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Livestock production, productivity, and sustainability in Ethiopian pastoral systems: evidence from Fentale District

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Livestock production is crucial for the livelihoods of pastoral societies in Ethiopia, specifically in arid and semi-arid lowlands, where crop farming is limited. This study aimed to assess livestock production, productivity, and sustainability in pastoral systems in the Fentale District of Ethiopia. A mixed methods approach was employed, integrating household surveys (n = 344), key informant interviews, focus group discussions and field observations. The results showed that camels contributed the highest number of tropical livestock units (9.86), followed by cattle, indicating that multiple species diversification is a key adaptation strategy. Natural grazing provided 60% of the feed, but 99.7% of the households reported that they did not have enough feed. This problem was mostly because there was insufficient grazing (69%), and bush encroachment took over (31%). Water scarcity was identified as the major production constraint (63%), and in the dry season, livestock had to walk up to 4 hours to get water. Only 24.7% of the households used extension services, and 76% did not have access to veterinary clinics. However, 52% of the farmers did not benefit from livestock markets because they were too far away and had weak infrastructure. Traditional practices, such as herd mobility (47%), seasonal feed conservation (*Kaloo system*) (59%), and trait-based animal selection, were significant coping mechanisms. Thus, this study highlights the critical gaps in livestock productivity, extension services, and policy inclusion. Strengthening essential interventions and providing targeted support are important for enhancing and building more resilient and sustainable pastoral systems in Ethiopia.

KEYWORDS

constraints, coping mechanisms, livestock productivity, pastoralists, sustainability

Introduction

In global food security systems, livestock production is crucial for rural livelihoods and ecological landscapes, especially in areas where cultivating farming systems are limited by climatic or topographical constraints. Thus, the contribution of livestock to the agricultural gross domestic product is approximately 40%, which means that over 1.3 billion people rely on livestock globally (FAO, 2023). Similarly, the livestock systems have a vital role in Sub-Saharan Africa, by serving as a source of food security, social capital, source of income generation, traction purposes, and as well as used as insurance against economic and environmental shocks (Omotoso et al., 2023). However, these systems are increasingly challenged by climate change, land degradation, and evolving socio-economic conditions.

Across Africa, particularly in arid and semi-arid regions where rainfall variability and low soil limit crop cultivation, livestock production systems are still dominant in pastoralism (Francis et al., 2014). It is predicted that approximately 268 million pastoralists and agro-pastoralists inhabit the continent, managing substantial proportions of Africa's cattle, goats, sheep, and camels (AU, 2011). Thus, despite its economic and cultural significance, African pastoralism is regularly marginalized in policy and development frameworks and receives insufficient investment in infrastructure, extension services, and market access. Furthermore, insecurity issues, the presence of recurrent droughts, and altering the use of land patterns are eroding the frequent sustainability of pastoral systems, threatening the resilience of the communities that depend on them (Debela et al., 2019; Ericksen et al., 2013).

In Ethiopia, nearly 80% of the population relies on livestock for employment and income generation, which accounts for approximately 40% of the agricultural gross domestic product (GDP) in the country (MoA, 2021). Ethiopia is the leading country in Africa with a large livestock population, which includes over 70 million cattle, 52 million goats, 42 million sheep, and a significant number of camels, most of which are found in pastoral and agro-pastoral areas (CSA, 2023). Pastoral systems in Ethiopia are predominantly in the lowland regions of Somali, Afar, and Oromia, where strategies such as mobility and maintaining diverse herds are crucial for adaptation. These regions are home to millions of pastoralists who depend primarily on livestock for food security, cultural identity, and social cohesion (Albore et al., 2025; Entity, 2021; Fenta et al., 2019; Kebede et al., 2020). However, due to the presence of in combination with biophysical, socioeconomic, and institutional constraints, the productivity of livestock remains low.

Pastoral livestock production is the backbone of livelihoods in Ethiopia's arid and semi-arid lowlands, where mobility, herd diversification, and adaptation to variable grazing and water resources are central to survival. In these systems, livestock are important not only for meat and milk production, but also for income, asset accumulation, transport, and social security (Tolera and Abebe, 2007). Recent evidence from Ethiopia indicates that pastoral and agro-pastoral herds are typically composed of cattle, camels, sheep, and goats, with herd composition adjusting to aridity, forage conditions, drought exposure, and household livelihood objectives. More broadly, contemporary dryland pastoralism research shows that mobility and flexible herd management are not maladaptive remnants, but rational and productive strategies for coping with environmental variability and sustaining resilience (Defar et al., 2026; Sintayehu et al., 2025).

Fentale District, situated in the East Shoa Zone of the Oromia Region, is a representative example of a pastoral area undergoing significant transformation. The district is predominantly characterized by erratic rainfall, arid climate, high temperatures, presence of invasive plants/bush encroachment, and recurrent drought events (Bekele and Amsalu, 2012; Kebede et al., 2020). The community in the area mainly rearing livestock such as cattle, goats, camels, and sheep constitutes the primary livelihood activity. However, the district is frequently prone to many challenges, including poor access to veterinary and extension services, inadequate feed and water resources, encroachment of agricultural and commercial investments onto traditional grazing

lands, and climate-related stressors (ATPS, 2013; Mekuyie and Mulu, 2021). These impacts have direct implications for livestock production and productivity and threaten the long-term sustainability of the region's pastoral livelihoods.

To modernize the Ethiopian livestock sector nationally, the Ethiopian Livestock Master Plan (LMP) and 10-year agricultural development plan focus on the importance of growing and increasing productivity, commercialization, and resilience. However, these policies and strategies mainly focus on and often emphasize highland mixed farming systems, while lowland pastoral areas receive less targeted attention and investment (Shapiro et al., 2017). This study is guided by the Sustainable Livelihoods Framework (SLF), which has been widely applied to analyze pastoral livelihood assets and adaptive strategies (Ashley and Carney, 1999). The SLF provides a structured analytical lens to examine how Fentale pastoralists utilize natural, physical, human, social, and financial capital assets to develop adaptive strategies in response to recurrent drought, land degradation, and socioeconomic marginalization (Thornton et al., 2024). Therefore, despite existing studies on pastoral systems, there remains limited empirical evidence linking livestock production practices, productivity constraints, and sustainability outcomes at the local level. This study addresses this gap by providing field-based evidence from the Fentale District. Specifically, it analyzes livestock production practices, identifies key factors affecting productivity, and evaluates the sustainability of pastoral livelihood strategies within a changing socio-ecological context. Therefore, the main aim of this study was to assess livestock production, productivity, and sustainability in Ethiopian pastoral systems, with a particular focus on the Fentale District.

