sheep owners who did not have a breeding ram in the Sekela district used borrowed neighbouring rams. The current result is also contrary to the finding that the majority of households that did not have a breeding ram in the Lagambo district of South Wollo Zone utilized a neighbour's ram to mate their ewes (Teramaj, 2020). On the other hand, in Meskan and Soddo, 95.35% and 90.32% of respondents permit mating related individuals, respectively. According to the key informants' information, most likely inbreeding can occur due to the pattern that permits mating between relative individuals throughout time.

4.10.2. Uses of keeping ram in the study area

Careful management is necessary to ensure the reproductive success of any small ruminant farm and to maximise the productive longevity of rams. Most of the respondents (68.92%) in the study area stated that rams were kept for fattening, while the remaining 18.92% and 12.16% of respondents claimed that rams were kept for mating and socio-cultural purposes, respectively. The current result is similar to the report of Abdilahi *et al*. (2023), who reported that fattening was the main reason for keeping rams in Awbarre district. Contrary to the present outcome, the majority of sheep owners in the Lagambo district of South Wollo Zone indicated they keep rams for mating (Teramaj, 2020).

4.10.3. Sources of breeding ram in the study area

The majority of respondents in Meskan (81.4%) and Soddo (54.84%) stated that the source of their breeding ram was one's own flock through birth, while the remaining respondents acquired breeding rams by means of purchase. Similar to the present study, for the majority of farmers in the Central and West Gondar Zones, the source of breeding rams was birth in one's own flock (Goshu, 2021). According to the report of most respondents (43.24%), the average time that a specific ram was used in the flock for reproductive purposes was roughly 3-4 years, and after that, the farmers cull this ram from their flock. The current result is not analogous to the findings of Abebe *et al*. (2020), who stated that an individual breeding ram usually stayed in the flock for 2.26 years to breed ewes in the Northwest Highlands of Ethiopia.

Table 21. Sources and purposes of keeping breeding rams in the study area

Descriptors	Districts							
	Meskan		Soddo		Overall			
	N	%	N	%	N	%	X^2	P-Value
Have breeding ram							0.46	0.496
Yes	43	44.33	31	39.24	74	42.05		
No	54	55.67	48	60.76	102	57.95		
Source of ram (s)							6.08	0.014
Born in the flock	35	81.40	17	54.84	52	70.27		
Through purchasing	8	18.60	14	45.16	22	29.73		
Purpose of keeping ram							0.72	0.703
For Mating	9	20.93	5	16.13	14	18.92		
Socio-cultural purpose	6	13.95	3	9.68	9	12.16		
For fattening	28	65.12	23	74.19	51	68.92		
Same breeding ram serving							18.82	0.000
2-3 years	9	20.93	21	67.74	30	40.54		
3-4 years	27	62.79	5	16.13	32	43.24		
4-5 years	4	9.30	3	9.68	7	9.46		
>5 years	3	6.98	2	6.45	5	6.76		

N = Number respondent, X^2 = Chi-square

4.10.4. Weaning age and status of lambs in the study area

The weaning age, parturition that occurred in the last one year, abortion cases that occurred in the last one year, and offspring mortality that occurred in the last one year in the current study area are illustrated in Table 22. According to the report of respondents in the current study area, the average number of lambs born in the last one year was 2.06 per household, and the mean number of offspring morality was 0.36 per household. Most of the time, the offspring mortality cases occurred during the wet season of the year in the study area. This might be due to the presence of different diseases, such as diarrhoea and bloating, which were more prevalent during the wet season in the current study area. The average occurrence of abortion causes in the last one year was 0.25 in Meskan and 0.43 in Soddo per household. Including the weaning age, all lamb statuses mentioned by farmers had statistically significant differences between the two districts.

The average weaning age of lambs was 3.66 and 3.44 months in Meskan and Soddo districts, respectively. The mean age at which lambs wean in the overall study area was 3.56 months. Similar to the current study, lambs of Blackhead Somali sheep were typically weaned at 3.7 months in Awbarre district (Abdilahi *et al*., 2023). The result of the current study is shorter than the investigation of Lamesegn *et al*. (2018), who reported that the weaning of lambs takes place around 5 months in the East Gojjam Zone. This difference might be due to the comparatively higher availability of feed sources and good management in the current study area than in East Gojjam Zone. However, the current result is quite longer than the reported average weaning age of lambs for Begait sheep, which was 1.98 months (Berhe *et al*., 2019). This might be due to the fact that there was comparatively better management and feed accessibility in the Western Tigray Zone than in the current study area.

Table 22. Status related to lambs in the study area

Lamb Status	**Districts**			**P-Value**
	Meskan	**Soddo**	**Overall**	
	Mean±SE	**Mean±SE**	**Mean±SE**	
Weaning age of lambs in month	3.66±0.05	3.44±0.07	3.56±0.04	0.008
Parturition occurred in the last 1 year	2.30±0.06	1.77±0.08	2.06±0.05	0.000
Abortion cases occur in the last 1 year	0.25±0.04	0.43±0.06	0.33±0.04	0.012
Offspring mortality in the last 1 year	0.27±0.05	0.47±0.08	0.36±0.05	0.027

SE = Standard error

4.11. Reproductive Performance of Sheep in the study area

The reproductive performance, like the age at sexual maturity of male and female sheep, age at first lambing, lambing interval, litter size, number of lamb crops per ewe life span, and reproductive life span of ewe is described in Table 23.

4.11.1. Age at first service

The average age at first service of rams and ewes was 7.80 and 8.22 months in Meskan district, respectively, while it was 7.66 and 7.89 months in Soddo. The present finding showed that males reach sexual maturity a little bit earlier than females in both districts. There was a statistically significant difference ($P < 0.05$) between the two districts in terms of the age at first service of females. The current study indicated that females in Soddo district reach sexual maturity earlier than females in Meskan. The possible reason behind this might be that there was a weather difference between the two districts.

On the other hand, the male's age at first service was statistically not significant ($P > 0.05$) between the two districts. In the current study, figures of age at first service were consistent with the finding of Yousuf *et al*. (2022), who investigated that the average age at first service for males and females was 7.62 and 8.44 months in Kellem Wollega Zone, respectively. However, the ewes in the current study are late early-sexual maturing compared to the sheep in Northwestern Ethiopia that first mated when they were 6.93 months old (Sisay *et al.*, 2021). The reason that the outcomes of the current study differ from those of other reported studies might be due to variations in feed availability, management, and environmental factors.

4.11.2. Age at first lambing

Age at first lambing was affected by nutrition, disease invasions, and other factors resulting in a wide difference between the two districts. The average age at first lambing in Meskan was 14.03 months, while it was 13.41 months in Soddo. The first lambing occurred at an average age of 13.75 months in the overall study area. The age at first lambing figures had a statistically significant difference ($P < 0.05$) between the two districts; this might be due to ewes raised in the Soddo district maturing earlier than in Meskan, which could be influenced by management approaches, better nutrition, and disease prevention that restricted early animal growth. Similar to the present study, the mean age at first lambing was 12.96 months in Lagambo district, South Wollo Zone (Teramaj, 2020).

4.11.3. Lambing interval

The average lambing interval was 8.15 months and 7.72 months in the Meskan and Soddo districts, respectively. Similar to the present study, the average lambing interval was 8.13 months in the Horro district (Tamiru, 2021). The current result is shorter than the finding of Deribe *et al*. (2021), who reported that the average lambing interval for indigenous ewes was 9.12 months in the Raya Kobo area. Similarly, the current result is much shorter than 13.10 months, which was reported for sheep in the Debre Birhan area (Goshme *et al*., 2021). The lambing intervals of ewe had a statistically significant difference ($P < 0.05$) between the two districts. The cause of these differences might be due to the effects of weather and mothering ability in both districts, which increase or decrease the chances of re-conception after parturition among indigenous sheep. Shorter lambing intervals might have resulted from better management practices, which would allow for about three lamb crops to be produced in two years.

4.11.4. Number of lamb crops per ewe reproductive lifetime

The average number of lambs born throughout the ewe's reproductive lifetime was 11.99 lamb crops in the study area. The average number of lambs born per ewe throughout its reproductive lifetime had statistically significant differences ($P < 0.05$) between the two districts. The current result is comparable with the report of Sisay *et al.* (2021), who investigated that an individual ewe had a mean of 11.4 lambs born throughout its reproductive lifetime in North Western Ethiopia, but it is greater than the study of Tesema *et al.* (2023), who reported that the average number of lambs per ewe's reproductive lifetime was 10.20 in the South and North Wollo Zones.

4.11.5. Litter size

The average litter size was 1.52 lambs in Meskan and 1.32 lambs in Soddo per ewe in a particular parturition. The mean litter size was 1.43 lambs per parturition of ewe in the overall study area. A higher litter size was obtained in Meskan than in Soddo, which indicates there was a statistically significant difference ($P < 0.05$) between the two districts. Litter size might be affected by the level of nutrition, in that poor nutrition during the service period might reduce ovulation rates and increase embryonic mortality, consequently decreasing litter size. The current result is similar to Kebede *et al*. (2022), who reported a 1.56 litter size in Doyogena district. However, it is greater than 1.13 that was reported by Gobezie (2020) for Bonga sheep.

4.11.6. Reproductive life span of ewe

The average reproductive lifespan of indigenous female sheep was 8.42 years in Meskan, which was longer than Soddo's 7.99 years. In terms of reproductive life span for ewes, there was a statistically significant difference ($p < 0.05$) between the two districts. The reason for this difference might be that in Meskan district there was a feed called *'awuta'* prepared by chopping the root of *'enset'*, which is believed to increase the physical strength and reproductive life span of the ewes. The average reproductive lifespan of breeding ewes was 8.23 years in the overall study area. The current study is in line with the findings that breeding ewes had a reproductive life expectancy of 8.98 years in the Central Highlands of Ethiopia (Mebrate, 2020).

Table 23. Reproductive performance of indigenous sheep in the study area

Reproductive Performance	Districts			P-Value
	Meskan	Soddo	Overall	
	Mean±SE	Mean±SE	Mean±SE	
Sexual maturity for male (in months)	7.80±0.06	7.66± 0.08	7.74± 0.05	0.125
Sexual maturity for female (in months)	8.22±0.08	7.89±0.08	8.07±0.06	0.003
Age at first lambing (in months)	14.03±0.09	13.41±0.10	13.75±0.07	0.000
Lambing interval (in months)	8.15±0.07	7.72±0.08	7.96±0.05	0.000
Occurrence of most births (litter size)	1.52±0.05	1.32±0.05	1.43±0.04	0.008
Reproductive life span of ewe (in years)	8.42±0.07	7.99±0.08	8.23±0.06	0.000
Number of lamb crops per ewe lifespan	12.22±0.08	11.72±0.10	11.99±0.07	0.000

SE = Standard error

4.12. Sheep Selection Criteria in the Study Area

4.12.1. Selection criteria for breeding ram in the study area

The indices computed for selection criteria that were applied to choose the best breeding ram in the study area are illustrated in Table 24. Respondents in both study districts mainly focused on traits including body size, fast growth, pedigree, and color when selecting the top breeding rams. Before selecting the best breeding ram, farmers in the district of Meskan look at the body size with an index value of 0.31. Additionally, in Meskan fast growth, pedigree, color, and age were ranked second, third, fourth, and fifth, with index values of 0.20, 0.15, 0.12, and 0.08, respectively.

Whereas farmers in the Soddo district gave priority to the growth rate with an index of 0.33 for selecting breeding rams. Body size, pedigree, color, and age were ranked second, third, fourth, and fifth, with index values of 0.25, 0.16, 0.12, and 0.06 in Soddo district, respectively. When farmers chose the best breeding rams, they gave close attention to body size (index = 0.28), lamb growth rate (index = 0.27), and pedigree (index = 0.16) in the overall study area. However, each trait's index value in the two districts was different.

Rams with a larger body size were regarded as good breeding rams in the study area; it was the first most crucial criteria in Meskan, while in Soddo, it was the second. This might be due to the high need of farmers to sell the large-body sheep in the local market to cover their different household expenses beyond the use of rams for mating purposes. The current investigation is in line with the finding that the primary criteria to select breeding rams was body size in Hadiya Zone (Hemacha *et al*., 2022). Similarly, body size was the first selection criteria for breeding rams in the Kellem Wollega Zone (Yousuf *et al*., 2022). Likewise, farmers in the Gedio Zone gave priority to body size when they chose a breeding ram (Tezera and Engidashet, 2022). Unlike the current finding, the major criteria to select the best breeding ram was coat color in Beyeda and Janamora, Semen Mountain (Mulat *et al*., 2022).

