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Research Article

Dynamics of Small-Scale Cattle Fattening Practices and Marketing in Three Different Production Systems—Pastoral, Agro-Pastoral and Mixed Farming Systems—In the Southern Ethiopian Rift Valley

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Abstract | A beef cattle farming plays a pivotal role in the livelihoods of pastoralists, agro-pastoralists, and small-scale mixed farmers in tropical countries, serving as a source of assets, food, income, and social status. This study investigated fattening practices and market dynamics in three production systems—pastoral, agro-pastoral, and mixed farming systems—in the Southern Ethiopian Rift Valley. Data were collected from 371 participants using a structured questionnaire, multi-stage sampling, and field observations. Farmers selected cattle for fattening based on traits such as breed, sex, age, conformation, reproductive performance, and body color, reflecting cultural and practical preferences (e.g., breed: $\chi^2 = 127.2$, $P < 0.001$; selection criteria: $\chi^2 = 208.9$, $P = 0.001$). For instance, 83.7% of pastoralists prioritized pedigree in cattle selection, compared to 51.6% of agro-pastoralists and 36.2% of mixed farmers ($P = 0.001$). Feed availability varied significantly across systems, creating both challenges and opportunities for sustainable fattening. Traditional practices, including disease management using plant materials, were integral to cattle management. The rainy season was preferred for fattening by 63.1% of participants due to abundant feed, while 84.8% associated fattening with religious holidays ($P < 0.001$). The marketing chain includes local, cross-border, and international trade. Despite these practices, challenges such as recurrent droughts, limited access to commercial feed, poor infrastructure, and insufficient extension services hindered progress. The findings underscore the need for policies that enhance feed security, infrastructure, and market access while integrating indigenous knowledge with modern techniques. Future research should focus on developing sustainable fattening models and scaling up best practices to improve livelihoods and meet market demands. This study contributes to understanding the complexities of cattle farming systems, with implications for sustainable livestock development in tropical regions.

Keywords | Agro-pastoralism, Cattle fattening practices, Market dynamics, Mixed farming, Ethiopia

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INTRODUCTION

The global food industry is currently facing a series of unprecedented challenges, including the impacts of climate change, rapid population growth, urbanization, and the rise of new diseases (Hassoun *et al*., 2024). These challenges have sparked a need for transformative changes in food production, particularly in how food is produced, transported, stored, perceived, and consumed. Since 2015, the Fourth Industrial Revolution has introduced numerous innovations in food production, fostering new trends and practices in the global food industry (Hassoun *et al*., 2024; Suychinov et al., 2024). Among the key sectors, the beef industry stands out as a significant contributor to the global agricultural economy. While specific figures for the global beef industry's annual value vary, estimates suggest it is a substantial component of the broader meat industry, which was valued at approximately $897 billion in 2021 and is expected to reach over $1.3 trillion by 2027 (Shahbandeh, 2023). Similarly, a report by Grand View Research (2022) projects the compound annual growth rate (CAGR) of the beef market to align closely with the overall meat industry due to increasing global demand and evolving consumer preferences.

The global cattle population, estimated at 1.3 billion, plays a crucial role in meeting the rising demand for beef, a high-quality protein source that is essential for human nutrition. As one of the most consumed meats worldwide, ranking third after poultry and pork, beef consumption continues to grow, with projections indicating a further increase in demand (Paul, 2021). While this global trend underscores the importance of cattle production, its impacts are especially pronounced in regions like Sub-Saharan Africa (SSA), where smallholder farmers are central to the agricultural system. These farmers, who depend heavily on rain-fed agriculture for both subsistence and income, play a critical role in ensuring regional food security and economic stability (Materechera, 2021). Furthermore, indigenous communities in SSA have made significant strides in advancing livestock management, contributing to innovations in reproductive techniques, veterinary care, and the preservation of genetic diversity (Teferi, 2019).

In many countries in the Global South, cattle are a critical source of income, providing essential products such as milk, meat, skin, manure, and even traction (FAO, 2022; FAO, 2023). However, the rising cost of meat could soon make regular beef consumption unaffordable for low-income households (World Bank, 2024). In this context, cattle fattening presents a promising solution by meeting current beef demand while ensuring a sustainable future supply of livestock. Cattle fattening, which involves improving the health and weight of cattle in a short period, offers not only economic benefits but also contributes to soil fertility in organic farming through the provision of manure (Urgesa, 2023; Osei-Amponsah *et al*., 2023). This process of cattle fattening also supports improved livestock management practices, which can lead to higher productivity and more resilient farming systems (Mekonnen *et al*., 2024). For farmers in resource-poor areas, cattle fattening provides a unique opportunity to generate income that can be reinvested in other ventures, such as purchasing land or funding other agricultural activities, thus helping to diversify income streams and increase economic resilience (Kebede *et al*., 2022; FAO, 2023).