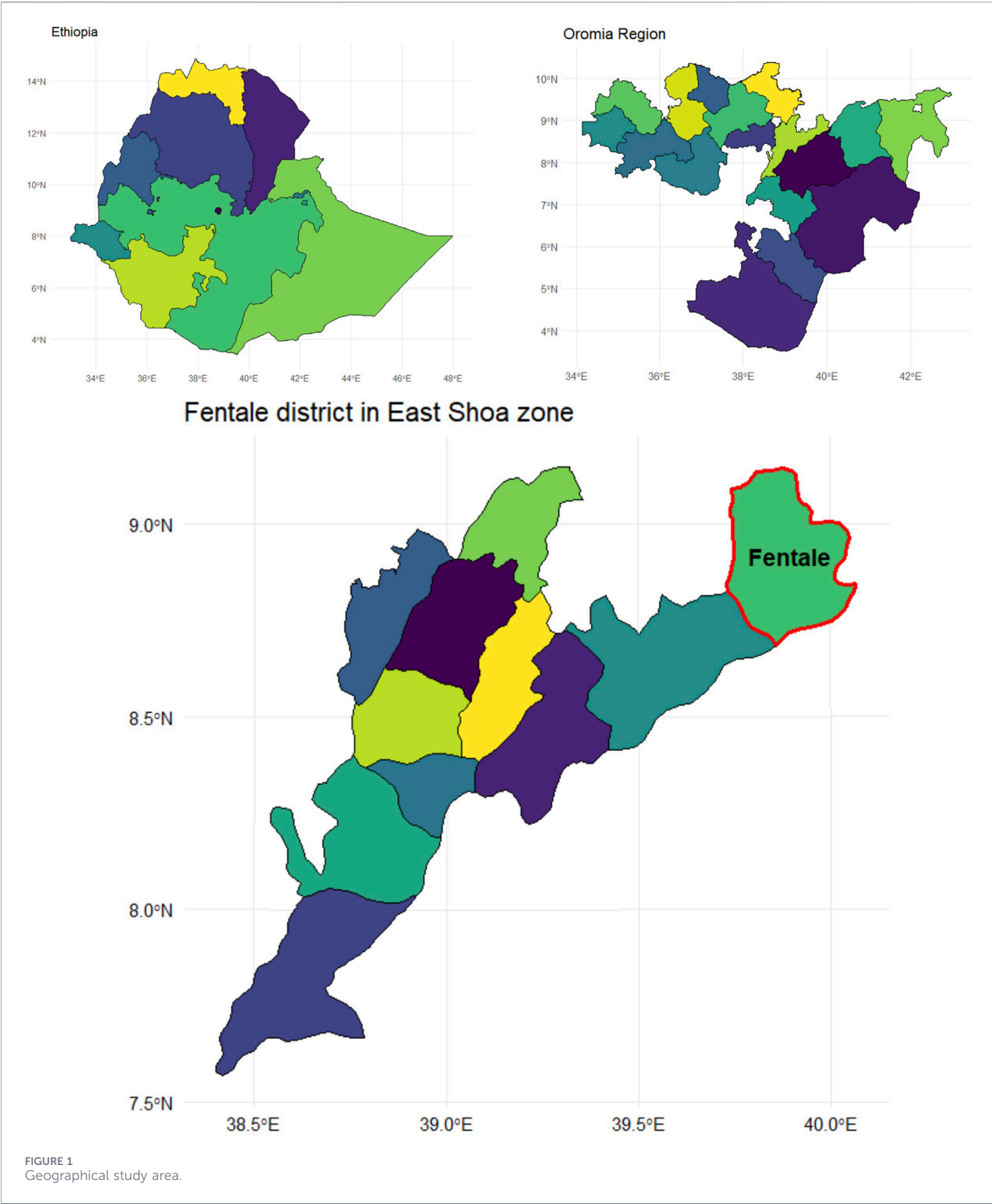
Materials and methods

Study areas description

This study was conducted in the Fentale District, East Shoa Zone, Oromia Regional State, Ethiopia. The geographical district of the area is located at 8°01' to 9°00'N latitudes and 30°03' to 40°01'E longitudes (Figure 1). Metehara town is one of the administrative towns of the district, located 200 km away from Addis Ababa, and the district has 18 rural villages (kebele) (Mekuyie and Mulu, 2021). The study area includes undulating plains, hills, and mountainous landscapes. The elevation ranges from 862 to 1997 m.a.s.l. The area is characterized by arid and semi-arid environments. The mean minimum and maximum monthly temperatures of the area ranged from 12.80 °C to 21.90 °C and 28.0 °C–36.70 °C, respectively. The district receives annual rainfall of 400–700 mm (Mekuyie and Mulu, 2021). The livelihood and income of the communities strongly depend on livestock production.

Study design

A cross-sectional study design was conducted to assess livestock production, productivity, and sustainability in the Ethiopian pastoral system: Evidence from the Fentale district. Individual pastoralists were interviewed using semi-structured questionnaires, key informants, and focus group discussions.



Sampling procedure and sample size determination

A multi-stage sampling procedure combining both random and purposive sampling techniques were used. In the first stage,

secondary information was obtained from East shoa Zone and Fentale Woreda Livestock Development and Fisheries Offices, which served as the sampling frame for selecting villages (kebele's). This official registry provided a complete list of all 18 kebeles within the district, from which 11 representative

kebeles were randomly selected using a simple random sampling method. The selection was further guided purposively based on the degree of pastoralism extent and availability of livestock population in each kebele, as confirmed by district-level experts. In the second stage, the sample size was determined using the formula, which was adopted from (Yamane, 1967).

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

Where n = is the sample size.

N = total population size (HH)

e = marginal error.

The marginal error (e) taken for this study was 5.3%–6%, which is equal to 0.053 with 95% CI.

Total sample size was estimated as follows.

$$n = \frac{10000}{1 + 10000(0.053)^2}$$

$$n = 344.$$

In the third stage, the 344 respondents were proportionally allocated across the 11 selected kebeles, with 25–35 participants selected from each kebele using systematic random sampling from the household register of each kebele. This ensured representative coverage across all selected study sites.