Table 24. Selection criteria for breeding rams in the study area

	Districts										
	Meskan					**Soddo**					**Overall**
Criteria	**Rank**					**Rank**					
	1st	**2nd**	**3rd**	**4th**	**Index**	**1st**	**2nd**	**3rd**	**4th**	**Index**	**Index**
Body size	49	25	13	4	0.31	22	21	20	3	0.25	0.28
Color	9	10	21	9	0.12	7	6	17	12	0.12	0.12
Character	0	1	1	9	0.01	0	2	1	6	0.02	0.02
Growth	14	30	17	15	0.20	41	28	2	7	0.33	0.27
Pedigree	13	15	21	9	0.15	5	15	23	19	0.16	0.16
Age	3	5	17	13	0.08	3	4	9	9	0.06	0.07
Libido	1	2	3	11	0.03	0	0	2	9	0.02	0.03
Tail length	6	5	1	15	0.06	0	0	1	6	0.01	0.04
Presence of horn	2	4	3	12	0.04	1	3	4	8	0.04	0.04

Figure 4. Indigenous male sheep in Meskan (left) and indigenous male sheep in Soddo (right)

4.12.2. Breeding ewe selection criteria in the study area

The indexes of various selection criteria that farmers mentioned to select the best breeding ewes are displayed in Table 25 according to their order of importance. Twining ability, lambing interval, lamb survival, body size, pedigree, color, AFL, lamb growth, and tail length were the traits that farmers considered during breeding ewe selection in the current study area. Twining ability was the primary criteria for selecting breeding ewes in the Meskan district (index = 0.32) and Soddo district (index = 0.29), and the second criteria to select the best breeding ewe was lambing interval in the Meskan district but lamb survival in the Soddo district.

Growth rate, body size, and pedigree were ranked as fourth, fifth, and sixth, with index values of 0.10, 0.09, and 0.06, respectively, to select the breeding ewe in the overall study area. When selecting breeding ewes in the current study area, tail length was given the lowest rank in terms of its importance. This might indicate that the economic weight of tail length in the study area is low. In both study districts, most of the index values for each trait were different. The present finding contradicts the result of Tezera and Engidashet (2022), who investigated that genotype was the first criteria in the Gedeo Zone among the various breeding ewe selection criteria.

Table 25. Selection criteria for breeding ewes in the study area

Criteria	Meskan Rank 1st	2nd	3rd	4th	Meskan Index	Soddo Rank 1st	2nd	3rd	4th	Soddo Index	Overall Index
Twining ability	52	28	7	4	0.32	39	21	4	4	0.29	0.31
Lambing interval	16	31	20	9	0.21	5	17	33	4	0.18	0.20
Lamb survival	8	9	33	8	0.14	20	24	10	7	0.23	0.19
Lamb growth	6	8	15	25	0.11	1	3	18	12	0.08	0.10
Body size	9	6	8	11	0.08	9	5	4	19	0.10	0.09
Color	1	5	5	13	0.04	1	4	5	8	0.04	0.04
AFL	1	2	4	11	0.03	0	2	2	9	0.02	0.03
Tail length	0	1	1	7	0.01	0	0	1	7	0.01	0.01
Pedigree	4	7	4	9	0.06	4	3	2	9	0.05	0.06

AFL = Age at first lambing

Figure 5. Sheep with three lambs (triplet) in the study area

4.13. Effective Population Size and Level of Inbreeding in the Study Area

The effective population size (Ne) and rate of inbreeding coefficient (ΔF) for the sampled indigenous sheep populations in both Meskan and Soddo districts are illustrated in Table 26. Effective population size is a measure of genetic diversity within a population. The Ne values tend to vary from large to small, with large values indicating greater genetic variability and lower values indicating lower genetic diversity (Maiwashe *et al*., 2006).

In the present study area, when a farmer's sheep flock was not mixed with another sheep flock, the ΔF values for sheep in Meskan and Soddo were 0.27 and 0.31, respectively. The current result is congruent with the finding of Yousuf *et al*. (2022), who reported an ΔF of 0.30 for Kellem Wollega Zone, whereas it is higher than 0.005, which is the reported ΔF for Bensa district (Kenfo *et al*., 2018). The majority of sheep keepers in both study districts use communal grazing land (on average, 5.8 and 7.3 sheep flocks in Meskan and Soddo districts were mixed together, respectively), which allows breeding females to mix with males from different herds and minimizes the risk of inbreeding by increasing the population size (Jaitner *et al*., 2001). The current result indicated that, when different sheep flocks were mixed, the rate of inbreeding coefficient (ΔF) decreased by 82.59% in Meskan and by 86.45% in Soddo, and the value fell below 0.063, which is a maximum acceptable threshold of ΔF (Armstrong, 2006).

If the effective population size of the current study is decreased, this acceptable level of inbreeding rate can be affected in the next generation. Because of this, mixing more different sheep flocks together is a better solution in the study districts to maximize the effective population size and minimize or maintain the rate of inbreeding. The lack of awareness about inbreeding and the unrestricted mating system might contribute to the flock's high levels of inbreeding and low genetic diversity (Falconer and Mackay, 1996; Kosgey, 2004).

Table 26. Effective population size and level of inbreeding in the study area

Districts	When sheep flocks are not mixed				When sheep flocks are mixed			
	NF	**Nm**	**Ne**	**ΔF**	**NF**	**Nm**	**Ne**	**ΔF**
Meskan	2.05	0.59	1.83	0.27	11.89	3.42	10.62	0.047
Soddo	1.72	0.53	1.62	0.31	12.56	3.87	11.83	0.042

Ne = Effective population size; Nm = Number of breeding males; Nf = Number of breeding females; ΔF = The rate of inbreeding coefficient

4.14. Health Complications and Their Controlling Methods in the Study Area

4.14.1. Common health problems of sheep in the study area

The health problems that affect sheep productivity most frequently are listed in Table 27. The majority of farmers in the present study area claimed various diseases that were economically important and common risks for sheep productivity, such as diarrhea, sheep cough, bloating, bottle jaw, coenurosis, sheep pox, FMD, pasteurellosis, and foot root were common. According to the respondents report in Meskan district, diarrhea, bloating, sheep cough, and bottle jaw had the principal influence on the productivity of indigenous sheep, with index values of 0.29, 0.24, 0.15, and 0.11, respectively. Other reported diseases in the Meskan district were coenurosis, sheep pox, FMD, pasteurellosis, and foot root, with index values of 0.08, 0.06, 0.03, 0.02, and 0.01, respectively.

The three most important diseases influencing the productivity of indigenous sheep in the Soddo district were diarrhea, sheep cough, and bottle jaw, with index values of 0.31, 0.25, and 0.14, respectively. Coenurosis, bloating, FMD, sheep pox, Pasteurellosis, and foot root were the other diseases reported in the Soddo district, with index values of 0.11, 0.06, 0.05, 0.04, 0.03, and 0.01, respectively. In contrast to the current investigation, Bachano and Monenus (2022) reported that pasteurellosis was the most common disease of sheep in the Kaffa Zone. The present study's result is also different from the finding of Sime *et al*. (2023), who reported that sheep pox was the main health problem in the Dodota district.

Information gathered from focus group discussions and key informants indicated that farmers in the current study area used traditional (ethno-veterinary) practices by preparing some herbs and non-herbal techniques with unlimited dosage. For instance, *'eba'* (*Vernonia amygdalina*) was the plant that used to treat sheep sick with diarrhea through drinking, and also sheep sick with bloating were treated with *'timboha'* (*Nicotiana tabacum*) through drinking. According to the suggestions of most elderly respondents, the usage of these herbal ethno-veterinary practices might be crucial if their dosage is adjusted and limited by taking advice from farmers who have enough experience in traditional animal medicine. Most of the time, farmers whose residential areas are far from modern veterinary stations and farmers who do not have enough money to take sick animals to modern veterinarians in the study area used this type of traditional animal medication.

Table 27. The most common health problems for sheep in the study area

		Districts										
		Meskan					Soddo					Overall
Common Names	Local Names	Rank					Rank					
		1st	2nd	3rd	4th	index	1st	2nd	3rd	4th	index	index
Diarrhea	*Wunat*	44	27	12	4	0.29	36	28	8	3	0.31	0.30
Sheep cough	*Ambk*	2	24	26	17	0.15	25	22	14	4	0.25	0.20
Bloating	*Dibdebe*	32	18	24	3	0.24	2	2	14	8	0.06	0.15
Bottle jaw	*Doddo*	6	8	15	25	0.11	7	9	17	19	0.14	0.12
Coenurosis	*Zulmat*	9	6	8	11	0.08	8	6	14	11	0.11	0.10
FMD	*Afetirs*	0	3	4	13	0.03	1	4	8	10	0.05	0.04
Pasteurolosis	*Adifik*	1	2	3	8	0.02	0	2	2	10	0.03	0.02
Sheep pox	*Kosho*	4	7	4	9	0.06	1	6	2	8	0.04	0.05
Foot root	*Ametmit*	0	1	1	7	0.01	0	0	0	6	0.01	0.01

4.14.2. Animal health managements in the study area

The animal health management practices in the study area are presented in Table 28. The majority of farmers (76.29% in Meskan and 83.54% in Soddo) took their sheep to a modern veterinary center for treatment and vaccination. This indicates that in the study area, most of the farmers were aware of modern veterinary services. In Meskan, 72.41% and in Soddo, 77.03% of farmers get primary health care services for their sheep from government animal health stations, which led the smallholder farmer to minimize using traditional animal medicine.

The majority of respondents (95.45%) got vaccines for their sheep, and the vaccine was reached to farmers after the report of disease (91.67%) in the overall study area. The main reason for this late vaccine delivery might be due to the weak exchange of information with the neighbouring districts about the disease invasion through the district office of livestock and fishery. Nearly 92.55% of farmers had been able to get veterinary services within a distance of less than five kilometres in the study area. The current study's investigation is similar to the result that the majority of farmers in South and North Wollo Zones reported that they had access to veterinary services within less than five kilometres (Tesema *et al*., 2023).

Table 28. Veterinary services and sources of veterinary services for sheep in the study area

Veterinary Services	Districts					
	Meskan		Soddo		Overall	
	N	%	N	%	N	%
What do when sheep are sick						
Treat with ethno-veterinary practices	13	13.40	8	10.13	21	11.93
Takes to a veterinary canter	74	76.29	66	83.54	140	79.55
Treat with treatments from local traders	10	10.31	5	6.33	15	8.52
Have veterinary service						
Yes	87	89.69	74	93.67	161	91.48
No	10	10.31	5	6.33	15	8.52
Distance to veterinary service						
< 5 km	82	94.25	67	90.54	149	92.55
6-10 km	5	5.75	7	9.46	12	7.45
Sources of veterinary services						
Government	63	72.41	57	77.03	120	74.53
Private shops	6	6.90	4	5.41	10	6.21
government and private shops	18	20.69	13	17.57	31	19.25
Get the vaccine						
Yes	92	94.85	76	96.20	168	95.45
No	5	5.15	3	3.80	8	4.55
How can get vaccine						
After the report of disease	86	93.48	68	89.47	154	91.67
After certain animals died	2	2.17	3	3.95	5	2.98
Before outbreaks	4	4.35	5	6.58	9	5.36

N = Number respondent, X^2 = Chi-square

4.14.3. Causes of sheep mortality in the study area

The top causes of sheep mortality in the study area are displayed in Table 29. According to the report of respondents in the study area, disease was the main cause of sheep mortality, with an index value of 0.35 among the listed causes, followed by predator and mechanical causes with index values of 0.24 and 0.13, respectively.

Both Meskan and Soddo districts had different index values for each sheep mortality cause. The mortality of sheep strictly increased during the dry season and earlier wet season. The reason for this might be that in the dry season, to some extent there was a shortage of feed in the study area, while during the beginning of the wet season, there were some fatal diseases due to the presence of knob weed (*'alansa'*), which is the main cause of bloating disease. The current finding is in line with the result that the major cause of sheep mortality was disease in Central and West Gondar (Goshu, 2021). However, the current investigation is different from the result that feed shortage was the major cause of sheep mortality in Dara and Hula districts of Sidama Region (Jilo, 2021).

Table 29. Major causes of sheep mortality in the study area

	Districts										
	Meskan					Soddo					Overall
Mortality Causes	Rank				Index	Rank				Index	Index
	1st	2nd	3rd	4th		1st	2nd	3rd	4th		
Disease	63	25	7	1	0.35	49	17	9	2	0.34	0.35
Predator	19	36	21	10	0.24	13	30	19	4	0.23	0.24
Drought	0	0	2	11	0.02	1	2	2	6	0.03	0.03
Accident	7	7	18	17	0.11	3	4	14	27	0.10	0.11
Mechanical cause	4	13	19	24	0.12	4	13	11	24	0.13	0.13
Feed shortage	0	8	18	7	0.07	5	8	17	5	0.11	0.09
Water shortage	0	1	4	18	0.03	1	1	0	6	0.02	0.03
Poisoning	4	7	8	9	0.06	3	4	7	5	0.05	0.06

4.15. Constraints to Sheep Production in the Study Area

Identifying the constraints of sheep production is a base for solving sheep productivity problems and improving sheep genetic resources (Bosenu *et al*., 2014). The production constraints of indigenous sheep in terms of their ranking order in the study area are shown in Table 30. In Meskan, disease incidence, predator, and labour shortage were ranked as first, second, and third sheep production constraints with index values of 0.29, 0.21, and 0.19, respectively. Whereas, in the Soddo district, feed shortage, disease incidence, and labour shortage were ranked as first, second, and third sheep production constraints with index values of 0.27, 0.25, and 0.18, respectively.