Beef cattle production in Southern Ethiopia faces multifaceted challenges driven by global factors like climate change, food insecurity, and economic instability, compounded by local constraints. Livestock is central to the region's income and food security, yet droughts and erratic rainfall exacerbate feed shortages, increase costs, and reduce profitability for farmers (Alemu *et al*., 2020; Guta, 2021). Global market fluctuations, including rising meat and feed prices, further strain the beef value chain, while limited market access undermines economic stability (FAO, 2023). Despite Ethiopia's status as home to Africa's largest cattle population (CSA, 2021), the beef sector struggles with nutritional deficiencies, high disease prevalence, and a lack of specialized beef breeds or efficient production systems. In highland areas, mixed crop-livestock farming relies on traditional fattening, while lowland pastoral and agro-pastoral systems adopt diverse management and marketing strategies (Tewodros, 2019; Yesihak, 2023). Addressing these issues demands improved fattening practices, efficient feeding systems, and enhanced market access to increase productivity, improve livestock health, and stabilize farmer incomes. Such interventions not only support sustainable beef production but also bolster Ethiopia's agricultural economy and contribute to global food security (Mekonnen *et al*., 2024; Urgesa, 2023; Osei-Amponsah *et al*., 2023).

The southern Ethiopian Rift Valley highlights the challenges faced by one of Ethiopia's least developed pastoral and agro-pastoral regions, where limited innovation and research in cattle fattening have hindered beef production. These issues are compounded by restricted market access, inadequate nutritional resources, the untapped genetic potential of local cattle, and a lack of documented indigenous knowledge on cattle fattening. To address these gaps, this research seeks to explore the role of indigenous knowledge in livestock management, compare small-scale cattle fattening practices, and analyze marketing dynamics, challenges, and opportunities in the region by focusing on three distinct farming systems—pastoral, agro-pastoral, and mixed farming. The Konso Zone (within the study area) represents the mixed farming system, while districts from the South Omo zone administration represent the agro-pastoral and pastoral systems. This targeted approach

aims to provide actionable insights for addressing critical issues and advancing the beef sector in the region.

MATERIALS AND METHODS

Description of the Study Areas

The study was carried out in three different production systems: pastoral, agro-pastoral, and mixed farming in the southern Ethiopian rift valley. These production systems are currently managed in two political administrative zones: South Omo (pastoral and agro-pastoral system) and Konso Zone (mixed farming system). South Omo zone: The administrative town of south Omo Zone is Dimeka, which is located about 750 km from Addis Ababa. It is located at 4° 27'–6° 26' north and 34° 57'–37° 49' east. South Omo zone is bordering with Ari, Gamo, Gofa, Keffa, Konta, and Besketo zones to the north; Konso and Ale zones to the east; Borana zone to the southeast; Kenya to the south; Sudan to the southwest; and Bench Maji zone to the west. Three districts, Dasenech, Nyangatom, and Salamago, out of six districts, were chosen from the south Omo zone in the current study. Konso Zone is another administrative zone in the south Ethiopian rift valley regions selected for the current study. The study site is approximately 525 kilometres south of Ethiopia's capital, Addis Abeba. It is located between $5^0$10'0 and $5^0$40'0 N latitude and 37^0, 0"0" and 37,045'0" E longitude (see Figure 1). The elevation ranges from 501 to 2000 meters above sea level, covering a total land area of 2,016.24 km2 (KDAO, 2012). The zone comprises 70% low altitude and 30% tropical mid-altitude. According to Cheung *et al.* (2008), the average annual temperature in the zone ranges from 17.6-27.50 degrees Celsius, with an average rainfall of 601-1200 millimeters.

Sample Procedures and Sample Size

This study selected two adjacent administrative zones to characterize and compare socioeconomic and cattle fattening systems. Districts within each zone were stratified based on livestock production systems—pastoral, agro-pastoral, and mixed systems—using a stratified random sampling technique. From the South Omo Zone, Dasenech, Nyangatom, and Salamago districts were selected, while Kolme District was chosen from the Konso Zone. These districts were chosen for their agro-ecological diversity, availability of natural pasture, mixed crop-livestock production, livestock population density, and the economic significance of livestock production to households, ensuring representation of diverse production systems. Within the selected districts, kebeles (wards) were classified as pastoral, agro-pastoral, or mixed agricultural systems based on smallholder production characteristics. Twelve kebeles, three from each district, were randomly selected using a simple random sampling technique to ensure unbiased representation. The selection of kebeles and districts aligned with the study's objectives, focusing on their relevance to beef cattle production. Key criteria included the number of households engaged in beef cattle farming, diversity of production systems, and accessibility for data collection. Respondents were chosen through a systematic random sampling procedure to ensure fair representation across all strata (Table 1). The sample size was calculated using Yamane's (1967) formula. The formula for the required sample size (n) is $n = N / (1 + N(e)^2)$, where N represents the population size and e is the margin of error expressed as a decimal. According to data from the South Ethiopia Regional Bureau of Agricultural and Natural Resources Development (SBoA, 2024), the total number of households actively engaged in beef cattle production in the selected districts was 5,129. Applying the Yemane's formula with a 5% margin of error yielded a sample size of 371 household heads. Table 1 summarizes the sample size determination and production systems for the selected districts and *kebeles*.