Method of data collection

To strengthen the mixed methods approach, qualitative findings from key informant interviews, focus group discussions, and field observations were systematically integrated with quantitative survey results during analysis, providing deeper contextual explanation of the diverse dynamics behind the quantitative findings such as constraints in livestock marketing, climate adaptation strategies, and sustainability of traditional social networks. Community leaders, Elders, Development agent and experts were used to triangulate the survey data. The primary data was collected through household interview, key informant interview along with focus group discussion and field observation for period of 6 months. The survey questions mainly focus on the demographic characteristics of pastoralists, livestock production and management practices, livestock marketing and constraints, livestock extension service and dissemination of information and early climate warning practices and awareness. Sustainability was assessed indirectly using proxy indicators, including grazing land quality, water security, and the resilience of traditional social networks, within the Sustainable Livelihoods Framework. All data were collected with the verbal informed consent of participants and cross-checked with local veterinary records for accuracy. Key informant interview along with focus group discussion were also used. Thus, twenty (20) key informants' interviews were purposely selected from the district along with focus group discussion for the qualitative information of this study. From field observation checklist analysis, available resource, potential risk and challenges, livestock husbandry practices and market pattern and possible challenges were observed. All the information obtained from field observations

were further analysed and triangulated with result obtained from questionnaire, key informant interview and focus group discussion.

Method of data analysis

The data were mainly analyzed using descriptive statistics, including means, percentages, standard errors, frequencies, and ranking indices. Because several variables were based on rankings, multiple responses, or highly uneven categories, inferential statistical analysis was not considered appropriate for this dataset. Descriptive statistics were used to summarize the main characteristics and key parameters of the study area, and the analyses were performed using SPSS version 29. Index ranking was used to identify the relative importance of selected variables. The index was calculated as:

$$\text{Index} = \frac{\sum (3 * \text{Rank } 1 + 2 * \text{Rank } 2 + 1 * \text{Rank } 3) \text{ for each reason}}{\sum (3 * \text{Rank } 1 + 2 * \text{Rank } 2 + 1 * \text{Rank } 3) \text{ for all reasons.}}$$

The livestock population was converted to Tropical Livestock Units (TLU) using the following conversion factors: 0.70 for cows, 0.20 for calves, 1.00 for oxen, 0.70 for heifers, 1.00 for bulls, 1.25 for camels, 0.10 for ewes, 0.10 for rams, 0.05 for lambs, 0.10 for does, 0.10 for bucks, 0.05 for kids, and 0.80 for equines (Rothman-Ostrow et al., 2020).

Results

Socio demographic characteristics of pastoralists in the study area

The socio demographic characteristics of pastoralists household can influence the livestock production, productivity and sustainability were presented in the [Supplementary Table S1](#). Most respondents in the study area were male (89.5%), and a large proportion of respondents had no formal education level (87.5%). The study area mainly dominated by the Muslim religious (90.4%).

Livestock population and purposes of keeping livestock

Livestock are key to determining the wealth and social status of pastoralists. The total livestock population was determined by the tropical livestock unit (TLU) as presented in [Table 1](#). Camels represented the largest distribution in the tropical livestock unit (9.86), followed by the cattle in the combined tropical livestock unit (7.91) for cows, calves, heifers, and bulls. The contribution of the goat population was also largest in the areas next to cattle, with a combined TLU of 3.24 for the does, bucks, and kids. The mean of the goat's distribution was particularly higher at 25.33 ± 10.26 . [Supplementary Table S2](#) summarizes the primary livelihood purposes of pastoralist households in the study area, emphasizing the keeping and rearing of diverse livestock species. The pastoralists ranked cattle on the top for milk compared to other livestock, with 0.46, 0.29, 0.25, and 0.11 for cattle, camel, goat, and sheep,

TABLE 1 Livestock population in study areas (n = 344).

Livestock type	Minimum	Maximum	Mean $\pm$ SD	Tropical livestock unit (TLU)
Cows	1	45	8.08 $\pm$ 6.61	5.65
Calves	0	15	2.34 $\pm$ 1.81	0.47
Oxen	0	5	0.28 $\pm$ 0.63	0.28
Heifers	0	19	2.16 $\pm$ 1.96	1.51
Bulls	0	12	1.46 $\pm$ 1.45	1.47
Camels	0	76	7.88 $\pm$ 9.64	9.86
Ewes	0	77	14.44 $\pm$ 12.49	1.44
Rams	0	14	3.17 $\pm$ 2.33	0.32
Lambs	0	70	4.20 $\pm$ 5.23	0.21
Does	0	400	25.33 $\pm$ 10.26	2.53
Bucks	0	40	4.42 $\pm$ 4.14	0.44
Kids	0	100	5.33 $\pm$ 7.28	0.27
Equines	0	11	1.61 $\pm$ 1.27	1.29

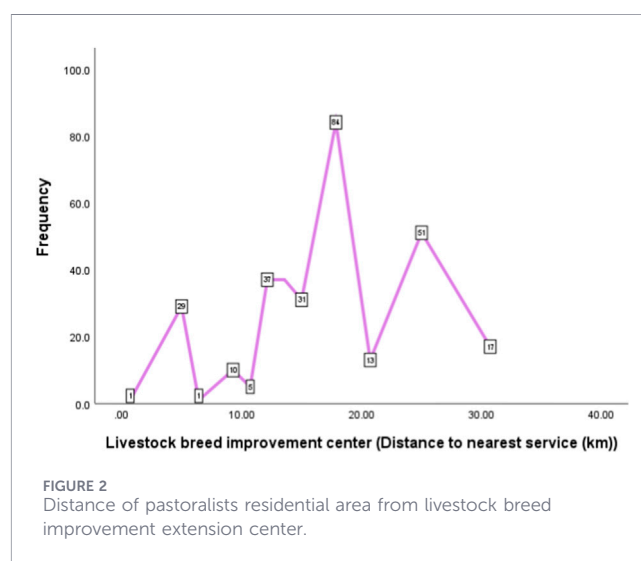
respectively. Whereas they kept livestock for meat at a ranked index of 0.29, 0.15, 0.08, and 0.01 for sheep, goats, camels, and cattle, respectively. In addition, pastoralists kept camels largely for prestige, as camels are often regarded as symbols of wealth, social status, and cultural value, which may explain their prestige ranking of 0.22 relative to other livestock.

Livestock husbandry practice

Livestock breeding improvement

Pastoralists used different mechanisms for the improvement of livestock in the areas. [Supplementary Figures S1a,b](#) indicates that about 86% of pastoralists brought the bulls from the neighboring area rather than having their own bull herd. This evidence shows most of the pastoralists rely on natural uncontrolled bulls for breeding purposes rather than using artificial insemination, which indicates only 0.58% used artificial insemination. The improvement center was far from the household residential area near to about 20 km, as presented in [Figure 2](#).