Disease incidence (index = 0.27), labour shortage (index = 0.19), and feed shortage (index = 0.18) were identified as the first, second, and third most important factors limiting sheep productivity overall in the study area. The shortage of feed might be caused by deforestation, a scarcity of pastureland, and the increased sowing of crops on marginal and damaging lands rather than leaving them for grazing. The current investigation is in accordance with the finding that the major obstacle to the productivity of sheep in the South and North Wollo Zones was disease (Tesema *et al*., 2023). However, the present study is to some extent different from the result that lack of feed was the main obstacle facing small ruminant productivity in the Mid Rift Valley of Ethiopia (Tulu, 2021).

Table 30. The main constraints that limit sheep productivity in the study area

	Districts										
	Meskan					Soddo					Overall
Constraints	Rank					Rank					
	1st	2nd	3rd	4th	Index	1st	2nd	3rd	4th	Index	Index
Disease incidence	45	24	15	4	0.29	25	21	14	3	0.25	0.27
Labour shortage	17	16	29	7	0.19	9	20	19	8	0.18	0.19
Predator	18	31	15	7	0.21	0	15	18	12	0.12	0.17
Superior genotype	5	9	17	13	0.10	1	4	16	19	0.08	0.09
Drought occurrence	1	1	2	21	0.03	1	1	2	14	0.03	0.03
Initial investment	3	4	10	19	0.06	2	4	4	13	0.05	0.06
Feed shortage	7	11	7	14	0.09	41	14	4	0	0.27	0.18
Water shortage	1	1	2	12	0.02	0	0	2	10	0.02	0.02

4.16. Participatory Identification of Breeding Objective Traits

4.16.1. Ewe traits in own-flock ranking experiments

A summary of the preferred ewe trait lists from the own-flock ranking experiment is shown in Table 31. Even though there is no organized breeding program in the study area, sheep keepers select breeding ewes based on their personal memories and other observable characteristics of the sheep. Several traits were selected by the farmers as their best choices for breeding ewes. The most important ewe traits that affected sheep keepers' preference in Meskan were twinning rate, lamb growth, lambing interval, body size, mothering ability, and lamb survival, which collectively comprised about 57.44% of the traits stated in the district. Other important traits of the ewe in Meskan were coat color (6.91%), pedigree (6.65%), and body conformation (5.85). On the other hand, the most important ewe traits reported by sheep keepers in Soddo were lamb growth, twinning rate, body size, lambing interval, lamb survival, and mothering ability, which collectively represented 65.38% of the traits reported in the district, and other important traits of the ewe in Soddo included drought tolerance (4.60%), age at puberty (4.12%), and pedigree (3.87%).

Despite similarities in trait preference between the two districts, some traits had very different preference values. For instance, drought tolerance was mentioned as an important trait by sheep keepers in Soddo, whereas the sheep keepers in Meskan did not mention this trait at all. This might be due to the presence of relatively difficult weather conditions at many times of the year in Soddo; as a result, the sheep keepers in Soddo have chosen ewes with superior drought tolerance. In comparable circumstances, it was also found that farmers preferred drought tolerance traits for sheep in the Amhara Region (Misganaw *et al*., 2022).

Compared to sheep keepers in Meskan, more sheep keepers in Soddo (16.71%) mentioned lamb growth as a preferred trait. This might be due to the weather difference between the two districts, which may cause offspring to grow quicker in Soddo district. Regarding this concept, Kugonza *et al*. (2014) explained that the growth of offspring is positively influenced by its management. In a similar manner, the higher twinning rate (14.29%) was mentioned as the desired trait for sheep keepers in Soddo, which might be due to sheep keepers in Soddo applying some improved management strategies for their sheep when compared to the sheep keepers in Meskan. In the current study, none of the sheep keepers mentioned drinking sheep milk, and ewes with excellent milk production were considered good mothers for their lambs.

Table 31. List of ewe traits in own-flock ranking experiments

Traits	Districts			
	Meskan		Soddo	
	Freq.	%	Freq.	%
Body size	33	8.78	43	10.41
Coat colour	26	6.91	14	3.39
Body condition	16	4.26	9	2.18
Mothering ability	31	8.24	21	5.08
Drought tolerance	_	_	19	4.60
Body conformation	22	5.85	10	2.42
Body length	4	1.06	3	0.73
Body width	_	_	7	1.69
Temperament	15	3.99	14	3.39
Age	12	3.19	9	2.18
Pedigree	25	6.65	16	3.87
Tail type	2	0.53	11	2.66
Udder size	8	2.13	6	1.45
Age at puberty	21	5.59	17	4.12
Lambing interval	37	9.84	41	9.93
Twinning rate	49	13.03	59	14.29
Sex of lamb	6	1.60	_	_
Lamb growth	39	10.37	69	16.71
Lamb survival	27	7.18	37	8.96
Incidence of abortion	3	0.80	8	1.94
Total	376		413	

4.16.2. Means ± SE of body weight and traits from the life history of the ranked animals

The mean and standard error (SE) values of the ewe dentition as well as certain productive and reproductive traits from the own-flock animal ranking experiment are displayed in Table 32. Including dentition, body weight, twinning rate, number of lambings, number of lambs born, and number of lambs weaned were statistically significant ($p < 0.001$), which influenced the ranking decisions of sheep keepers in both Meskan and Soddo districts.

Almost all of the traits taken into account showed obvious differences when comparing the mean values of the ewes selected as the first-best and the inferior ewes in both districts. This indicated that the farmers' selection of ewes was supported by the sheep breeding objective proportions. For instance, for sheep in Meskan, the live weight, number of lambing, number of lambs born, and number of lambs wean differences between the first-best and inferior ewes were 5.10 kg, 1.90, 3.96, and 3.94, respectively. Similarly, for sheep in Soddo, the difference between the same two groups for the same traits was body weight (5.50 kg), number of lambing (3.53), number of lambs born (5.14), and number of lambs weaned (5.64).

When measuring the individual ewes that have the same rank in the own flock ranking experiment, most of the ewes scored approximately the same figures for the given traits. For some traits, the smaller ranks had a higher average value than the larger ranks. For instance, the average dentation of the inferior ewes (2.57) was greater than the average dentation of the third best ewes (2.33), the mean number of lambing of the inferior ewes (3.17) was greater than the mean number of lambing of the third best ewes (2.93), and the average number of lambs born per inferior ewe (3.97) was greater than the average number of lambs born per third best ewe (3.43) for sheep in Meskan.

The older age of the first-best ewes in both study districts might indicate that sheep keepers were willing to keep them for long service years to achieve their objectives in terms of getting better benefits. Most of the time, the sheep that have been ranked as inferior are excluded from the flock to be replaced by better animals. The accurate identification and implementation of the sheep keepers' indigenous knowledge for choosing the best breeding ewes and rams is taken as a feasible alternative to beginning proper breeding programs, in situations where performance and pedigree recordings are extremely poor for sheep (Oumer *et al*., 2019).

Table 32. Mean ± SE values of traits for ewes from own-flock ranking experiments

Districts	Traits	P-Value	Overall mean	Rank			
				1	2	3	Inferior
Meskan	Dentation	***	2.80±0.10	$3.37±0.13^{a}$	$2.93±0.18^{ab}$	$2.33±0.18^{b}$	$2.57±0.21^{b}$
	BW	***	23.25±0.22	$26.17±0.28^{a}$	$23.35±0.22^{b}$	$22.43±0.30^{b}$	$21.07±0.27^{c}$
	NL	***	3.76±0.17	$5.07±0.30^{a}$	$3.87±0.31^{b}$	$2.93±0.30^{b}$	$3.17±0.30^{b}$
	Twining	***	1.28±0.04	$1.57±0.07^{a}$	$1.33±0.08^{ab}$	$1.18±0.07^{bc}$	$1.03±0.03^{c}$
	NLB	***	5.09±0.28	$7.93±0.53^{a}$	$5.03±0.50^{b}$	$3.43±0.35^{b}$	$3.97±0.44^{b}$
	NLW	***	4.47±0.28	$7.27±0.57^{a}$	$4.43±0.49^{b}$	$2.83±0.37^{b}$	$3.33±0.38^{b}$
Soddo	Dentation	***	2.91±0.08	$3.43±0.13^{a}$	$3.07±0.13^{ab}$	$2.77±0.13^{bc}$	$2.37±0.19^{c}$
	BW	***	23.95±0.24	$27.07±0.24^{a}$	$24.53±0.23^{b}$	$22.63±0.29^{c}$	$21.57±0.39^{c}$
	NL	***	4.41±0.21	$6.40±0.44^{a}$	$4.67±0.30^{b}$	$3.70±0.41^{bc}$	$2.87±0.24^{c}$
	Twining	***	1.32±0.04	$1.55±0.08^{a}$	$1.45±0.08^{ab}$	$1.23±0.07^{bc}$	$1.05±0.04^{c}$
	NLB	***	5.59±0.31	$8.27±0.65^{a}$	$6.47±0.41^{a}$	$4.50±0.58^{b}$	$3.13±0.29^{b}$
	NLW	***	4.50±0.29	$7.47±0.60^{a}$	$5.13±0.42^{b}$	$3.57±0.51^{b}$	$1.83±0.15^{c}$

BW = Body weight; NL = Number of lambing; NLB = Number of lambs born/ewe; NLW = Number of lambs weaned/ewe; $^{a, b, c}$ = means on the same column with different superscripts are significantly different; and *** = P ≤ 0.001

4.16.3. Ewe traits in group-animal ranking experiments

The preferred ewe traits of the group-animal ranking experiment are listed in Table 33. The top five most crucial traits of ewes in Meskan were coat color, twinning rate, body size, lambing interval, and appearance, which accounted for 19.81%, 14.98%, 12.08%, 10.14%, and 8.21% of all identified traits, respectively. These traits collectively accounted for 57.01% of the traits listed in the Meskan ewe group-ranking experiment. Whereas the most important chosen traits for ewes in the group-animal ranking experiment were body size (17.62%), twinning rate (13.47%), coat color (11.92%), lambing interval (8.81%), and appearance (7.25%), which collectively contributed more than half (59.07%) of the traits mentioned in Soddo district.

The traits of ewes in both Meskan and Soddo districts considered by farmers after the provision of the ewes' life history generally implied the breeding objectives that sheep keepers practiced in the study area. During the group-animal ranking experiments, most sheep keepers in both Meskan and Soddo districts gave a strong emphasis to the ewe's physical traits (like body size and coat color types) and reproductive performance (such as the twinning rate and lambing interval), as well as related reproductive traits like mothering ability, age at puberty, and so on. A shorter lambing interval will result in a larger flock and quick generation replacement. It would also be helpful for the genetic improvement program (Solomon, 2014).

In Meskan, the traits such as body width, horn length, body length, udder size, height, age, alertness, colour pattern, body condition, and body conformation had a lower preference proportion for selecting the best breeding ewes, while in Soddo, the traits like udder size, body width, age, horn length, alertness, tail type, body conformation, height, drought tolerance, mothering ability, and body condition had a lower preference proportion for selecting the best breeding ewes. On the other hand, the tail type and drought tolerance in Meskan and the body length trait in Soddo were not mentioned at all for ewe selection. The possible reason that farmers did not prefer these traits in each study district might be due to the lower importance of these traits in the local market. Similar to the current study, Sheriff *et al*. (2021) reported relatively the same investigation in phenotypic ranking experiments to identify breeding objective traits of smallholder farmers for Arab and Oromo goat breeds in North-Western Ethiopia.

Table 33. List of ewe traits in group-ranking experiments

Traits	Districts			
	Meskan		Soddo	
	Freq.	**%**	**Freq.**	**%**
Body size	25	12.08	34	17.62
Body conformation	10	4.83	7	3.63
Body width	1	0.48	3	1.55
Body length	3	1.45	_	_
Body condition	9	4.35	13	6.74
Appearance	17	8.21	14	7.25
Height	5	2.42	7	3.63
Coat colour	41	19.81	23	11.92
Colour pattern	8	3.86	5	2.59
Mothering ability	15	7.25	13	6.74
Twinning rate	31	14.98	26	13.47
Lambing interval	21	10.14	17	8.81
Age	6	2.90	3	1.55
Horn length	3	1.45	4	2.07
Tail type	_	_	6	3.11
Drought tolerance	_	_	11	5.70
Udder size	5	2.42	2	1.04
Alertness	7	3.38	5	2.59
Total	207		193	

4.16.4. Ram traits in group-animal ranking experiments

The lists of ram traits used during the group-animal ranking experiment are shown in Table 34. The main important morphometric traits indicated in the group ranking of rams with a different proportion were body size, fast growth, body condition, and appearance, which together account for 51.33% and 43.83% of the traits stated by Meskan and Soddo sheep keepers, respectively. Fast growth, body size, body condition, and appearance were the traits that appeared most frequently by sheep keepers in Meskan to select the best breeding rams, with magnitudes of 20.63%, 14.29%, 8.47%, and 7.94%, respectively. Important traits for selecting rams in the Soddo district were body size (18.72%), appearance (10.34%), libido (9.36%), and body condition (8.37%). To some extent, the choice of farmers for the breeding ram was influenced by the body size in the study area.