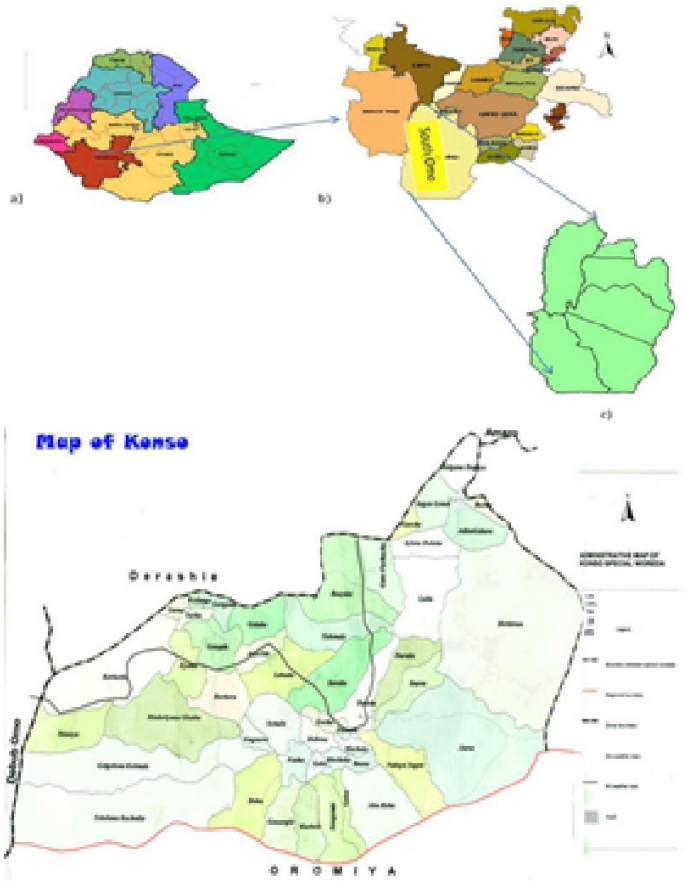

Figure 1: The administrative map of the study areas in southern Ethiopia.

Data Collection Method

A structured questionnaire, consisting of pre-coded and tested types, was meticulously designed and utilized to gather both qualitative and quantitative data primarily focusing on indigenous knowledge system pertaining to the cattle fattening such as materials used, characteristics of

fattening, breeds used for fattening, indigenous pastures highly preferred traditionally for fattening and so on. The household survey was executed by a team of 12 trained and experienced enumerators proficient in the local language. The interviews were recorded using audio devices with the consent of the key informants, and a focus group discussion using a checklist that consisted of selected 9 individuals in different groups was conducted in the selected district. Primary observation data was meticulously recorded, while secondary data was sourced from both published and unpublished reports of district and regional agricultural bureaus in the study areas.

Table 1: Sample size determination from the selected districts in the study areas.

Zone	District	Name of Kebele	Production system	Proportional sample	sample size
South Omo	Dasenech	Direyelere	Pastoralist	31	92
		Delenyemur		31	
		Akatakach		30	
	Nyangatom	Lokorlam	Pastoralist	31	92
		Lebere		31	
		Aypa		30	
	Salamago	Omo Hana	Pastoralist	31	92
		Dakuba	Agro-pastoralist	31	
		Gero	Mixed farming	30	
Konso	Kolume	Gelgelo-qolmala	Mixed farming	32	95
		Tebela	Mixed farming	32	
		Massoya	Agro-pastoral	31	
Total	4	12	3	371	371

Ethical Considerations

Ethical considerations were carefully addressed to ensure the study met conventional research standards. Ethical approval was obtained from the Arba Minch University research and development ethics committee. A structured questionnaire was designed and tested to collect qualitative and quantitative data on indigenous knowledge systems related to cattle fattening. Informed consent was obtained from all participants, including key informants and focus group members, who were informed of the study's purpose, data collection process, and their right to withdraw at any time. Audio recordings were made with explicit consent, ensuring privacy. Focus groups and observational data collection followed conventional ethical guidelines, safeguarding participant rights and dignity.