Castration of male animals was a common husbandry practice in the study areas, as presented in [Table 2](#). Almost 93% of respondents had castrated the male animals mainly for the purposes of fattening (56%) and reducing aggressive behavior (42%). The castration of male cattle mainly takes place at 5 months of age, followed by castration at 6 months of age ([Figure 3](#)). Most of the pastoralists had practiced the selection of livestock (61.6%), as indicated in [Table 2](#). This traditional selection criteria relies on the trait presences of bulls and cows/heifers presented in [Table 3](#). Index ranking indicated that bulls' selection depends mainly on coat color, adaptive ability, and dam's milk yield at 0.46, 0.19, and 0.19, respectively. In contrast, the selection criteria for cows focused on milk yield, udder size, and fertility, with rankings of 0.37, 0.31, and 0.23, respectively.



Livestock feed resources and feeding system

[Table 4](#) index rank indicated that most of the pastoral community relied on the natural grazing, followed by the crop residues as feed resources at 0.60 and 0.28, respectively. Free grazing and standing hay were the two primary livestock feeding systems, showing 0.56 and 0.22, respectively. According to the information from the key informant interview, animals in the pastoral catchment obtain their feed from communal rangelands, individual pastures around homesteads, and traditionally irrigated crop farms. Livestock production and productivity mainly face different kinds of constraints, grazing land shortage, land degradation, poor palatability of feed resources, and bush encroachment were ranked 0.35, 0.28, 0.19, and 0.18, respectively. However, the pastoral community were relying on the constraints by adopting and using different coping

TABLE 2 Livestock selection practices and reasons for castrating male animals among pastoral households in Fentale District (n = 344).

Variables	Dummy	Frequency (n)	Percentage (%)
Selection livestock practice	Yes	212	61.6
	No	132	38.4
Castrate male animal	Yes	321	93.3
	No	23	6.7
Reasons for castration (n = 321)	Fattening	180	56.1
	To reduce aggressive behavior	135	42.1
	Prevent unwanted males from spring futures generations	6	1.9

mechanisms for sustaining their livestock, such as using herd mobility, using different feed conservation when it is surplus, destocking and purchasing of feed, ranked 0.47, 0.44, 0.27 and 0.10, respectively. This showed seasonal herd mobility was widely practiced among Fentale pastoralists. Within the sustainable livelihood framework, this represents a natural capital strategy enabling pastoralists to access spatially variable rangeland resources in response to climatic shocks.

Table 5 indicated the pastoralists' perceptions regarding the trends in grazing land and the adequacy of feed resources. Almost 99% of grazing land trends in the study showed decreasing grazing states. This indicated that 99.7% of the respondents responded that feed resources in the study areas were inadequate due to a shortage of grazing land (69%) and the presence of bush encroachment (31%). Such a shortage of grazing land was more critical during the dry season than the rainy season. For good coping strategies, 59% of the respondents practiced the kaloo system, or enclosure of the grazing land during the rainy season, for use during the dry season when feed shortages existed. Figure 4 showed that most of the land use covered in the study area was mainly occupied by the forest, small shrub or bush, and natural grazing, with means of 18, 16, and 14 ha, respectively.

Major livestock constraints, water sources and milk productivity

The main sources of water for livestock's drinking in the study area were ranked as rivers, ponds, deep wells, and springs at 0.47, 0.31, 0.21, and 0.01, respectively, as presented in Table 6. The constraints related to water drinking in the study area were the inaccessibility of water drinking sources, shortage of water, poor quality of water, and community conflict, ranked 0.52, 0.31, 0.14 and 0.03, respectively. Livestock primarily travelled for 2 h, followed by 4 h, to reach water sources, especially during the dry season, as presented in Figure 5.

Supplementary Figure S2 indicated the livestock species water drinking interval in the pastoralist area. Thus, cattle and sheep were drinking water daily (58%) and at 2 days (42%) interval, whereas camel and goat were having water within a day interval of 2 days (56%), 3 days (40%), and greater than 3 days (4%). Equines were drinking water daily (63%), at 2 days (36%) and 3 days

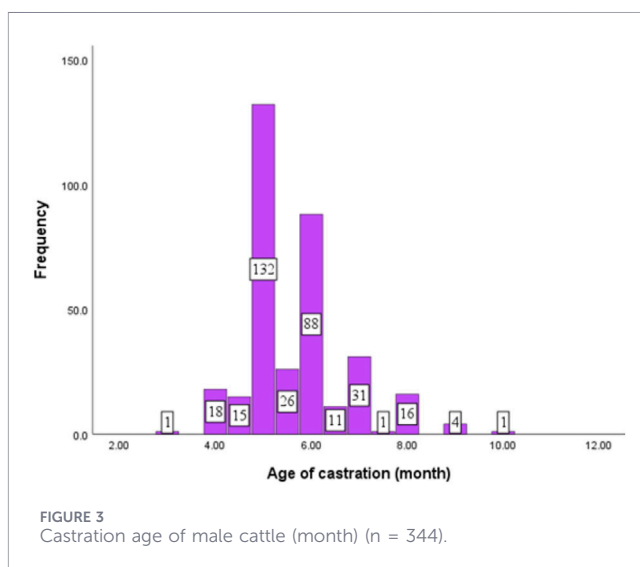


TABLE 3 Traditional selection based on trait preferences of breeding animal (n = 344).

Selection category	Selection trait	Rank			
		R.1	R.2	R.3	Index
Bulls' selection criteria	Coat color	194	-	57	0.46
	Body size	-	-	56	0.16
	Horn shape	-	4	166	0.17
	Dam's milk yield	87	49	40	0.19
	Adaptive ability	63	94	25	0.19
Cows' selection criteria	Coat color	35	16	41	0.09
	Fertility	35	111	152	0.23
	Udder size	51	206	84	0.31
	Milk yield	223	11	67	0.37

intervals (0.87%). Livestock production is mainly prone to different natural and manmade constraints in the pastoralists' area. Thus, according to the ranking in Table 6, recurrence of drought was the primary factor hindering livestock production,

TABLE 4 Common livestock feed resources, feeding system, associated problems, and coping strategies (n = 344).