The preference of sheep owners for fast growth in Meskan and for large body size in Soddo districts might be due to the main objective of keeping sheep in both study districts as a source of income for different household expenses, such as purchasing crops for consumption during human feed shortage and purchasing fertilizes for the next cultivation period. Most of the time, sheep with large bodies are highly demanded in the local market, and sheep with quick growth often reach market age early. The traits preferred by the smallholder farmers indicate the versatile use of sheep. The investigation of the current study is in line with the method of breeding ram selection that has been reported in the Western Tigray Zone (Hagos *et al*., 2018).

In the Meskan district, traits such as body width, neck thickness, colour pattern, face structure, age, libido temperament, horn length, coat color, and height had a lower preference proportion for selecting the best breeding rams, while in the Soddo district, traits like colour pattern, body width, activeness, body conformation, temperament, age, horn length, tail type, fast lamb growth, coat color, height, and body length had a lower preference proportion for selecting the best breeding rams. On the other hand, the tail type in Meskan district and the face structure and neck thickness traits in Soddo district were not mentioned at all for ram selection. The possible reason farmers did not prefer these traits in each study district might be due to the lower economic importance of these traits from the point of view of the farmer. The current result is similar to an earlier study on the identification of breeding objective traits, which found that male breeding animals were more likely chosen through body size and related traits (Solomon, 2014).

Table 34. List of ram traits in group-ranking experiments

Traits	Districts			
	Meskan		Soddo	
	Freq.	%	Freq.	%
Body size	27	14.29	38	18.72
Coat colour	13	6.88	14	6.90
Colour pattern	3	1.59	2	0.99
Body width	2	1.06	3	1.48
Fast growth	39	20.63	13	6.40
Body condition	16	8.47	17	8.37
Body conformation	7	3.70	7	3.45
Height	13	6.88	16	7.88
Temperament	10	5.29	9	4.43
Body length	12	6.35	16	7.88
Libido	8	4.23	19	9.36
Appearance	15	7.94	21	10.34
Face structure	4	2.12	_	_
Neck thickness	3	1.59	_	_
Tail type	_	_	12	5.91
Activeness			5	2.46
Horn length	11	5.82	11	5.42
Age	6	3.17	10	4.93
Total	189		203	

4.16.5. Comparisons objective traits ranking before and after the provision of life history

The ranking proportions for grouped animals before and after receiving information about the life histories of ewes and rams are summarised in Table 35. When life histories were provided for ewes in Meskan from the group-ranking experiment that had previously been ranked as first, second, and third, about 77.33%, 76.00%, and 85.33% of them remained in their first positions, respectively. Whereas, for similar ranks, the corresponding proportions for ewe in Soddo were 61.33%, 57.33%, and 69.33% remained in their first positions, respectively. For rams in Meskan, 93.33%, 92.00%, and 94.67% of them retained their first positions as the first, second, and third after the provision of life histories for those ranked rams, respectively. The comparable percentages of 94.60%, 93.33%, and 97.33%, respectively, remained in their first positions for the same ranks of rams in Soddo.

Breeding ewe ranking modification was greatly influenced by the attached life history information of the individual animal. In the Meskan district, 13.33% and 9.33% of ewes shift from first to second and first to third positions, respectively. For the same rank-shifting, the ewes in the Soddo district had observed figures of 22.67% and 16.00%. The most probable reason for this difference might be that, in addition to physical traits like body size and coat color, farmers commonly select female animals for their reproductive performance and mothering abilities. Contrary to ewes, the respondents' decision on the ram-group ranking experiments was slightly altered through the attached life history information. For instance, only 5.33% and 1.33% of respondents shifted their ranking in the categories of male sheep in Meskan from first to second and first to third, respectively. For the sheep in Soddo, similar rank-shifting was observed; the comparable figures were 4.00% and 1.33%. Similar outcomes were found in studies on the identification of breeding objective traits using group ranking experiments for sheep breeds in Ethiopia (Mirkena, 2010).

The majority of farmers in the group-animal ranking experiment selected the sheep based on physical appearances like coat color, body size, and body conformation while not considering other performance factors. In contrast to the group-animal ranking experiment, for their own-flock ranking experiment, farmers gave more attention to the animal's performance, such as its reproductive performance, mothering ability, and growth rate. Identification of traits associated with both subjective and objective criteria is crucial for developing sustainable breeding programs for tropical small ruminant production systems. Therefore, it could be desirable to use both techniques to identify breeding objective traits in comparable production systems (Sheriff *et al.*, 2021).

Table 35. Rank proportion before and after the provision of additional information for both sexes in group-ranking experiments

Districts	RBLH	RALH Ewes			RALH Rams		
		1	**2**	**3**	**1**	**2**	**3**
Meskan	1	**58 (77.33%)**	10 (13.33%)	7 (9.33%)	**70 (93.33%)**	4 (5.33%)	1 (1.33%)
	2	14 (18.67%)	**57 (76.00%)**	4 (5.33%)	3 (4.00%)	**69 (92.00%)**	3 (4.00%)
	3	3 (4.00%)	8 (10.67%)	**64 (85.33%)**	2 (2.67%)	2 (2.67%)	**71 (94.67%)**
Soddo	1	**46 (61.33%)**	17 (22.67%)	12 (16.00%)	**71 (94.67%)**	3 (4.00%)	1 (1.33%)
	2	20 (26.67%)	**43 (57.33%)**	12 (16.00%)	4 (5.33%)	**70 (93.33%)**	1 (1.33%)
	3	9 (12.00%)	14 (18.67%)	**52 (69.33%)**	0 (0.00%)	2 (2.67%)	**73 (97.33%)**

RBLH = Rank before provision of life history; RALH = Rank after provision of life history; unchanged ranks are given along the diagonal.

4.17. Phenotypic Characterization of Indigenous Sheep in the Study Area

4.17.1. Qualitative traits of indigenous sheep in the study area

The main qualitative traits of the sampled indigenous sheep population in the study area are illustrated in Table 36. The most commonly exhibited coat colour pattern of the indigenous sheep population in the study area was plain (76.30%), followed by spotty (15.56%) and patchy (8.15%). The current finding is similar to the result of Hussein *et al*. (2022), who reported that the majority of indigenous sheep in Feven Zone had a plain coat color pattern. The most common coat colour type of indigenous sheep in the study area was grey/*'sancha'* (25.19%), followed by dark brown/'gerebet' (19.26%), red/*'bisha'* (18.52%), white (11.85%), black with a white head/*'tikur boqa'* (9.26%), black and white with black dominant/'tikur *bure'* (6.67%), red and white with white dominant/*'bisha bure'* (5.56%), and black (3.70%). The larger proportion of animals with a grey (*'sancha'*) coat colour could be a result of farmers' strong selection for animals with a grey coat colour type to suit different worship purposes, which is most likely related to their cultural faith. The current result contradicts the finding of Markos *et al.* (2023), who identified dark red as the common coat colour type of indigenous sheep in the Bench Sheko Zone.

The majority of sheep (88.89%) lacked wattle and had no ruff (long hair around the neck region of the inner part) (81.48%). The majority of the female sheep in Meskan (55.83%) and Soddo (68.33%) were horned; similarly, 66.67% of the male sheep in Meskan and 86.67% in Soddo were horned. The present finding is similar to the outcome of Kerga (2021), who stated that the majority of indigenous sheep in Gurage Zone were horned. The majority of sheep in the current study had a medium tail length (75.93%), followed by a long tail length (16.67%). Most of the sampled sheep population (90%) had a straight tip-down ward tail conformation. In contrast to the current result, Goshu (2021) reported that most indigenous sheep in the Central and West Gondar Zones had twisted-end tails. The most prominent ear orientation of the sampled sheep population was carried horizontally (74.07%), followed by semi-pendulous (20.74%) and erected (5.19%). The majority of the sampled sheep population in the study area had a medium body condition (72.96%), followed by thin (18.89%) and fat (8.15%) during the study period. Similar to the current study, the body condition of indigenous sheep in Bansa district was medium (Kenfo, 2017). There was a statistically significant difference ($p < 0.05$) between the two districts for coat colour pattern, coat colour type, tail length, presence of wattle, temperament, presence of horn, and body condition.

Table 36. Descriptions of qualitative traits for both sexes of indigenous sheep in the study area

Descriptors	Districts								
	Meskan			Soddo					
	Male	Female	Total	Male	Female	Total	Overall		
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	X^2	P-Value
Coat color pattern								8.25	0.016
Plain	7 (46.67)	86 (71.67)	93 (68.89)	8 (53.33)	105 (87.50)	113 (83.70)	206 (76.30)		
Patchy	2 (13.33)	12 (10.00)	14 (10.37)	3 (20.00)	5 (4.17)	8 (5.93)	22 (8.15)		
Spotted	6 (40.00)	22 (18.33)	28 (20.74)	4 (26.67)	10 (8.33)	14 (10.37)	42 (15.56)		
Coat color type								45.49	0.000
White	0 (0.00)	11 (9.17)	11 (8.15)	1 (6.67)	20 (16.67)	21 (15.56)	32 (11.85)		
Black	1 (6.67)	6 (5.00)	7 (5.19)	0 (0.00)	3 (2.50)	3 (2.22)	10 (3.70)		
Red	1 (6.67)	27 (22.50)	28 (20.74)	1 (6.67)	21 (17.50)	22 (16.30)	50 (18.52)		
Grey	5 (33.33)	40 (33.33)	45 (33.33)	4 (26.67)	19 (15.83)	23 (17.04)	68 (25.19)		
Dark brawn	1 (6.67)	6 (5.00)	7 (5.19)	3 (20.00)	42 (35.00)	45 (33.33)	52 (19.26)		
Black and white	3 (20.00)	10 (8.33)	13 (9.63)	1 (6.67)	4 (3.33)	5 (3.70)	18 (6.67)		
Red and white	1 (6.67)	8 (6.67)	9 (6.67)	2 (13.33)	4 (3.33)	6 (4.44)	15 (5.56)		
Black white head	3 (20.00)	12 (10.00)	15 (11.11)	3 (20.00)	7 (5.83)	10 (7.41)	25 (9.26)		
Ruff								0.10	0.754
Present	11 (73.33)	13 (10.83)	24 (17.78)	13 (86.67)	13 (10.83)	26 (19.26)	50 (18.52)		
Absent	4 (26.67)	107 (89.17)	111 (82.22)	2 (13.33)	107 (89.17)	109 (80.74)	220 (81.48)		
Tail length								7.80	0.020
Short	2 (13.33)	14 (11.67)	16 (11.85)	1 (6.67)	3 (2.50)	4 (2.96)	20 (7.41)		
Medium	10 (66.67)	88 (73.33)	98 (72.59)	12 (80.00)	95 (79.17)	107 (79.26)	205 (75.93)		
Long	3 (20.00)	18 (15.00)	21 (15.56)	2 (13.33)	22 (18.33)	24 (17.78)	45 (16.67)		

Table 36. "Continue…"

Wattle								5.40	0.020
Present	4 (26.67)	17 (14.17)	21 (15.56)	3 (20.00)	6 (5.00)	9 (6.67)	30 (11.11)		
Absent	11 (73.33)	103 (85.83)	114 (84.44)	12 (80.00)	114 (95.00)	126 (93.33)	240 (88.89)		
Temperament								16.55	0.000
Docile	10 (66.67)	102 (85.00)	112 (82.96)	8 (53.33)	74 (61.67)	82 (60.74)	194 (71.85)		
Moderately tractable	4 (26.67)	14 (11.67)	18 (13.33)	4 (26.67)	39 (32.50)	43 (31.85)	61 (22.59)		
Aggressive	1 (6.67)	4 (3.33)	5 (3.70)	3 (20.00)	7 (5.83)	10 (7.41)	15 (5.56)		
Horn								5.19	0.023
Present	10 (66.67)	67 (55.83)	77 (57.04)	13 (86.67)	82 (68.33)	95 (70.37)	172 (63.70)		
Absent	5 (33.33)	53 (44.17)	58 (42.96)	2 (13.33)	38 (31.67)	40 (29.63)	98 (36.30)		
Ear orientation								1.93	0.381
Horizontal	9 (60.00)	96 (80.00)	105 (77.78)	8 (53.33)	87 (72.50)	95 (70.37)	200 (74.07)		
Semi-pendulous	4 (26.67)	20 (16.67)	24 (17.78)	6 (40.00)	26 (21.67)	32 (23.70)	56 (20.74)		
Erected	2 (13.33)	4 (3.33)	6 (4.44)	1 (6.67)	7 (5.83)	8 (5.93)	14 (5.19)		
Tail conformation								0.37	0.543
Tip down ward	12 (80.00)	111 (92.50)	123 (91.11)	13 (86.67)	107 (89.17)	120 (88.89)	243 (90.00)		
Twisted end	3 (20.00)	9 (7.50)	12 (8.89)	2 (13.33)	13 (10.83)	15 (11.11)	27 (10.00)		
Body condition								9.57	0.008
Thin	3 (20.00)	32 (26.67)	35 (25.93)	2 (13.33)	14 (11.67)	16 (11.85)	51 (18.89)		
Average	10 (66.67)	82 (68.33)	92 (68.15)	8 (53.33)	97 (80.83)	105 (77.78)	197 (72.96)		
Fat	2 (13.33)	6 (5.00)	8 (5.93)	5 (33.33)	9 (7.50)	14 (10.37)	22 (8.15)		

N = Number of sheep exhibiting a particular qualitative character; % = Percentage; X^2 = Chi-square

4.17.2. Quantitative physical body measurements of indigenous sheep

The least-squares means and standard errors for body weight and other linear body measurements for sampled indigenous sheep populations in the study area are shown in Table 37. Body weight and other linear body measurements are essential economic and growth traits for sheep. Body weight is not always easy to measure because of weighing equipment shortages, especially in distant rural areas. Based on their effectiveness in determining animal evolution trends, different linear body measurements can also be routinely used in body weight estimation and selection programmes (Dea *et al.*, 2023).