Statistical Analysis

Quantitative and qualitative data was cleaned, coded, and analyzed using the Statistical Package for Social Sciences version 20. Statistical variations of qualitative data have been studied by means of crosstabs and determined with statistical differences at $P < 0.05$. Variance analysis was carried out for the quantitative data, and mean differences were considered significant at $P < 0.05$. The outcomes are presented using tables, graphs, percentages, means, and standard error of mean. The appropriate statistical model is indicated below:

$$Y_{ij} = \mu + \alpha i + \Sigma_{ij}$$

Where Yij represents the response variables, μ is the overall mean, αi is the fixed effect of the ith production sub-system (i = 1, 2, 3), and Σij is the residual effect. The fixed effect "i" corresponds to the different farming systems—pastoral, agro-pastoral, or mixed farming—and accounts for the variability in the dependent variable (Y) based on the type of farming system in the study area.

RESULTS AND DISCUSSION

Socio-Economic Characteristics of Respondents

This study examined the socio-economic characteristics of respondents from different farming systems: pastoral, agro-pastoral, and mixed farming (Table 2). Significant variations were observed in gender distribution, educational status, religious affiliation, and business experience. Gender distribution varied across farming systems ($P = 0.004$), with 59.3% male respondents, the highest proportion in agro-pastoral systems (66.1%). Female representation was higher in mixed farming systems (42.6%) than in agro-pastoral systems (33.9%), emphasizing the significant role of women in labor-intensive mixed systems, in line with the findings of Njuki and Sanginga (2023).

Educational attainment also differed significantly ($P = 0.001$), with 70.6% of respondents being illiterate, especially in pastoral systems (80.0%). Agro-pastoral systems showed better education levels, with 35.5% completing primary school, consistent with Alemayehu *et al.* (2023), who linked education to proximity to infrastructure. Religious affiliations varied ($P = 0.001$), with Protestantism being dominant overall (56.9%) and indigenous religions more common in pastoral (34.9%) and agro-pastoral (56.5%) systems. This reflects the cultural ties between indigenous practices and pastoralism (Dyer, 2023). Business experience also differed ($P < 0.001$), with 77.6% of respondents having over 10 years of experience, especially in agro-pastoral (93.5%) and mixed farming (89.4%). The findings reveal socio-economic disparities, suggesting that agro-pastoralists and mixed farmers have greater education and business experience, enhancing their adaptability to market changes (Kamara *et al.*, 2023).

Table 2: Socioeconomic characteristics of households in different production systems.

Socio-economic	Farming system, N (%)			Overall mean N=371(%)	χ^2	P value
	Pastoral N=215 (%)	Agro-pastoral N=62 (%)	Mixed farming N=94(%)			
Gender						
Male	125(58.1)	41(66.1)	54(57.4)	220(59.3)	1.45	0.004
Female	90(41.9)	21(33.9)	40(42.6)	151(40.7)		
Educational status						
Illiterate	172(80.0)	38(61.3)	52(55.3)	262(70.6)	56.98	0.001
Informal school	6(2.8)	2(3.2)	16(17)	24(6.5)		
Primary school	19(8.8)	22(35.5)	17(18.1)	58(15.6)		
Read and write	7(3.3)	0(0)	3(3.2)	10(2.7)		
Secondary	10(4.7)	0(0)	6(6.4)	16(4.3)		
Diploma and above	1(0.5)	0(0)	0(0)	1(0.3)		
Religion						
Protestant	121(56.3)	26(41.9)	64(68.1)	211(56.9)	57.13	0.001
Orthodox	18(8.4)	1(1.6)	19(20.2)	38 (10.2)		
Muslim	1(0.5)	0(0)	4(4.3)	5(1.3)		
Indigenous	75(34.9)	35(56.5)	7(7.4)	117(31.5)		
Business experience (year)						
< 2	1(0.5)	0(0)	0(0)	1(0.3)	29.71	<0.001
2-4	15(7.0)	0(0)	1(1.1)	16(4.3)		
5-7	26(12.1)	1(1.6)	5(5.3)	32(8.6)		
8-10	27(12.6)	3(4.8)	4(4.3)	34(9.2)		
>10	146(67.9)	58(93.5)	84(89.4)	288(77.6)		

Land Ownership, Land Use and Livelihood Strategy of the Respondents in the Study Area

Land ownership was nearly universal among the respondents, with 98.7% of households owning land across all farming systems, reflecting its critical role in agricultural livelihoods (Table 3). A significant difference ($\chi 2$=3.68, P=0.002) was observed among the systems, with no landlessness recorded in agro-pastoralists and mixed farming households. Secure land tenure is essential for agricultural productivity and economic stability, as emphasized by Deininger *et al.* (2022). Land use patterns also varied significantly across the farming systems (X^2=27.39, P=0.001). Pastoralists primarily used land for arable farming and living purposes (56.7%), while agro-pastoralists had a similar pattern (61.3%). Mixed farmers demonstrated more diversity, with 45.7% combining arable and living purposes and 26.6% integrating arable and grazing, highlighting adaptive strategies to optimize land use.