Category	Variable	Rank			
		R.1	R.2	R.3	Index
Livestock feed resources	Natural forage	340	82	50	0.60
	Crop residue	4	236	95	0.28
	Improved forage	-	-	71	0.21
	By product	-	26	89	0.14
	Other	-	-	39	0.11
Livestock feeding system	Free grazing	273	92	148	0.56
	Standing hay	2	190	72	0.22
	Rotational grazing	14	14	78	0.07
	Cut & carry	-	48	46	0.14
Problems associated with livestock feed	Grazing land shortage	150	101	72	0.35
	Poor palatability	30	120	62	0.19
	Bush encroachment	46	27	173	0.18
	Land degradation	118	96	37	0.28
Coping strategies	Destocking	71	165	4	0.27
	Herd mobility	273	69	5	0.47
	Feed conservation	-	109	231	0.44
	Feed purchase	-	1	104	0.10

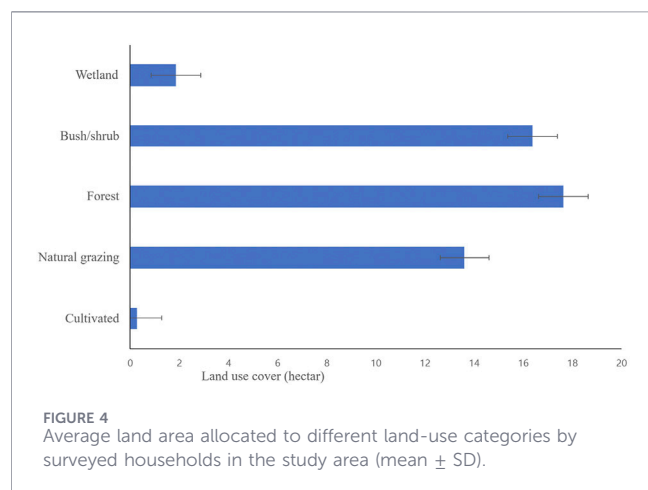
TABLE 5 Perceptions of respondents on grazing land trends, feed resources availability and management practices.

Category	Variable	Frequency (n)	Percentage (%)
Grazing land trend (n = 344)	Decreasing	342	99.4
	No change	2	0.6
Adequacy of feed resources (n = 344)	Yes	1	0.3
	No	343	99.7
Reasons for the inadequate of feeds (n = 343)	Grazing land shortage	237	69.1
	Bush encroachment	106	30.9
Seasons feed shortage critical (n = 344)	Dry season	343	99.7
	Rain season	1	0.3
Do you practice kaloo system or enclosure? (n = 344)	Yes	202	58.7
	No	142	41.3
Reasons for enclosure (n = 202)	To use in dry season	156	77.2
	As rehabilitation strategies	46	22.8

followed by the, feed shortages, water scarcity, poor genetic makeup, and outbreaks of various diseases and parasites, with respective index values of 0.51, 0.25, 0.11, and 0.02. Average indigenous cows' milk production during the rainy and dry seasons in the pastoralists was 1.6 and 1 L, respectively, as presented in Supplementary Figure S3.

Animal health management and practices

Blackleg, anthrax, FMD, pasteurellosis, LSD, and internal and external parasites were among the most common and economically important cattle diseases frequently occurring in the areas, as presented in Table 7. CCPP, sheep pox, peste des petits



ruminants, FMD, and internal and external parasites are also the common diseases affecting sheep and goats in the area. Camels were susceptible to the parasites, blackleg, and brucellosis. African horse sickness, blacklegs, and anthrax were common diseases frequently occurring in equines. The pastoralists did not have access to clinical service for their livestock, which accounts for only 23.8% of household respondents reporting accessibility, as presented in [Supplementary Table S3](#). However, 95% of the pastoralists reported vaccinating their livestock at least once per year. Accordingly, cattle, sheep, goats, and camels receive vaccinations at least once a year, at rates of 83%, 72%, and 82%, respectively. Livestock are prone to different kinds of problems in the area, as the region was warm. Thus, as ranked in the index presented in [Supplementary Table S3](#), lack of clinical availability, inadequate vaccination, the expensive price of the drug, and

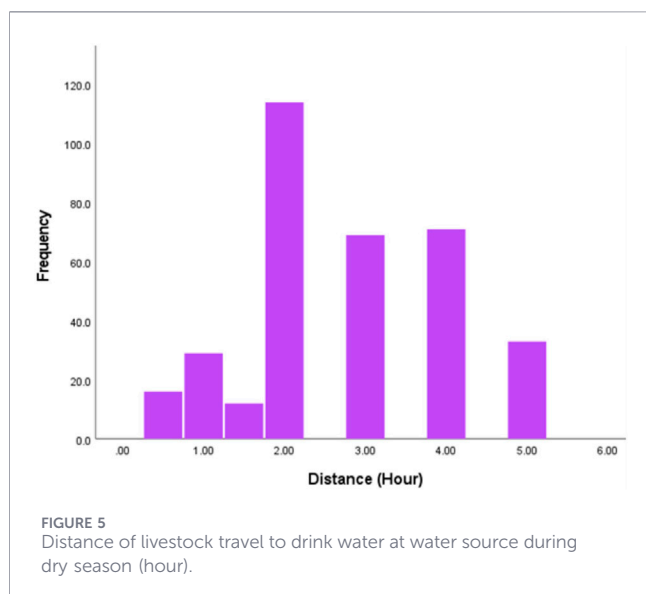
shortage of the drug account for 0.43, 0.26, 0.14, and 0.11, respectively.

Livestock marketing system

[Figure 6](#) presents the diversity of marketing systems adopted by pastoralists in the study area. As a result, the primary marketing system was the dominant marketing system in the area, followed by the secondary market, tertiary market, and bush market, accounting for 72%, 13%, 12%, and 3%, respectively. The result indicates that most of the respondent pastoralists had to travel a long distance from their residential area to access livestock markets, which accounts for nearly 20 km, as shown in [Figure 7](#). This considerable distance represents a significant physical capital limitation within the Sustainable Livelihoods Framework, as inadequate market infrastructure and road connectivity increase transaction costs, reduce market participation frequency, and ultimately constrain the financial capital accumulation of pastoral households. It demonstrates that 52% of the pastoralists are not benefiting from the marketing centre ([Supplementary Table S4](#)). Small ruminants were the primary animals to be sold, followed by the cattle and camels, which are ranked in the index as 0.49, 0.35, and 0.25, respectively, as presented in [Table 8](#). Selling dairy products was not a common practice in the area (92%) unless they were intended for home consumption ([Supplementary Table S4](#)). The respondents commonly sold their livestock during the spring and dry seasons, accounting for 44% and 39%, respectively, as presented in [Supplementary Figure S4](#). The live livestock and livestock products marketing system in the study areas was observed to be very weak due to numerous constraints related to the marketing system. Thus, as ranked in the index [Table 8](#), lack of market information, weak market linkage, presence of illegal brokers, and lack of a market account are 0.33, 0.27, 0.20, and 0.15, respectively.