The mean values for live body weight, heart girth, body length, pelvic width, height at wither, height at rump, horn length, ear length, and tail length of sampled indigenous sheep in the overall study area were 24.95 kg, 66.35 cm, 57.93 cm, 14.99 cm, 63.11 cm, 64.36 cm, 14.40 cm, 11.23 cm, and 32.31 cm, respectively. The investigated body weight in the current study is consistent with the previous report that the body weight of indigenous sheep and its crossbred was 25.55 kg in South Wollo (Mohammed *et al.*, 2017).

District effect

The district had a statistically significant effect ($P < 0.05$) on body weight and most linear body measurements except for body length and height at wither of indigenous sheep in the current study. The possible cause of this variation might be that Meskan and Soddo districts had slight to big differences in terms of animal management, feeding, and watering practices. Similar to the present study, Abera (2020) reported that the district had a statistically significant effect ($p < 0.05$) on live body weight and most other linear body measurements of sheep in Northern Ethiopia.

In the current study, the result indicated that the indigenous sheep in Meskan district had considerably greater body weight and other linear body measurements than the indigenous sheep in Soddo district. The main reason for this significant variation might be due to feeding and management differences between the two districts. According to the findings of the present study, the average body weight of indigenous sheep in Meskan district was 25.18 kg and in Soddo district was 24.72 kg. The body weights investigated in the current study are comparable to those reported for indigenous sheep in Ejha (25.7 kg) and Gumer (25.9 kg) districts of Gurage Zone (Kerga, 2021).

Sex effect

Rams had a mean body weight of 25.75 kg, a heart girth of 66.57 cm, a body length of 58.48 cm, a pelvic width of 15.55 cm, a height at wither of 64.37 cm, a height at rump of 65.59 cm, a horn length of 21.52 cm, an ear length of 11.24 cm, and a tail length of 32.75 cm, while ewes had a mean body weight of 24.16 kg, a heart girth of 66.13 cm, a body length of 57.37 cm, a pelvic width of 14.43 cm, a height at wither of 61.85 cm, a height at rump of 63.13 cm, a horn length of 7.29 cm, an ear length of 11.22 cm, and a tail length of 31.87 cm overall in the study area. The sex of the sheep had a statistically significant effect ($P < 0.05$) on the live body weight and most of the other linear body measurements except heart girth and ear length in the current study area.

Males were dominantly larger than females for traits that showed a statistically significant difference, which might indicate that males had a larger muscularity and skeleton. Similarly, Mamo and Wakeyo (2020) investigated that the sex of the sheep had a statistically significant effect ($P < 0.05$) on the body weight and most of the linear body measurements, and males had greater linear body measurements than females in Arsi Zone. The mean body weight of the rams (25.75 kg) and ewes (24.16 kg) in the current study is greater than that reported for Gamo highland rams and ewes, which was 21.15 kg and 20.05 kg, respectively (Dea *et al*., 2023). On the contrary, the current study's result is lower than that reported for the Central and West Gondar Zones, rams (27.9 kg) and ewes (26.9 kg) (Goshu, 2021).

Age effect

The variation across age groups was found to have a statistically significant ($p < 0.05$) effect on body weight and all other linear body measurements (shown in Table 37). In most cases, the trend in body weight and other linear body measurements increased with the increment of dental class up to the third dentition and then remained constant or slightly decreased. The average value of body weight for each age group was 21.29 kg, 24.45 kg, 26.23 kg, and 27.84 kg for 1PPI, 2PPI, 3PPI, and 4PPI, respectively. Similar to the current result, Demeke *et al*. (2020) reported that body weight and most linear body measurements increase with age in indigenous sheep for the first three years and subsequently decrease somewhat after four years in Meket and Gidan districts. In contrast to the present study, Hasen *et al*. (2019) found that age had no significant ($p > 0.01$) effect on body weight and most linear body measurements of indigenous sheep in the Eastern Arsi Zone.

Sex by age effect

The age-by-sex interaction exhibited a statistically significant effect ($p < 0.05$) on body weight and the majority of linear body measurements, with the exception of pelvic width and tail length. In other words, it means that there was a significant difference in body weight and most linear body measurements between the two sexes of the same age class of indigenous sheep in the study area. Similar to the present outcome, for indigenous sheep in Gurage Zone, the interaction between sex and age group was statistically significant ($p < 0.05$) for all quantitative variables except tail length (Kerga, 2021).

Males had a higher mean body weight than females in all age groups of indigenous sheep in the study area except for 1PPI, although the mean heart girth and most of the other linear body measurements were analogous for the two sexes in all age groups. For both sexes, body weight and other linear body measurements were increased as the sheep aged, resulting in males being larger than females. However, females had a larger average body weight (21.34 kg), heart girth (63.12 cm), body length (54.75 cm), ear length (10.85 cm), and tail length (29.89 cm) at 1PPI than males in the same age group, but not in the other age group. This could be due to unequal sample proportions taken for both females and males in the same age group. Similar to the current result, male sheep had heavier body weight and larger linear body measurements than females for most age groups in Bansa district (Kenfo, 2017).

The male sheep in age groups 1PPI, 2PPI, 3PPI, and 4PPI had mean body weights of 21.25 kg, 25.55 kg, 27.58 kg, and 28.62 kg, respectively, while females in the same age groups had mean body weights of 21.34 kg, 23.36 kg, 24.89 kg, and 27.06 kg, respectively. The current investigation is similar to the body weight reported for Arsi-Bale sheep (Mamo and Wakeyo, 2020). The change in body weight was greater in males between the age classes of 1PPI and 2PPI, which was 4.30 kg, whereas in females, the change was greater between the ages of 3PPI and 4PPI, recording 2.17 kg. For the other age groups, the body weight of the indigenous male sheep population increased by 2.03 kg and 1.04 kg as the animal grew from 2PPI to 3PPI dentition class and from 3PPI to 4PPI dentition class, respectively. Whereas the female sheep grew from 1PPI to 2PPI dentition class and from 2PPI to 3PPI dentition class, their body weight increased by 2.02 kg and 1.53 kg, respectively. A slightly similar figure was reported by Sintayehu (2021) for indigenous sheep in the South Gonder Zone.

Table 37. Least squares means and standard errors (LSM ± SE) of the live body weight (Kg) and body measurements (cm) for the main effect of district, sex, age and sex by age interaction for sampled indigenous sheep in the study area

Effects	N	BW	HG	BL	PW	HW	RH	HL	EL	TL
		LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE
Overall	270	24.95±0.11	66.35±0.12	57.93±0.17	14.99±0.08	63.11±0.16	64.36±0.15	14.40±0.30	11.23±0.06	32.31±0.18
District		***	*	NS	***	NS	**	*	**	***
Meskan	135	25.18±0.13[a]	66.50±0.14[a]	57.97±0.20[a]	15.18±0.09[a]	63.22±0.18[a]	64.63±0.17[a]	14.77±0.35[a]	11.13±0.07[b]	32.75±0.21[a]
Soddo	135	24.72±0.13[b]	66.20±0.14[b]	57.88±0.20[a]	14.80±0.09[b]	63.00±0.18[a]	64.08±0.17[b]	14.04±0.35[b]	11.32±0.07[a]	31.86±0.21[b]
Sex		***	NS	***	***	***	***	***	NS	*
Male	30	25.75±0.21[a]	66.57±0.23[a]	58.48±0.32[a]	15.55±0.15[a]	64.37±0.29[a]	65.59±0.28[a]	21.52±0.56[a]	11.24±0.11[a]	32.75±0.34[a]
Female	240	24.16±0.06[b]	66.13±0.09[a]	57.37±0.12[b]	14.43±0.06[b]	61.85±0.11[b]	63.13±0.13[b]	7.29±0.20[b]	11.22±0.04[a]	31.87±0.13[b]
Age		***	***	***	***	***	***	***	***	***
1PPI	32	21.29±0.30[d]	62.56±0.32[d]	54.50±0.44[d]	13.44±0.21[d]	59.31±0.40[d]	60.72±0.39[d]	10.66±0.77[c]	10.43±0.15[c]	29.69±0.47[c]
2PPI	92	24.45±0.19[c]	65.80±0.20[c]	57.27±0.28[c]	14.63±0.13[c]	62.70±0.25[c]	63.95±0.24[c]	14.00±0.48[b]	11.04±0.09[b]	32.26±0.30[b]
3PPI	89	26.23±0.19[b]	67.77±0.21[b]	59.25±0.29[b]	15.46±0.14[b]	64.26±0.27[b]	65.51±0.25[b]	15.59±0.51[ab]	11.62±0.10[a]	33.34±0.31[ab]
4PPI	57	27.84±0.22[a]	69.26±0.24[a]	60.69±0.34[a]	16.43±0.16[a]	66.18±0.30[a]	67.25±0.29[a]	17.37±0.58[a]	11.83±0.11[a]	33.94±0.36[a]
Sex by age		***	**	*	NS	*	**	***	***	NS
Male*1PPI	4	21.25±0.55[e]	62.00±0.60[d]	54.25±0.83[de]	13.75±0.39[def]	59.50±0.75[de]	60.75±0.72[ef]	15.63±1.44[c]	10.00±0.28[d]	29.50±0.89[de]
Male*2PPI	10	25.55±0.35[c]	66.33±0.38[bc]	58.11±0.53[bc]	15.24±0.24[bc]	64.27±0.48[b]	65.46±0.46[bc]	20.87±0.91[b]	10.93±0.18[bcd]	33.09±0.56[abc]
Male*3PPI	9	27.58±0.37[ab]	68.57±0.40[a]	60.45±0.56[a]	16.13±0.26[ab]	65.90±0.50[ab]	67.25±0.48[ab]	23.37±0.96[ab]	11.99±0.19[a]	34.16±0.59[ab]
Male*4PPI	7	28.62±0.42[a]	69.36±0.46[a]	61.13±0.63[a]	17.06±0.29[a]	67.81±0.57[a]	68.88±0.55[a]	26.20±1.09[a]	12.04±0.21[a]	34.24±0.67[ab]
Female*1PPI	28	21.34±0.21[e]	63.12±0.23[d]	54.75±0.32[e]	13.14±0.15[f]	59.12±0.28[e]	60.68±0.27[f]	5.69±0.55[e]	10.85±0.11[cd]	29.89±0.34[e]
Female*2PPI	82	23.36±0.12[d]	65.30±0.13[c]	56.44±0.18[cd]	14.02±0.09[e]	61.13±0.17[d]	62.45±0.16[e]	7.14±0.32[de]	11.14±0.06[bc]	31.43±0.20[cd]
Female*3PPI	80	24.89±0.12[c]	66.98±0.13[b]	58.04±0.19[b]	14.78±0.09[cd]	62.63±0.17[c]	63.76±0.16[d]	7.81±0.32[d]	11.25±0.06[b]	32.51±0.20[b]
Female*4PPI	50	27.06±0.16[b]	69.15±0.17[a]	60.25±0.24[a]	15.79±0.11[b]	64.54±0.21[b]	65.61±0.21[c]	8.53±0.41[d]	11.62±0.08[a]	33.63±0.25[a]

[a, b, c, d, e, f] = Means within the same column and class with different superscripts are significantly different (P<0.05); N=Number of sheep respondent; Ns=Non-significant (P>0.05); * = significant at P<0.05, ** = significant at P<0.01; *** = significant at p<0.001 BW=Body weight; HG=Heart girth; BL=Body length; PW = pelvic width; WH=wither height; RH=Rump height; HL=horn length; EL=Ear length; TL=Tail length; 1PPI = 1 pair of permanent incisor; 2PPI = 2 pair of permanent incisor; 3PPI = 3 pair of permanent incisor and 4PPI = 4pair of permanent incisor; LSM = least square mean and SE = standard error


Figure 6. Measuring body weight (left) and measuring body length (right) of sheep

4.17.3. Correlation between body weight and other linear body measurements

The Pearson correlation coefficients of live body weight with other linear body measurements for male and female indigenous sheep types in the study area are illustrated in Table 38. Except for horn length and tail length in males and horn length and ear length in females, all linear body measurements had strong and statistically significant ($p < 0.01$) positive relationships with body weight. The strong correlation between linear body measurements and body weight implies that these measurements can be used to predict body weight (Rather *et al*., 2020).