The acquisition of land differed significantly across farming systems (X^2=113.3, P=0.001). Mixed farmers primarily inherited land (68.1%), while land redistribution was more common among pastoralists (52.4%) and agro-pastoralists (38.7%). Squatting was notably present among agro-pastoralists (45.2%), pointing to challenges in land tenure security in this group, which aligns with Holden and Otsuka's (2023) findings on rural land tenure complexities. Grazing resource usage also varied (X^2=74.3, P=0.001). Pastoralists predominantly relied on communal grazing (42.3%), while mixed farmers utilized both communal and village grazing areas (70.2%). Agro-pastoralists employed a mixed approach, with 43.5% using both systems. These variations underscore the importance of communal grazing in sustaining livestock production, as noted by FAO (2022).

Significant differences were found in landholding sizes, with agro-pastoralists and mixed farmers holding larger total farm sizes (1.25 ± 0.13 ha and 1.23 ± 0.13 ha, respectively) compared to pastoralists (0.45 ± 0.13 ha, P=0.001) (Table 4). These differences reflect the greater emphasis on diverse cultivation activities in agro-pastoral and mixed systems. The smaller land sizes in pastoral systems align with their focus on livestock grazing and mobility. The results suggest that tailored interventions are needed to support each farming system, enhancing livestock productivity for pastoralists, improving irrigation and crop-livestock integration for agro-pastoralists, and promoting sustainable intensification for mixed farmers (Thornton *et al.*, 2023).

Table 3: Land use, land ownership, and livelihood strategies in different production systems.

Land functional distribution and livelihood activity	Farming system, N (%)			Overall N=371(%)	χ^2	P value
	Pastoralists N=215(%)	Agro-pastoralist N=62(%)	Mixed farming N=94(%)			
Do you have own land?						
Yes	210 (97.7)	62 (100)	94 (100)	366 (98.7)	3.68	0.002
No	5 (2.3)	0(0)	0(0)	5(1.3)		
Purpose of land use						
Arable	38 (18.1)	21 (33.9)	25 (26.6)	84 (23)	27.39	0.001
Grazing land usage	6 (2.8)	1 (1.6)	1(1.1)	8 (0.8)		
Arable and living	119 (56.7)	38 (61.3)	43 (45.7)	200 (54.6)		
Arable and grazing	52 (24.8)	1 (1.6)	25 (26.6)	78 (21.3)		
Living housing	0(0)	1 (1.6)	0(0)	1 (0.3)		
Acquiring land ownership						
Inherited	64 (29.8)	10 (16.4)	64 (68.1)	138 (37.2)	113.3	0.001
Rented in	3 (1.4)	0	5 (5.3)	8 (2.2)		
Squatter	23 (11)	28 (45.2)	6(6.4)	57 (15.4)		
Land redistribution	110 (52.4)	24 (38.7)	19 (20.2)	153 (41.2)		
Share cropped in	15 (7.4)	0	0	15 (4.1)		
Grazing area						
In common village	4 (1.9)	14 (22.6)	19 (20.2)	37 (10)	74.3	0.001
Communal grazing	91(42.3)	21 (33.9)	6 (6.4)	118(31.8)		
Both	120 (55.8)	27 (43.5)	66 (70.2)	213(57.4)		
Other	0	0	3 (3.2)	3 (0.8)		
Livelihood activity					174.7	0.001
Fishing	1(0.5)	0(0)	0(0)	1(0.3)		
Livestock	136 (63.2)	31(50)	0(0)	167 (45)		
Merchant	0(0)	0(0)	2(2.1)	2(0.5)		
Crop	5(2.3)	29(46.8)	48(51.1)	82(22.1)		
Mixed farming	70(32.6)	2(3.2)	44(46.8)	116(31.3)		
Others	3 (1.4)	0(0)	0(0)	3 (0.8)		

N: Number of respondents.

Trends and Patterns of Livestock Ownership

This study examined livestock ownership trends over the past decade across various production systems, including pastoralist, agro-pastoralist, and mixed farming systems. The majority of respondents reported owning livestock, with 99.1% of pastoralists, 100% of agro-pastoralists, and 98.9% of mixed farmers indicating ownership, resulting in an overall 99.2% livestock ownership rate across all systems (χ^2 = 0.62, P = 0.073) (Table 5). Only 0.8% of participants did not own livestock, emphasizing its crucial role in these farmers' livelihoods. The cattle population showed a notable decline, with significant decreases reported by 59.5% of pastoralists, 80.6% of agro-pastoralists, and 61.7% of mixed farmers (χ^2 = 10.48, P = 0.032), likely due to environmental conditions, market access, or changes in farming practices. While a few pastoralists (37.2%) and mixed farmers (34%) saw cattle increases, the overall trend indicated a reduction in cattle numbers across all systems.