TABLE 6 Major water sources for the livestock and their constraints regarding livestock drinking water (n = 344).

Category	Variable	Rank			
		R.1	R.2	R.3	Index
Sources of water	River	246	72	91	0.47
	Ponds	63	210	46	0.31
	Deep wells	35	62	205	0.21
	Springs	-	-	2	0.01
Constraints related to water	In accessibility	297	66	50	0.52
	Shortage	31	272	9	0.31
	Quality	3	6	282	0.14
	Conflict	13	-	3	0.03
Major livestock production constraints	Recurrence drought	296	48	-	0.51
	Feed shortage	37	184	13	0.26
	Water scarcity	-	-	216	0.11
	Poor genetic make up	-	44	66	0.08
	Diseases and parasite	-	-	45	0.02
	Livestock market	11	-	4	0.02



Extension service accessibility and information dissemination

Supplementary Table S5 indicates that 75% of the respondents had not accessed extension services for their livestock production. Even for those who did receive information, its accessibility was insufficient, as reflected by 81% of the respondents. The lack of access to extension services in the area was primarily due to the unavailability of extensions nearby (49%) and refusal to use them (39%). Extension workers do not frequently contact pastoralists, as 83% reported meeting them only occasionally. The government extension center was the main extension provider for livestock breed improvement, market and feed management, and climate early warning, as presented in Supplementary Table S6. The Pastoralists Training Center (PTC) was the key route for disseminating information to pastoralist communities among other routes. However, the level of satisfaction of pastoralists with such extension services was very low (dissatisfied).

Discussion

Socio demographic characteristics of pastoralists

Herd management practices and the adoption of improved technologies may be influenced by socio-demographic factors,

particularly education level. In the present study, the proportion of male respondents was higher (89.5%), and most of the pastoralists in the area did not have formal education (87.5%). This indicates that the vulnerability of communities in the study area to climate variability and change was high, as households with low literacy levels were less likely to adopt new adaptive technologies and extension and had limited employment opportunities in non-farming activities compared to their counterparts. This finding is consistent with studies conducted in the Fentale district, which reported that 72% of respondents had no formal education level, indicating that they were illiterate (Mekuyie and Mulu, 2021). Likewise, additional research in the Afar region demonstrated that education bolsters households' resilience to climate-induced shocks and stress (Fenta et al., 2019).

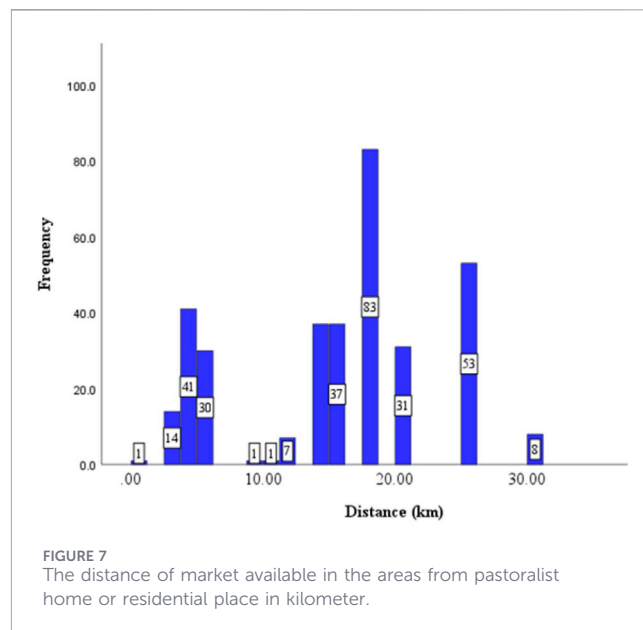
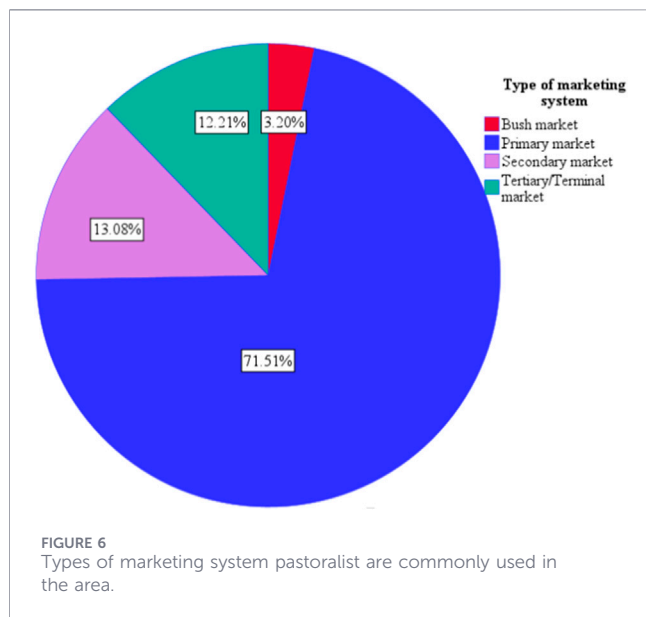
As documented throughout the Horn of Africa (Marty, 2024), formal education has remained rare, with most respondents reporting there is no formal educational system. In relation to occupational status in the study area, almost 99% of respondents were categorized as pastoralists. This means that the livelihood of the households mainly relies on keeping livestock rather than on any other farming systems. This phenomenon might be because the livelihoods of pastoralists in the area fully rely on pastoralism, and they lack experience in practising other farming systems, which makes it difficult for them to build resilience against drought outbreaks in the area (Ayele et al., 2020; Bekele and Amsalu, 2012).

Livestock population and purposes of keeping livestock

Livestock population in the study area has an implication for the livelihood sustenance of the pastoral communities and helps to identify the gaps and potentials to have a clearer understanding for the development planning aimed at transforming the livelihood of the pastoral community and poverty alleviation in the future. Accordingly, the total TLU per pastoralist household is characterised by a high degree of species diversification. Camels accounted for the largest share of total livestock units (TLU = 9.86), whereas cattle contributed TLU of 7.91 across cows, heifers, bulls, and calves. This indicates that camels make the greatest contribution to total livestock biomass in the study area, while cattle remain important in terms of cultural and economic value. The higher camel TLU may reflect their better adaptation to arid pastoral environments. (CSA, 2023), reported there an increasing trend in the annual livestock population. The livelihood of most pastoralists worldwide, specifically in Ethiopia, mainly relies on livestock keeping. The present study revealed that most pastoralists keep

TABLE 7 Common livestock diseases in the study areas.