Heart girth was a variable that had the strongest positive correlation with body weight in both indigenous male ($r = 0.975$) and female ($r = 0.953$) sheep in the current study. The strong association of heart girth with body weight in males and females in the present study is analogous with other earlier findings of indigenous sheep types in the Eastern Arsi Zone, where heart girth had the strongest positive correlation with body weight (Hasen *et al*., 2019). The strongest positive and significant relationship between body weight and heart girth indicates that the heart girth alone or combined with other linear quantitative variables may provide a good estimate for predicting the live weight of indigenous sheep when there is no other instrument like a spring balance to measure the exact live body weight of the indigenous sheep in the current study area.

The body weight also had a strong and statistically significant ($P < 0.05$) positive correlation with body length (r = 0.973), height at wither (r = 0.929), height at rump (r = 0.926), ear length (r = 0.804), pelvic width (r = 0.769), and scrotal circumference (r = 0.757) for indigenous male sheep, while for indigenous female sheep, body weight was strongly correlated with height at rump (r = 0.869), body length (r = 0.857), height at wither (r = 0.850), pelvic width (r = 0.819), and tail length (r = 0.737) in the study area. Because of the strong correlation between body weight and other body measurements, these could be used as indirect selection criteria to enhance the live weight of sheep (Faraz *et al.*, 2021).

On the other hand, body weight had a moderate correlation with horn length (r = 0.552) and tail length (r = 0.483) in male sheep, while in female sheep it had a moderate correlation with ear length (r = 0.348), which means these variables exhibit medium consistency with the live body weight. Live body weight had a weak association with horn length (r = 0.254) in females. As a result, it could be determined that this variable did not have the ability to predict live body weight. This weak correlation demonstrated that breeders should be aware of the effects of selecting a single set of traits for body weight estimation. The findings of the current study are more or less similar to the report for indigenous sheep in Central and West Gondar Zone, Amhara Region (Goshu, 2021).

Beyond body weight, some linear body measurements had strong correlation with one another; for instance, heart girth with body length (r = 0.961), body length with height at wither (r = 0.911), heart girth with height at wither (r = 0.909), body length with height at rump (r = 0.908), heart girth with height at ramp (r = 0.887), and body length with ear length (r = 0.821) for male sheep. Whereas height at rump with height at wither (r = 0.876), heart girth with height at rump (r = 0.833), heart girth with height at wither (r = 0.808), and heart girth with body length (r = 0.800) had a strong and significant positive correlation for female sheep in the study area. All of the high correlations in the present study implied that there were strong interrelationships among the traits, and this knowledge is highly valuable in sheep breeding and management practices as selection for one trait directly favours other positively associated traits. The majority of linear body measurements had a moderate correlation with one another in both male and female sheep in the study area. The current investigation is similar to the result in North Eastern Amhara that was reported; most linear body measurements had a moderate correlation with one another (Jemal *et al.*, 2018).

Table 38. Pearson correlation coefficient between body weight and other linear body measurements of sampled indigenous sheep in the study area (above the diagonal for males and below the diagonal for females)

Trait	BW	HG	BL	PW	HW	RH	HL	EL	TL	SC
BW		0.975**	0.973**	0.769**	0.929**	0.926**	0.552**	0.804**	0.483**	0.757**
HG	0.953**		0.961**	0.698**	0.909**	0.887**	0.554**	0.789**	0.430*	0.704**
BL	0.857**	0.800**		0.731**	0.911**	0.908**	0.516**	0.821**	0.446*	0.717**
PW	0.819**	0.799**	0.679**		0.735**	0.730**	0.554**	0.663**	0.377*	0.606**
HW	0.850**	0.808**	0.715**	0.715**		0.935**	0.516**	0.704**	0.445*	0.667**
RH	0.869**	0.833**	0.731**	0.731**	0.876**		0.607**	0.699**	0.501**	0.668**
HL	0.254**	0.214**	0.171**	0.249**	0.224**	0.278**		0.532**	0.288^{ns}	0.523**
EL	0.348**	0.316**	0.305**	0.229**	0.426**	0.353**	0.080^{ns}		0.460*	0.733**
TL	0.737**	0.703**	0.588**	0.620**	0.634**	0.670**	0.271**	0.220**		0.305^{ns}

NS = Non-significant (P>0.05); * = Correlation is statistically significant (P<0.05); ** = Correlation is statistically significant (P<0.01); BW = Body Weight; HG = Heart girth; BL = Body length; PW = pelvic width; HW = Height at Wither; RH = Rump height; HL = Horn length; EL = Ear Length; TL = Tail length; SC = Scrotum circumference

4.17.4. Prediction of body weight from other linear body measurements

The number of variables used to predict the best-fitted models through the results of a stepwise multiple linear regression approach for each male and female sex separately is illustrated in Table 39. Regression analysis is commonly used in animal studies to describe quantitative relationships between the response (dependent) variables and explanatory (independent) variables, such as body weight and other linear body measurements (heart girth, body length, pelvic width, height at wither, height at ramp, tail length, and so on), especially when weighing equipment is not accessible (Cankaya, 2009).

A multiple linear regression equation was developed for predicting live body weight from other linear body measurements (heart girth, body length, pelvic width, height at wither, rump height, horn length, ear length, and tail length) for indigenous female sheep and adding scrotum circumference for male sheep in the study area. A stepwise multiple linear regression approach was also used in order to determine the best-fitted model for predicting the body weight of indigenous male and female sheep separately from linear body measurements having a higher positive association with body weight. The best-fitted model was developed by picking the highest R^2 value and the lowest MSE value. The coefficient of determination (R^2) indicates the proportion of total variability explained in the model.

In the absence of facilities to take perfect body weight measurements, the contribution of heart girth was larger and more reliable than other linear body measurements in predicting body weight at the farmer level in the study area. However, because of the higher mean square of error observed when heart girth is used alone, live body weight in both male and female sheep could be more accurately predicted from heart girth and body length measurements in combination in the study area.

When more linear body measurements were incorporated into the multiple linear regression equation, the coefficient of determination (R^2) would become larger while the MSE would become smaller for both male and female sheep. Even though there was a little marginal increment on adjusted R^2, adding more linear body measurements to heart girth resulted in considerable improvements in body weight prediction accuracy. This shows that in the study area for indigenous sheep types, combinations of two or more parameters may be more reliable than heart girth alone in predicting body weight.

Generally, heart girth alone explained about 95% and 91% of the variation in body weight for male and female indigenous sheep, respectively. The possible reason behind this might be that the heart girth is one of the variables least affected by animal posture and easier to measure than other linear body measurements such as height at wither, height at rump, and body length (Mohammed *et al.*, 2017). Similar to the current study, the heart girth has been reported as a reliable linear body measurement to predict live body weight for indigenous sheep in Jimma Zone (Derbie and Tilahun, 2023).

Technically, four quantitative traits (HG, BL, PW, and RH) had a higher positive significant association with live body weight when overall age groups were observed together for males, which explained the total variability of 98% in the dependent variable (body weight). In similar manners, when overall age groups were seen for females, six variables (HG, BL, PW, RH, HW, and TL) had a significant association with live body weight, which explained 95% of the total variability to the dependent variable (body weight). Stepwise multiple linear regression analysis for both male and female sex groups was performed by entering the linear body measurements all together, but the scrotal circumference was removed for female sheep. Similar to the current study, the result reported in Gurage Zone indicated that HG, BL, and PW were the three variables that had the largest contribution to predicting the live body weight for males and females (Kerga, 2021).

The regression equation developed from the linear body measurements for predicting body weight in males and females of indigenous sheep in the current study area is as follows:

For indigenous males:

$$Y = -34.80 + 0.48HG + 0.29BL + 0.19PW + 0.13RH$$

Where Y = Response variable (body weight) and HG, BL, PW, and RH are explanatory (independent) variables with an R^2 value of 0.98

For indigenous females:

$$Y = -34.00 + 0.47HG + 0.18BL + 0.16PW + 0.09RH + 0.10HW + 0.01TL$$

Where Y = Response variable (body weight) and HG, BL, PW, RH, HW, and TL are explanatory (independent) variables with an R^2 value of 0.95

Table 39. Multiple linear regression analysis of live body weight on different body measurements for male and female sheep separately in pooled age group by stepwise method

Sex	Model	Regression coefficients										
		I (β0)	β1	β2	β3	β4	β5	β6	R^2	Adj. R^2	SE	Sig.
Male	HG	-37.97	0.96						0.95	0.95	0.59	0.000
	HG+BL	-36.49	0.50	0.49					0.97	0.97	0.49	0.001
	HG+BL+PW	-34.53	0.51	0.39	0.23				0.97	0.97	0.43	0.008
	HG+ BL+ PW +RH	-34.80	0.48	0.29	0.19	0.13			0.98	0.98	0.40	0.038
Female	HG	-35.17	0.90						0.91	0.91	0.62	0.000
	HG+BL	-34.97	0.70	0.23					0.93	0.93	0.53	0.000
	HG+BL+HW	-36.40	0.58	0.20	0.17				0.95	0.95	0.48	0.000
	HG+BL+HW+TL	-35.21	0.54	0.19	0.16	0.10			0.95	0.95	0.46	0.000
	HG+BL+PW+HW+TL	-33.13	0.49	0.19	0.17	0.14	0.09		0.95	0.95	0.45	0.000
	HG+BL+PW+RH+HW+TL	-34.00	0.47	0.18	0.16	0.09	0.10	0.01	0.95	0.95	0.45	0.007

HG = Heart Girth; BL = Body Length; PW = Pelvic width; WH = RH = Rump height; Wither height; TL = Tail Length; SE = Standard error; R^2 = R- square; Adj. R^2 = adjusted R-square

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Generally, the present study was conducted in the Meskan and Soddo districts of the East Gurage Zone, Central Ethiopia Region, to identify husbandry practices, breeding objectives, and selection criteria of indigenous sheep populations. The larger part of the sheep flock was composed of breeding ewes in both study districts. The dominant sheep production system in the study area was a semi-intensive production system. The study determined that the farmers' main sheep breeding objective was for household income, followed by cultural ceremonies, saving as an asset for future use, and manure. The most common source of feed in the study area was natural pasture during the wet season and grazing aftermath during the dry season. The major source of water was pipe water in the dry season and river water in the wet season. The majority of sheep owners in both study districts used modern castration methods to castrate their sheep. The reasons that most of the respondents practiced castration in the study area were to improve fattening, have a better temperament, and control breeding.

Mating of sheep was usually occurring everywhere, as uncontrolled breeding management was practiced in the study area. The main reasons for uncontrolled mating in both districts were a lack of awareness and sheep grazing together on the same grazing land. It was also usual to use breeding rams from grazing land or neighbouring rams in the village for farmers who did not have a breeding ram. The major selection criteria used by farmers for the best breeding ram in the study area were body size, fast growth, and pedigree, while the majority of farmers gave more attention to traits like twining ability, lambing interval, and lamb survival to select their best breeding ewe. The top three important diseases that affected the productivity of sheep in the study area were diarrhea, sheep cough, and bloating. The major constraints challenging the productivity and reproductive performance of sheep in the study area were disease incidence, labour shortage, and feed shortage. In the own-flock ranking experiment, farmers tended to select the animals based on productive and reproductive traits like twinning rate, lamb growth, and lambing interval, whereas in the group-animal ranking experiment, there was a general tendency to focus on observable physical traits such as coat color, body size, and body condition for both ewes and rams. A positive and strong correlation was found between body weight and heart girth ($r = 0.975$ and $r = 0.953$) in males and females, respectively.

5.2. Recommendation

Based on the current study the following recommendations have been made:

- To enhance the productivity of indigenous sheep in the study area, the stakeholders should aware farmers about the use of improved forage in addition to the use of available feed resources, and feed conservation should be applied in terms of quality and quantity.
- Mixing and herding together sheep flocks within the village on communal grazing land is important. Thus, efforts should be made to develop the capacity of sheep producers on the subject through the district livestock production and development office and the kebele development agent office. This helps reduce the risk of inbreeding more by increasing the effective population size in the study area.
- A larger effort should be put into the selection and identification of the best indigenous breeding rams at an early age to minimize the wholesale of male sheep to cover household expenses without identifying the better ones.
- Phenotypic characterization plays a crucial role in understanding the evolution, adaptation, and biological diversity of sheep. Therefore, phenotypic characterization of sheep should be done using more accurate molecular tools in the future.
- Traits like body weight, growth rate, twinning ability, and post-weaning survival of the growing sheep influenced the decisions of farmers in choosing sheep in the current study area. Therefore, such traits should be well considered when conservation and improvement programs are undertaken for indigenous sheep.
- The economic weight of the trait reflects how changes in a specific trait affect overall profitability. There is a need to add the economic weight of the preferred traits to make the breeding objectives and the selection criteria more complete when rearing sheep.