In terms of sheep, 59.5% of pastoralists, 37.1% of agro-pastoralists, and 43.6% of mixed farmers reported a decrease in population, with significant differences in the increase of sheep numbers (χ^2 = 50.2, P = 0.001). The smaller number of agro-pastoralists (9.7%) and mixed farmers (21.3%) experiencing increases suggests varying environmental challenges, such as disease outbreaks or climate change, which may affect sheep farming viability. For goats, 33.5% of pastoralists, 24.2% of agro-pastoralists, and 41.5% of mixed farmers observed population growth (χ^2 = 9.78, P = 0.030), with the lower decline in mixed systems indicating that the integration of crop and livestock farming may offer more resilience to population changes.

Table 4: Average (mean ± SE) age, family size, land area under different cultivation activities, experience, and livestock composition of respondents in the production system.

Variable	Production system, mean ± SE			Overall (Mean ± SE)	P value
	Pastoralist	Agro-pastoralist	Mixed		
Family size	7.09[a]±0.22	8.13[b]±0.44	7.73[c]±0.31	7.43±0.17	0.044
Age in year	35.38[a]±0.58	42.02[c]±1.12	41.86[b]±0.87	38.13±0.43	0.001
Total farm size (ha)/head	0.45 ± 0.13[c]	1.25 ± 0.13[a]	1.23±0.13[b]	0.72 ± 0.05	0.001
Homestead area	0.18±0.02	0.27±0.09	0.2±0.03	0.19±0.02	0.240
Farm area rain-fed	0.35 ± 0.03[c]	1.01 ± 0.16[a]	0.6±0.06[b]	0.59 ± 0.07	0.040
Farm area irrigable	0.09 ± 0.01[c]	0.58 ± 0.06[b]	0.9±0.14[a]	0.43 ± 0.05	0.001
Years in cultivation	13.16 ± 0.55[b]	12.21 ± 1.3[c]	19.87±1.2[a]	14.7 ± 0.5	0.001
Cattle (TLU)/head	89.27 ± 10.4[a]	25.95 ± 2.8[b]	13.85 ± 2.5[c]	60 ± 6.4	0.001
Sheep (TLU)/head	6.6 ± 0.8[a]	0.85 ± 0.1[b]	0.8 ± 0.1[c]	48.7 ±0.5	0.001
Goat (TLU)/head	5.2 ± 0.4a	2.3 ± 0.2[bc]	1.8 ± 0.2[c]	3.9 ± 0.24	0.003

[abc] Different superscripts denote significant differences at P<0.05 between means within rows, TLU, tropical livestock unit.

Table 5: Trend of livestock ownership in last ten year in different production system.

Variable	Production System, N (%)			Overall (N=371) N%	χ^2	P-value
	Pastoralist (N=215) N%	Agro-past. (N=62) N%	Mixed farm(N=94) N%			
Do you have your own livestock in the last ten years?						
Yes	213 (99.1)	62(100)	93 (98.9)	368 (99.2)	0.62	0.073
No	2 (0.9)	0	1 (1.1)	3(0.8)		
Trends of cattle population in the past ten years						
Increase	80 (37.2)	12 (19.4)	32 (34)	124 (33.4)	10.48	0.032
Decrease	128 (59.5)	50 (80.6)	58 (61.7)	236 (63.6)		
No change	7 (3.3)	0	4 (4.3)	11 (3)		
Trends of sheep population in the past ten years						
Increase	60 (27.9)	6 (9.7)	20 (21.3)	86 (23.2)	50.2	0.001
Decrease	128 (59.5)	23 (37.1)	41 (43.6)	192 (51.8)		
No change	27 (12.6)	33 (53.2)	33 (35.1)	93 (25.1)		
Trends of goat population in the past ten years						
Increase	72 (33.5)	15 (24.2)	39 (41.5)	126 (34)	9.78	0.030
Decrease	131 (60.9)	38 (61.3)	47 (50)	216 (58.2)		
No change	12 (5.6)	9 (14.5)	8 (8.5)	29 (7.8)		

N: Number of respondent.