Livestock type	Economic importance of diseases
Cattle	Blackleg (abbaa gorbaa), anthrax (abbaa sangaa), foot and mouth diseases (FMD), pasteurellosis, diarrhea, lumpy skin diseases (LSD), tuberculosis (TB), dermatophylosis, parasites, brucellosis
Sheep and goat	Contagious caprine pleuro pneumonia (CCPP), sheep pox, peste des petits ruminants (PPR), pasteurellosis, foot and mouth diseases (FMD), external and internal parasites
Camel	External and internal parasites, blackleg, pasteurellosis, brucellosis
Equines	African horse sickness (AHS), blackleg (abbaa gorbaa), pasteurellosis, external and internal parasites, anthrax (abbaa sangaa)



cattle and camels primarily for the milk production, while sheep and goats are mainly raised for meat and for cash as rural banking. This multi-species strategy reflects a diversification of natural capital assets, serving as a risk-spreading mechanism within the SLF vulnerability context of recurrent drought. Likely (Mutono et al., 2025), studied that milk production from cattle and camels supported by the livestock feed programmes improved the women's and children's dietary diversity in Kenyan pastoralist households. In addition, small ruminants, particularly sheep and goats, have served as mobile savings and insurance and can easily be sold or exchanged to cover costs such as medical care, education and food purchases during shortages (Sabahelzain et al., 2025).

Livestock husbandry practices

Livestock breeding improvement is a crucial parameter for sustaining the future generation of livestock. A natural breeding service (usually uncontrolled) using a bull is widely practised in smallholder and pastoralist systems (Assefa et al., 2026). In the present study area, 99% of respondents used bulls for mating purposes. However, most of the respondents did not have their own bull; only around 13% did, while others brought bulls from their neighbours. This finding is inconsistent with a previous study in Somalia (Mumin et al., 2025), which reported that bull ownership exceeded 88% and that mating was largely uncontrolled, with 53%–76% of bulls servicing both owner and neighbour herds. In the area, it is common to castrate male animals in order to make them fatter and less aggressive. A similar study revealed that most pastoralists in Somalia castrated their male animals for the purposes of fattening (Mumin et al., 2025).

Traits selection for animal production is among the most important criteria for sustaining livestock for future generations. In this regard, the present findings focus on traditional selection practices based on trait preferences of breeding bulls and cows, where cows' selection criteria mainly emphasize milk yield, while bulls' selection is primarily based on coat colour. This emphasis is reflected in most selection criteria among pastoralists and agro

pastoralist in Africa, where cows' selection for future generations largely relies on milk production. For instance, studies conducted in Somalia (Abdi-Soojeede et al., 2024; Mumin et al., 2025) and in Tanzania (Gillah et al., 2014); indicate that pastoralists place significant importance on milk production as a key trait in the selection of cows. Selection traits for bulls mainly focus on the coat colour because the pastoralists prefer aesthetically pleasing colours for next-generation. This finding aligns with the study by (Mumin et al., 2025), which reported that pastoralists in Somalia preferred coat colour during bull selection.

Natural grazing was the primary feed resources for livestock, followed by the crop residue in the study area. Based on information obtained from the key informant interview and focus group discussion, pastoralists in the Fentale district feed their livestock using resources from the communal rangelands, individual pastureland around homestead, and by product from sugar factories, such as those from the Wenji sugar factory. This is consistent with the recent livestock feed resource assessment in Ethiopia indicating that natural pasture and crop residues are contribute the largest share of annual livestock feed resources (Begna and Masho, 2024). Free grazing is a common feeding systems like as other pastoralists are, with consistent with the previous work reported that pastoralists adopt mainly extensive grazing systems including free grazing as mechanisms for providing livestock with feed in rangelands (Dong, 2016).

Feed is a major input in the livestock sector and covers almost up to 70% of the total cost of producing meat, milk and eggs (Makkar, 2016). Feed scarcity was identified as a major constraint affecting livestock productivity in the study area. Survey results showed that high index of rank of respondents reported seasonal feed shortages. This finding is consistent with evidence from Ethiopian livestock systems, where feed shortages in both quantity and quality are reported as a major factor limiting livestock-sector development (Fenta et al., 2019). In pastoral areas, drought-related feed shortages have also been linked to high livestock mortality and rangeland degradation. Recent household-level evidence from Ethiopia further

TABLE 8 Livestock species commonly sold, and their products demand constraints related to marketing and veterinary services (n = 344).

Category	Variable	Rank			
		R.1	R.2	R.3	Index
Species of livestock to be sell	Cattle	43	284	34	0.35
	Camel	-	13	234	0.25
	Small ruminant	301	47	22	0.49
	Donkey	-	-	54	0.16
Livestock product demand	Milk	138	107	35	0.32
	Beef/meat	178	158	15	0.42
	Egg	13	77	195	0.19
	Hide & skin	15	2	99	0.07
Constraints related to marketing	Lack of market infrastructure	41	74	45	0.15
	Illegal brokers	50	42	184	0.20
	Clan conflict	-	31	29	0.09
	Lack of market information	140	126	4	0.33
	Weak market linkage	113	71	82	0.27
Problems related to veterinary services	Inadequate vaccination	14	211	77	0.26
	Drug shortage	11	11	171	0.11
	Expensive price of the drug	35	77	20	0.14
	Veterinary personnel	2	34	64	0.07
	Lack of clinical availability	282	11	12	0.43

Illegal brokers refer to unlicensed intermediaries operating outside formal market systems.

shows that feed shortage is associated with increased livestock deaths and higher livestock production expenses (Dejene et al., 2024). Consequently, feed shortage is one of the primary factors hampering the livestock production and productivity among other factors. As a result, shortage of grazing land and poor palatability of pasture due excessive invasive plants or bush encroachments were identified as the primary constraints contributing of feed shortage in area. However, destocking and herd mobility during dry season, when feed shortage exist, were the two major coping mechanisms used to build resilience to these problems.