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7. APPENDIXES

Appendix 1. The semi-structured questionnaire, qualitative and quantitative data collection

A. **General House Hold Information**

1. Date of interview_______________ interviewee name _________________________

2. Name of family head________________

Region________________Zone______________Woreda_____________kebele______________

3. Sex A) Male B) Female

4. Position in household

A) Household head B) Spouse of head C) Relative D) Son E. Daughter

5. Age (in yrs.) A) < 31 B) 31–40 C) 41–50 D) 51–60 E) >61

6. Marital status A) Single B) Married C) Divorced D) Widowed

7. Education level A) Illiterate B) Able to read and write C) Primary school D) Secondary school E) Religious schools F) University/college

8. What is your major farming activity?

A) Livestock production B) Crop production C) Mixed D) Trade E) other types

9. What is your major source of income?

A) In the dry season i) Crop ii) Livestock iii) Both iv) Trade v) Other

B) In wet season i) Crop ii) Livestock iii) Both iv) Trade v) other

10. Number of people living in the house by age and sex

Composition	<31 years	31-40 year	41-50 year	51-60 year	> 60 years	Total
Male						
Female						
Total						

11. Major crop grown

Crop	Main season	Short rain
Barley		
Wheat		
Teff		
Sorghum		
Maize		
Bean		
Pea		
Others		

12. Landholding (in ha)

S/N	Landholding (in ha)	Land allocated in *Timad*	Own	Rent
1	Cereal crop			
3	Pulse crop			
4	Sugar cane			
5	Coffee			
6	*Enset*			
7	Grazing land			
8	Forest land			
9	Vegetables			
	Average total land			

13. Type of grazing land and ownership

Grazing land	Tick	Own	Rent	Communal
Open grassland				
Tree covered grassland				
Bush/shrub grassland				
Stone covered grassland				
Swampy grassland				

14. How many numbers of livestock do you have?

Livestock	Number
Cattle	
Goat	
Sheep	
Donkey	
Chickens	

15. How many sheep numbers do you have according to sex, age, and breeding category?

Flock structure	Numbers
$< 6 - month\ male\ lambs$	
$< 6 - month\ female\ lambs$	
Male 6 months to 1 year old (ram)	
Female 6 months to 1 year old (ewe)	
Male $> 1\ year\ (Breeding\ ram)$	
Female $> 1 year\ (Breeding\ ewe)$	
Castrated Male (older than 1 year)	

16. How do you have acquired/main reasons for the source of breeding sheep you have currently?

A) Born in flock B) Inherited as gift C) Purchased from markets

17. What are the major objectives of sheep production in your family?

Use	Tick	Rank
Income		
Meat		
Saving		
Wealth status		
Manure		
Ceremonies		
Skin		
Dowry		

Others (specify) ____

16. Members of household and hired labor responsible for sheep activities *(Tick one or more boxes in each column and row)*

Activities	<15 years		>15 years		Husband only	Wife only
	Male	Female	Male	Female		
Purchasing the sheep						
Selling the sheep						
Herding						
Breeding						
Feeding and watering						
Caring sick animals						
Barn cleaning						

Others ____

B. Production and Management Practice

14. Do you have a plan to expand your sheep flock?

A) Yes, reason______________ B) No, reason_____________________

15. What types of production systems do you use?

A) Semi-intensive B) Extensive

16. In the family to whom has his/her sheep?

A) Husband B) Wife D) Both C) Children D) All

17. Who has more responsibility for keeping sheep? _____________Why? ____________

18. Trend of livestock species in the last 10 years.

Livestock species	Increasing	Decreasing	Stable	Reason
Cattle				
Goat				
Sheep				
Chicken				

C. Housing-related Husbandry Practices

1. Do you provide separate houses for your sheep flock?

A) Yes, reason ________________ B) No, reason_______________________

2. Housing/enclosure for adult sheep (*Tick one or more boxes)*

With roof	Tick	Without roof	Tick
In family house		Kraal	
Separate house		Yard	
Veranda		None	

Other (specify) ______________

3. What types of materials do you use to construct the sheep house?

Type of material	Roof	Wall	Floor
Iron sheet			
Grass/bush			
Wood			
Stone /bricks			
Mud			
Concrete			
(Plastic sheet)			
Others (specify)			

4. Are lambs housed with the adults?

A) Yes, reason______________________ B) No, reason___________

5. Are your sheep housed with the other livestock?

A) Yes, reason ________________ B) No, reason_______

D. Feeds and Feeding Management

6. What are the major feed sources for your sheep?

Type of Feed	Dry season	Rank	Wet season	Rank
Natural pasture				
Established pasture				
Hay (standing hay)				
Shrubs and Bushes				
Crop Residues				
Fallow land				
By-product of human food				
Concentrate				
improved forages				

Other, specify_______________________________

7. What are the grazing/ browsing methods of your sheep flock during different seasons?

Grazing/Browsing method	Dry Season	Rank	Wet Season	Rank
Free grazing /Browsing				
Rotational grazing				
Herded				
Paddock				
Tethering				
Zero- grazing				

Others, specify________________________________

8. Crop residues used for sheep

Crop residues	Wet season	Rank	Dry season	Rank
Wheat				
Barley				
Sorghum				
Teff				
Maize				
Bean				

Pea				
Lentil				
Chick pea				

Other, specify___________________________

9. Concentrates used for sheep

Concentrate feed	Tick if use	Rank	Type
Homemade grain			
Oil seed cakes			
Local brewery by-products			
Flour by-products			

10. Supplementation regime *(Tick one or more boxes)*

Supplementation	Dry season	Wet season
Roughage		
Minerals (salts)/vitamins		
Concentrates		
None		

Other, specify_______________________________

11. What do trends of communal browsing and grazing lands look like (in the last 10 years)?

A) Increasing B) Decreasing C) stable D) Unknown Reason _______________

12. Is there a seasonal feed shortage? A) Yes B) No reason_________________

13. At which season of the year do you experience feed shortage? ____________________

14. What are coping mechanisms during feed shortage?

E. Herding practice

Do you keep your sheep flock with the other animals?

A) Yes, reason______________________ B) No, reason____________________

15. How is sheep flock herded during the daytime?

Sheep Herded	Tick
Male and female are separated	
Lambs are separated	
All classes' sheep herded together	

Other, specify_____________________

15.1 Sheep flock is herded

Herded With	Tick
Together with cattle	
Together with goat	
Together with calves	
Together with donkeys	
All herded together	
Sheep herded separately	

16. Way of herding

A) Sheep of a household run as a flock B) Sheep of more than one household run as a flock

Others (specify) ___________________________

If the answer is b, how many households mix their sheep together__________?

F. Water Management

17. Do you provide water for your sheep flock? A) Yes B) No, reason__________

18. What is the source of water for your sheep in different seasons?

Source of Water	Dry Season		Wet Season	
	Yes	Rank	Yes	Rank
Borehole/water well				
Dam/Pond				
River				
Spring				
Pipe water				
Rainwater				
Others (specify)				

19. How far are the sources of water from your home and what does the quality of water look like

Distance to watering point	Dry Season	Wet Season
At home		
< 1km		
1-5km		
6-10km		
≥10km		

Water quality	Dry season	Wet season
Clean		
Muddy		
Salty		
Smelly		

20. Are lambs watered with the adults? A) Yes b) No

21. If no, describe the watering distance and frequency for lambs. ____________________

22. How many chances to have water (watering frequency)?

Frequency of watering	Dry season	Wet Season
Freely available		
Once a day		
Once in two days		
Once in three days		
Others		

G. Castration

1. Do you castrate your male sheep? A) Yes B) No

2. What is the reason for castrating your ram?

A) Control breeding B) Improve fattening C) Reduce an aggressive behavior D) Better price

3. At what age do you castrate? A) < 3 months B) 3- 6 months C) > 6 months

4. Season of castration _______________ Reason___________________________

5. Who castrate for you?

A) Myself B) Use the service of extension staff C) Other people who are knowledgeable in traditional castration D) Others (specify) _________________________

6. Which type of castration method do you use?

A) Modern B) Traditional If say traditional specify its method _____________________

7. Do you give supplementary feed to castrated sheep? A) Yes B) No

If yes which supplementary feed is given?

A) Concentrate B) Home leftover C) Grass D) Chat E) Other If no, reason____________

8. What are the problems that limit not castrate your ram?

A) Feed or land shortage B) Lack of money C) Disease D) Lack of castration equipment

H. Culling

9. Do you practice culling for your sheep? A) Yes B) No

If yes, what are the reasons for culling male or female sheep? A) Old age B) Sickness C) Reproductive problem D) Unwanted physical character. If no, reason__________

10. If age is one of the reasons for culling at what age(average) do you cull your sheep:

Male __________ Female ___________

11. What are the different culling modes you practice?

Culling Mode	Male	Female
Sold		
Slaughtered		
Exchanged		
Donated/gift		

I. Fattening

12. Do you practice fattening of sheep? A) Yes, reason________ B) No, reason_______

1. If yes, which categories of animals do you fatten?

Rank the top three

Type	Tick
Culled young female	
Culled young male	
Young females	
Young males	

Type	Tick
Castrates	
Older males	
Older female	
Other, specify	

Rank	
1.	
2.	
3.	

2. Which season is more favorable to fatten the sheep?

A) Dry season, reason ____________ B) Wet season, reason ________

3. How long does it take to fatten your sheep?

A) 3-4 months B) 4-6 Months C) > 6 months

4. What types of feed resources do you use to fatten? A) Natural pasture B) Chat C) Concentrates D) Crop residue E) Improved forage F) Other, specify

J. Health Related Management

17. What types of diseases frequently occur and affect the productivity of sheep in the area?

No.	Disease type	Symptom	Season of occurrence	Actions take (Treatment)	
				Modern	Tradition
1					
2.					
3.					
4.					
5.					

18. What would you do when your sheep is sick?

A) Treat with ethno veterinary practices B) Sales immediately C) Slaughters immediately

D) Takes to a veterinary center E) Treat with treatments from local traders F) others ________

19. Do you have a veterinary service? A) Yes B) No

If yes, what distance to the veterinary service? A) < 5 km B) 6-10 km C) >10 km D) Other ___

20. What are the sources of veterinary services for the sheep when they are sick?

A) Government B) Private shops C) both

21. Did your sheep get the vaccine in the appropriate period? A) Yes B) No

If yes, how can you get it?

A) After the report of disease cases B) After certain animals died C) Before outbreaks

22. Has there been any death of your sheep in the last 12 months? A) Yes, Number ______B) No

23. What were the major causes of death/loss of your sheep? (Rank)

No.	Factors that cause death	Tick	Rank
1	Droughts		
2	Feed and water shortages		
3	Predators		
4	Parasites		
5	Poisoning		
6	Diseases		
7	Accident		
8	Mechanical causes		
9	Undetermined		
10	Others, specify		

K. Sheep Production Constraint

24. What are the main constraints that limit sheep productivity?

Constraints	Tick	Rank	Improvement Option
Drought occurrence			
Feed shortage			
Water shortage			
Disease incidence			
Lack of superior genotype			
Market problem			
Predator			
Labor shortage			
Lack of extension service			
Others (specify)			

25. How do you describe the level of resistance of your indigenous sheep to some stress?

Stress	Level of Resistance /Tolerance		
	Low	Medium	High
Heat			
Drought			
Feed shortage			
Water shortage			
Parasite			
Disease			

L. Practices Related to Breeding Objectives

1. What are the major types of traits that should be considered the best for the use of breeding rams for breeding purposes in the future?

A) Growth rate____________ E) Coat color_____________

B) Physical appearance _____________ F) Pedigree _____________

C) Sexual ability ________________ G) Temperament _______________

D) Testicular Structure________________ H) Horns_________________

2. What are the major types of traits that should be considered the best for use breeding ewe for breeding purposes in the future?