Roles of Indigenous Knowledge in Fattening Livestock

Tools and methods used traditionally to castrate cattle: The study results, presented in Tables 6 and 7, show a significant reliance on indigenous knowledge for cattle fattening, with notable differences observed across pastoralist, agro-pastoralist, and mixed farming systems. Traditional cattle fattening methods utilize a variety of locally sourced materials, each serving a specific function in the process (Table 6). For example, the "Ekidongit" (local Burdizzo) and "Ekileng" (sharp knife) are used to castrate cattle, a practice believed to enhance growth by manipulating the reproductive organs. Other materials like "Pillow," "Korr," and "Stone" are used as supportive tools during castration, based on the belief that this procedure accelerates fattening. Additionally, tools such as "Block of wood" and "Two parallel sticks" are employed to support the testicles, further illustrating traditional methods of managing livestock for optimal weight gain. Other materials, including "Shade," "boat," "Jerikan," and "baldi," are critical for maintaining proper conditions, such as feeding, watering, and providing shelter, which are essential for the fattening process. These practices reflect a deep connection between farmers and their livestock, passed down through generations, with adaptations tailored to the specific environmental and cultural needs of the farming systems (Blench, 2020; Omer et al., 2021).

Table 6: Conventional techniques and supplies for traditional cattle fattening employed in the research sites.

Traditional materials used during fattening	Purpose during cattle fattening
Ekidongit (known as local Burdizzo)	Made of stick and used for damaging the animal testicles
Ekileng (sharp knife)	used to remove animal testicles
Pillow (made of woody material)	Used as testicles supportive
Korr (made of woody materials)	Used for damaging testicles
Stone	testicle crushing material
Block of wood	under testicles supporting material
Heavy woody material	used to beat testicles
Two parallel sticks	Supporting testicles
Shade, boat, Jerikan and baldi	For maintaining, shading, feeding and watering the animal

The study highlights the widespread use of traditional fattening techniques across all production systems. A significant majority of participants—99.1% of pastoralists, 95.2% of agro-pastoralists, and 97.9% of mixed farmers—reported utilizing these methods (χ^2 = 4.01, P = 0.014), indicating the continued importance of indigenous knowledge in cattle fattening. Market benefits were the primary motivation for fattening among mixed (70.2%) and agro-pastoral farmers (48.4%), while pastoralists (22.3%) were less market-driven (χ^2 = 154.24, P = 0.001). Family needs were more frequently cited by pastoralists (28.8%). Furthermore, pastoralists were more likely to use cattle fattening for cultural and ritual purposes (85.6%), in contrast to agro-pastoralists (62.9%) and mixed farmers (29.8%) (χ^2 = 109.4, P = 0.001). Despite the dominance of traditional methods, a higher proportion of mixed farmers (67%) reported integrating modern techniques, reflecting the changing economic environment and increased access to new technologies (Ndagala *et al*., 2022).

Selection criteria and characteristics for fattening cattle: Table 8 summarizes the castration practices and selection criteria for fattening cattle in three production systems: Pastoralist, Agro-pastoral, and Mixed farm systems. Significant differences were observed in castration practices and the selection criteria for bulls/oxen.

Castration practices: A large proportion of pastoralists (98.6%) and agro-pastoralists (93.5%) castrate cattle before fattening, while only 50% of mixed farmers do so. Overall, 85.4% of respondents castrate cattle prior to fattening, which is statistically significant (χ^2 = 127.17, P = 0.001). Castration is commonly practiced in pastoralist and agro-pastoral systems to manage reproductive performance and reduce aggressive behavior, while mixed farms may employ

Table 7: Level of indigenous knowledge utilization and reasons of cattle fattening in different production system.

Variables	Production system, N (%)			Overall N=371(%)	χ^2	P value
	Pastoralist N=215(%)	Agro-past. N=62(%)	Mixed farm N=94(%)			
Did you commonly apply traditional fattening practices?						
Yes	213(99.1)	59 (95.2)	92 (97.9)	364 (98.1)	4.01	0.014
No	2(0.9)	3 (4.8)	2 (2.1)	7 (1.9)		
Why you practice fattening?						
It has good market benefit	48(22.3)	30 (48.4)	66(70.2)	144 (38.8)	154.24	0.001
Told by extension workers	2(0.9)	4 (6.5)	7(7.4)	13 (3.5)		
To solve family issues	62(28.8)	6 (9.7)	15 (16)	83 (22.4)		
All	101(47)	20 (32.3)	4(4.3)	125 (33.7)		
I didn't start fattening	2(0.9)	2 (3.2)	2 (2.1)	6 (1.6)		
Purpose of fattening						
For ritual believes	1 (0.5)	0	0	1 (0.3)	107.4	
For income	23(10.7)	23 (37.1)	63 (67)	109 (29.4)		0.001
For family consumption	4 (1.9)	0	3 (3.2)	7 (1.9)		
Cultural ceremonies	3 (1.4)	0	0	3 (0.8)		
All	184 (85.6)	39 (62.9)	28 (29.8)	251 (67.7)		
How do you utilize traditional fattening practices?						
Still as usually practiced	119 (55.3)	35 (56.5)	30 (31.9)	184 (49.6)	18.41	0.001
Slightly practiced	96 (44.7)	26 (41.9)	63 (67)	185 (49.9)		
Not practiced	0	1 (1.6)	1 (1.1)	2 (0.5)		

N: Number of respondent.