Livestock get water basically from three main sources: drinking water, water contained in feed and metabolic water. Its critical input for the direct consumption of livestock and the production of animal feed. Shortage of water forces pastoralists to increase walking long distances, prone to wasted body condition and reduced production and reproductive efficiency (Weindl et al., 2017). Water scarcity and recurrent of drought was the primary constraints which makes reduce the livestock production, productivity, and sustainability in the study area. This result is aligned with the previous study in which reported that the main constraints of livestock production was because of frequently observed of the drought vulnerability (Bogale and Erena, 2022). A result, low milk production from cows might be because of shortage of grazing land and presence of bush encroachment in area. In consistently, milk production is related to

feed availability (Kebede et al., 2020), and environmental factors like seasonality and rainfall, water availability and heat stress (Beyene and Gudina, 2009).

As the study was conducted in a warm area, the livestock were susceptible to various types of diseases prevalent and disease-causing vectors. Blackleg locally called “Abbaa Gorbbaa”, Anthrax locally “Abbaa Sangaa,” Foot and mouth diseases, Pasteurellosis, sheep pox, Contagious Caprine Pleuro Pneumonia, Peste des Petits Ruminants, Brucellosis and Africa horse sickness were the most economically important diseases frequently occurring in livestock. A study in Afar region revealed that livestock were mainly prone to similar diseases frequently observed in livestock (Fenta et al., 2019). The reasons why most such diseases were often observed in the area were the limited accessibility of veterinary clinics and insufficiency of livestock vaccination services.

Livestock market and marketing system

Improving the accessibility of livestock markets nearby is the single most effective non-biological intervention for improving pastoralist livelihoods. Thus, proximity to markets makes pastoralists transition from subsistence-based accumulation to market-oriented production, which provides the cash liquidity needed to survive the droughts (Biswas et al., 2025; Ndiritu and Gichuki, 2025). The market proximity to livestock from the

pastoralists' residential area was mainly within 20 km. The data indicates that, although the market is far from the residential area, it directly and indirectly impacts the price of livestock due to weight loss from trekking long distances. According to (Lkhanaa, 2024) a household's income from livestock usually goes down by about 1.0% for every ten km (10 km) they live away from a market center. Results obtained from key informant interviews and focus group discussions revealed that livestock and livestock product marketing in the study area is perceived as fragile due to several factors: the absence of an organized marketing system, a lack of market infrastructure (such as marketplaces with full facilities), long distances from the source, insufficient facilitated stock routes, unattractive prices, and inadequate financial institutions. This indicated pastoralists prone to limited access to livestock markets and unfair pricing. These constraints reflect vulnerabilities in financial capital accumulation, limiting livelihood diversification options available to pastoral households. These challenges contribute to the overall instability of livestock marketing, making it difficult for producers to sustain their income and engage effectively in the market. Consequently, the economic viability of livestock farming in these areas suffers significantly.

Extension service accessibility and information dissemination

Extension service delivery encompasses institutions that provide extension methods, tools and aids, organizational arrangements, training for relevant stakeholders, transferable technologies, technology demonstration, and knowledge and technology transfer centers (Khwidzhili and Worth, 2019). There was limited accessibility to extension services, and the means for disseminating information to pastoralist communities were also insufficient in the area. Based on the information obtained from the key informant interview and focus group discussion, it was revealed that the central reason why there were few numbers of trained manpower working on livestock development, including (development agents, livestock production experts, and veterinarians, in the studied districts was due to remoteness, poor access to infrastructures and high turnover of trained manpower. Additionally, the integration between research centers, technology innovation organizations, stakeholders, and extension service delivery institutes were very weak, highlighting an urgent need for improvement in this area. Another important institution in the district like traditional social institutions such as the Gadaa system played a key role in resource governance. These networks constitute critical social capital assets that enhance community resilience under the SLF framework. Previous study evidence stated that weak linkage between research centers and extension services disseminates to communities (Alemnew and Abebe, 2023); poor infrastructure is a bottleneck of extension services (Kibrom et al., 2025); and a lack of awareness and "separation between developers and users" prevents adoption in livestock sectors (Schillings et al., 2024).

Conclusion

This study emphasizes the significance of livestock for pastoral livelihoods in Fentale District, where camels and cattle constitute the

backbone of household economies. Even with the species diversity and adaptive traditional practices, the sustainability of these systems is under increasing threat from environmental and socio-economic stressors. Inadequate feed and water scarcity limited veterinary services, the prevalence of livestock diseases, and insufficient extension services are major vulnerability context that undermine the human and physical capital of pastoral households, significantly constraining livestock productivity and livelihood sustainability. Seasonal herd mobility enables access to spatially variable rangeland resources, reflecting a natural capital management strategy. The enclosure grazing system (Kalo) represents a community-based social capital mechanism for sustainable rangeland governance rooted in indigenous institutional knowledge. The selection of indigenous animals based on native adaptive traits further demonstrates the strategic mobilization of human capital through traditional ecological knowledge. However, these strategies are increasingly insufficient to address the intensifying challenges of land degradation and climate variability. The lack of market access, infrastructure, and tailored development programs further exacerbates financial capital vulnerability of among these pastoralist communities.

Therefore, through the lens of the sustainable livelihood framework, the findings reveal that while Fentale pastoralists employ diverse and historically effective adaptive strategies across all five livelihood capital categories, the intensification of environmental and socioeconomic pressures necessitates urgent and inclusive external intervention. Policy interventions should therefore prioritize dry-season feed and water security, expansion of mobile veterinary and extension services, improved livestock market infrastructure, and stronger drought early-warning systems. These actions require coordinated implementation by district and regional livestock offices, water authorities, pastoral cooperatives, research institutions, and development partners. In addition, national livestock policies should better reflect the specific needs of lowland pastoral systems rather than primarily focusing on highland mixed-farming areas. Integrating indigenous practices such as seasonal mobility, Kalo grazing management, and indigenous breed selection with scientific and institutional support could strengthen resilience and enhance the long-term sustainability of pastoral livelihoods in Fentale District.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Ethics statement

The study protocol was reviewed by the Borana University Institutional Research Ethics Review Committee (BRU-IRERC), which granted an ethics exemption because the study involved a non-invasive questionnaire survey of adult pastoralists. Verbal informed consent was obtained from all participants before data collection, and confidentiality was maintained throughout the study.

Livestock data were collected through questionnaires and observation only; no animal experimentation or invasive procedures were conducted, so separate animal ethics approval was not required.

Author contributions

AF: Conceptualization, Investigation, Writing original draft, Methodology, Validation, Formal analysis, Data curation, Software, Supervision. KM: Writing – review and editing, validation, methodology, formal analysis, data curation, investigation, software, and supervision. BB: Writing – review and editing, methodology, investigation, supervision. HF: Investigation, Writing – review and editing, Data curation. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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