A) Mothering ability ____________ E) Twinning ability______________

B) Milk yield __________________ F) Family history _______________

C) Coat color __________________ G) Horn _______________________

D) Physical Appearance__________________

4. Do you have your breeding ram? A) Yes B) No

If yes, do you allow a ram to mate with his mother, sister, and daughter? A) Yes B) No

If not, how do you mate your ewe? A) Neighboring ram B) Communal grazing area

5. What is the number of rams in your flock? A) 1 B) 2 C) 3 D) More than 3

If more than one, why do you keep more than one ram? ______________________

6. For how many years on the average is the same breeding ram serving in your flock and why?

A) 2-3 B) 3-4 C) 4-5 D) more than 5 Reason________________________

7. Do you give special management for breeding male sheep? A) yes B) No

8. If yes, what is the special management for a breeding ram? ____________________

9. Do you use control mating? A) Yes B) No

If yes, how do you control mating? ________________________________

10. Do you know the impact of mating-related individuals? A) Yes B) No

11. Could you able to identify the sire of a lamb? A) Yes B) No

If yes, how________________________

12. Average market age in month: Male ______ Female __________

M. Practices Related to Selection Criteria

1. Selection criteria/trait preferences for breeding ram and ewe? (Rank)

Breeding ram			**Breeding ewe**		
	Selection criteria	**Rank**		**Selection criteria**	**Rank**
1	Appearance/conformation		1	Size/Appearance	
2	Color		2	Color	
3	Horn		3	Lamb survival	
4	Character		4	Lamb growth	
5	Adaptability		5	Age at first sexual maturity	
6	Growth		6	Lambing interval	
7	Libido		7	Twining ability	
8	Wool/hair		8	High milk yield	
9	Age		9	Ability to walk long distance	
10	Ability to walk long distance		10	Tail type/length	
11	Pedigree		11	Wool/hair	
12	Tail type/length		12	Mothering ability	
13	Others		13	Others	

N. Reproductive Performances of Indigenous Sheep Used as Selection Criteria

1. Type of breeding/mating A) Controlled B) Uncontrolled

2. If uncontrolled, what is the reason?

A) Sheep graze together B) Lack of awareness C) Insufficient number of ram D) Other, specify_____

3. Do you allow your ram to serve ewes other than yours? A) Yes B) No Reason________

4. Do you allow your ewe to be served by anyone else ram? A) Yes B) No Reason_________

P. Reproduction Characteristics

1. Average age at sexual maturity: - Male _____ months; Female _____ months

2. Age at first lambing: - Average _____ months

3. Lambing interval: - Average _______ months

4. Do you fix the age at first mating for the females? A) Yes B) No

5. Do you fix the age at first mating for the males? A) Yes B) No

6. Average reproductive life span of ewe (in years) _______

7. Average number of lamb crops per ewe life span ________

8. Average reproductive life span of ram______________

9. Occurrence of most births (type of birth) and season of most birth occurs.

A) Single B) Twin C) Single and Twin D) Others __________________

10. How much parturition occurred with your flock during the last 1 year? ______________

11. How many abortion cases occur in your flock in the last 1 year? ___________

12. How many offspring mortalities occurred in the last 2 months____________________?

13. Average weaning age of lambs: -

A) < 3 months B) 3-4 months C) 4-5 months D) >5 months

14. Milk feeding up to weaning

A) Unrestricted suckling B) Bucket feeding C) Restricted suckling D) Others______

Q. Breeding practices

1. Purpose of keeping breeding ram and Source of ram (s)

Purpose	Tick
Mating	
Socio-cultural	
For fattening	
Others (specify)	

Source	Tick
Born in the flock	
Purchased, private	
Purchased in partner	
Rent	

2. If you do not have a breeding ram, how do you mate your ewe?

A) Neighboring ram B) Unknown others (specify)_________________________

3. Do you practice selection for breeding males? A. Yes, B. No

4. Do you practice selection for breeding females? A. Yes, B. No

5. If yes, specify the criteria to identify. ______________________________________

R. Herd Dynamics

1. Is your sheep number increasing in the last 12 months?

A. Increased B. Decreased C. Stable

2. Numbers of animals added and reduced in the last 12 months

Added animals	**Males**	**Females**
Born		
Bought		
Donated/gift		
Exchanged		
‘*Rebi*’		
Share from ‘*Rebi*’		

Reduced animals	**Males**	**Females**
Sold		
Slaughtered		
Exchanged		
Died		
Predator		
Donated/gift		

Appendix Table 1. Format for own-flock ranking of breeding ewes by owners

Farmers Name______________________________ District_______________

Flock size _____ewes_________ rams__________ Female lambs_____ Male lambs_____ castrated_____ young ewe_____ Young ram_________

No	Traits and ID	1st best	2nd best	3rd best	Inferior
1	ID				
2	Color pattern				
3	Color Type				
4	Wattles				
5	Ruff				
6	Dentation				
7	Horn length				
8	Ear length				
9	Wither height				
10	Heart girth				
11	Body length				
12	Rump height				
13	Pelvic Width				
14	Tail length				
15	Body weight				
16	Body condition				
17	AFL				
18	Lambing interval				
19	Birth type				
20	Number of lambing				
21	Twining				
22	Number of lambs born				
23	Number of lambs weaned				
24	Price				
	Reasons				
	1				
	2				
	3				
	4				

AFP = Age at first lambing

Appendix Table 2. Format for own-flock measuring of breeding rams by owners

Farmers Name ________________________________District_______________ Flock size_______ ewes_______ rams_______ Female lambs________ Male lambs_______ castrated______ young ewe______ Young ram________

No	Traits and ID	Remark
	ID	
1	Color pattern	
2	Color Type	
3	Wattles	
4	Ruff	
5	Dentation	
6	Horn length	
7	Ear length	
8	Wither height	
9	Heart girth	
10	Body length	
11	Rump height	
12	Pelvic Width	
13	Tail length	
14	Body weight	
15	Scrotum circumference	
16	Body condition	
17	Temperament	
18	Price	

Name of farmer ranked the animal _______________________District______________

Appendix Table 3. Recording format for ranking ewes in group-ranking experiments

Pen 1		Pen 2		Pen 3		Pen 4		Pen 5	
ID	Rank	ID	Rank	ID	Rank	ID	Rank	ID	Rank

Reasons (pen 1)	Reasons (pen 2)	Reasons (pen 3)	Reasons (pen 4)	Reasons (pen 5)

Appendix Table 4. Recording format for ranking rams in group-ranking experiments

Pen 1		Pen 2		Pen 3		Pen 4		Pen 5	
ID	Rank	ID	Rank	ID	Rank	ID	Rank	ID	Rank

Reasons (pen 1)	Reasons (pen 2)	Reasons (pen 3)	Reasons (pen 4)	Reasons (pen 5)

Appendix Table 5. ANOVA for own-flock ranking of indigenous sheep in Meskan district

	DF	**Sum of Squares**	**Mean Square**	**F-Value**	**Sig.**
Dentation	3	18.333	6.111	6.394	0.000
BW	3	418.523	139.508	64.738	0.000
Number of lambing	3	82.625	27.542	10.131	0.000
Twining	3	4.656	1.552	11.437	0.000
NLB	3	362.825	120.942	18.98	0.000
NLW	3	353.8	117.933	18.485	0.000

Appendix Table 6. ANOVA for own-flock ranking of indigenous sheep in Soddo district

	DF	**Sum of Squares**	**Mean Square**	**F-Value**	**Sig.**
Dentation	3	18.425	6.142	9.428	0.000
BW	3	524.033	174.678	65.859	0.000
Number of lambing	3	207.358	69.119	17.992	0.000
Twining	3	4.506	1.502	10.019	0.000
NLB	3	454.692	151.564	19.927	0.000
NLW	3	515.533	171.844	27.979	0.000

Appendix Table 7. ANOVA for body weight of sheep to district, sex, age and sex by age effects

Source	**DF**	**Type III SS**	**Mean Square**	**F-Value**	**Sig.**
District	1	14.127	14.127	11.635	0.001
Sex	1	59.003	59.003	48.595	0.000
Age	3	436.042	145.347	119.71	0.000
Sex * Age	3	20.373	6.791	5.593	0.001
Error	261	316.897	1.214		

Appendix Table 8. ANOVA for heart girth of sheep to district, sex, age and sex by age effects

Source	**DF**	**Type III SS**	**Mean Square**	**F-Value**	**Sig.**
District	1	6.423	6.423	4.459	0.036
Sex	1	4.363	4.363	3.029	0.083
Age	3	464.696	154.899	107.532	0.000
Sex * Age	3	20.463	6.821	4.735	0.003
Error	261	375.968	1.44		

Appendix Table 9. ANOVA for body length of sheep to district, sex, age and sex by age effects

Source	**DF**	**Type III SS**	**Mean Square**	**F-Value**	**Sig.**
District	1	0.466	0.466	0.168	0.682
Sex	1	29.002	29.002	10.456	0.001
Age	3	407.931	135.977	49.024	0.000
Sex * Age	3	23.104	7.701	2.777	0.042
Error	261	723.925	2.774		

Appendix Table 10. ANOVA for pelvic width of sheep to district, sex, age and sex by age effects

Source	**DF**	**Type III SS**	**Mean Square**	**F-Value**	**Sig.**
District	1	9.476	9.476	16.009	0.000
Sex	1	28.928	28.928	48.869	0.000
Age	3	93.429	31.143	52.61	0.000
Sex * Age	3	1.424	0.475	0.802	0.494
Error	261	154.503	0.592		

Appendix Table 11. ANOVA for height at wither of sheep to district, sex, age and sex×age effect

Source	DF	Type III SS	Mean Square	F-Value	Sig.
District	1	3.285	3.285	1.451	0.229
Sex	1	148.14	148.14	65.438	0.000
Age	3	462.964	154.321	68.169	0.000
Sex * Age	3	24.565	8.188	3.617	0.014
Error	261	590.857	2.264		

Appendix Table 12. ANOVA for height at ramp of sheep to district, sex, age and sex by age effect

Source	DF	Type III SS	Mean Square	F-Value	Sig.
District	1	20.554	20.554	9.811	0.002
Sex	1	141.473	141.473	67.527	0.000
Age	3	421.689	140.563	67.093	0.000
Sex * Age	3	31.725	10.575	5.048	0.002
Error	261	546.807	2.095		

Appendix Table 13. ANOVA for horn length of sheep to district, sex, age and sex by age effects

Source	DF	Type III SS	Mean Square	F-Value	Sig.
District	1	36.219	36.219	4.359	0.038
Sex	1	4731.221	4731.221	569.434	0.000
Age	3	444.439	148.146	17.83	0.000
Sex * Age	3	147.262	49.087	5.908	0.001
Error	261	2168.554	8.309		

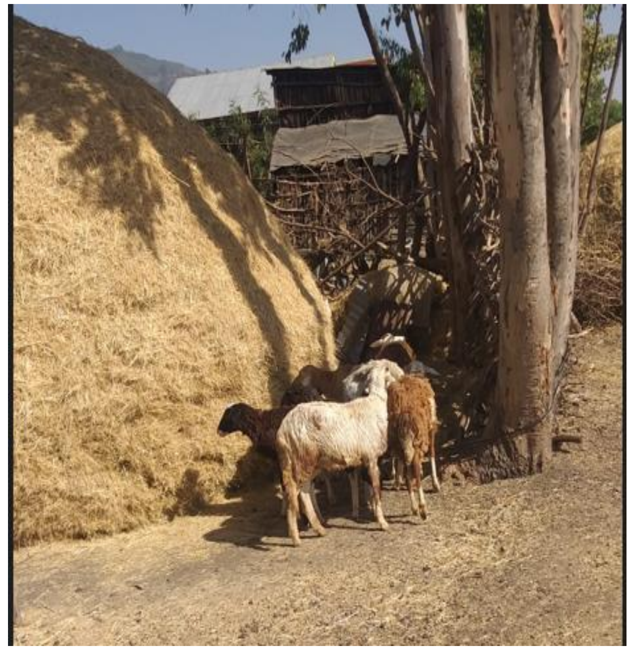
Appendix Table 14. ANOVA for ear length of sheep to district, sex, age and sex by age effects

Source	DF	Type III SS	Mean Square	F-Value	Sig.
District	1	2.474	2.474	7.816	0.006
Sex	1	0.014	0.014	0.045	0.832
Age	3	23.332	7.777	24.572	0.000
Sex * Age	3	7.934	2.645	8.356	0.000
Error	261	82.609	0.317		

Appendix Table 15. ANOVA for tail length of sheep to district, sex, age and sex by age effects

Source	DF	Type III SS	Mean Square	F-Value	Sig.
District	1	52.914	52.914	16.874	0.000
Sex	1	18.166	18.166	5.793	0.017
Age	3	183.475	61.158	19.503	0.000
Sex * Age	3	14.411	4.804	1.532	0.207
Error	261	818.459	3.136		

Appendix Figure 1. Focus group discussion in the area



Appendix Figure 2. Crop residue in the area

Appendix Figure 3. Sheep on communal grazing land

Appendix Figure 4. Watering point in the area

BIOGRAPHICAL SKETCH

The author, **Wolyu Shifa** was born on January 10, 1998 G.C, in the Meskan district of Gurage Zone (now East Gurage Zone), Southern Nations, Nationalities, and Peoples’ Region (now Central Ethiopia Region), Ethiopia from his father **Shifa Temam** and his mother **Muhaba Awol**. He attended his elementary education (1–8) at Debub Shershera Primary School from 2005 to 2012; his junior high school education (9–10) at Mekicho Millennium Secondary School from 2013 to 2014; and pursued his preparatory education (11–12) at Butajira Preparatory School from 2015 to 2016.

Then, he joined Werabe University College of Agricultural and Natural Resource Management in 2017 and was awarded a BSc degree in Animal Science in January 2021. Soon after graduation, the author was employed at Werabe University College of Agricultural and Natural Resource Management in the Animal Science department and served as a graduate assistant I/junior lecturer for six months. Then, he joined the School of Postgraduate Program Directorate of Hawassa University in 2021 to pursue his **Master of Science** in Animal Breeding and Genetics under the School of Animal and Range Science.