Table 8: Castration and selection criteria of fattening animal across farming system.

Variables	Production system, N (%)			Overall (N=371) N (%)	χ^2	P value
	Pastoralist (N=215) N (%)	Agro-past. (N=62) N (%)	Mixed farm (N=94) N (%)			
Do you castrate cattle before fattening?					127.17	0.001
Yes	212 (98.6)	58 (93.5)	47 (50)	317 (85.4)		
No	3 (1.4)	4 (6.5)	47 (50)	54 (14.6)		
Criteria of bull/ox selection for fattening					133.9	0.001
By age group	11(5.1)	4 (6.5)	6 (6.4)	21 (5.7)		
By color	0	0	3 (3.2)	3 (0.8)		
Physical appearance	19 (8.5)	10 (16.1)	48 (51.1)	77 (20.8)		
Reproductive performance	5 (2.3)	16 (16.1)	3 (3.2)	24 (6.5)		
Parental/pedigree info.	180 (83.7)	32 (51.6)	34 (36.2)	246 (66.3)		
What type of animal needed for fattening?					79.55	0.001
Aged plowed oxen	20 (9.3)	37 (59.7)	49 (52.1)	106 (28.6)		
Finished production	29 (13.5)	4 (6.5)	10 (10.6)	43 (11.6)		
With dental problem	0	1 (1.6)	2 (2.1)	3 (0.8)		
Don't have any preferences	6 (2.8)	1 (1.6)	2 (2.1)	9 (2.4)		
Young, aged and finished	160 (74.4)	19 (30.6)	31 (33)	210 (56.6)		

N: Number of respondent.

more diverse practices or place less emphasis on castration. These findings align with previous studies in African pastoral systems, where castration serves both production and management purposes (Hassan *et al*., 2018).

Criteria for bull/ox selection: The primary selection criterion varied by farming system. Pastoralists mainly consider parental/pedigree information (83.7%), reflecting their preference for animals with known lineage, ensuring better quality and performance. In contrast, agro-pastoralists and mixed farmers prioritize physical appearance and reproductive performance. This suggests that pastoralists value genetic background, while mixed farmers focus on visible traits and reproductive potential for immediate fattening success. The differences in selection criteria were statistically significant (χ^2 = 133.9, P = 0.001), supporting previous studies highlighting the importance of indigenous knowledge and pedigree in livestock selection (Sogbohossou *et al*., 2020).

Type of Animal Needed for Fattening: Pastoralists (74.4%) prefer young, aged, and finished cattle for fattening, while agro-pastoralists and mixed farmers (59.7% and 52.1%) favor aged plowed oxen, indicating the differing economic roles of cattle. This difference was statistically significant (χ^2 = 79.55, P = 0.001), reflecting the importance of both work and fattening in different farming systems.

Cattle fattening across farming systems: breed, type, and season: Table 9 presents a summary of cattle types, breeds, and fattening seasons across three farming systems. The results highlight notable differences in cattle selection and fattening seasons.

Type of Cattle Used for Fattening: Pastoralists primarily use oxen (15.3%) and a combination of heifers and bulls (36.3%) for fattening, while agro-pastoralists and mixed farmers predominantly prefer oxen (54.8% and 73.4%, respectively). These differences are statistically significant (χ^2 = 208.86, P < 0.001), indicating that oxen play a more labor-intensive role in mixed and agro-pastoral systems, where cattle serve as draught animals as well as for meat production. Similar trends have been reported in mixed farming systems, where oxen fulfill dual roles in work and fattening (Koh *et al*., 2019).

Breed Preferences for Fattening: The preferred breeds for fattening also vary across systems. Pastoralists favor Zebu, while agro-pastoralists and mixed farmers prefer Boran and Zebu breeds. Pastoralists choose indigenous breeds like Zebu for their adaptability, whereas agro-pastoralists and mixed farmers opt for Boran for its higher productivity. These breed preferences were statistically significant (χ^2 = 117.18, P < 0.001), influenced by environmental conditions and desired production outcomes. This aligns with earlier studies that highlight the resilience and productivity of Boran and Zebu (Yami and Dadi, 2017).

Season of Fattening: Fattening mostly occurs during the wet season (63.1%), with transition periods (30.7%) being the second most common time. Pastoralists primarily fatten cattle during the wet season (71.2%), while agro-pastoralists

Table 9: Cattle fattening throughout farming systems: breed, kind and season.

Variables	Production System, N (%)			Overall (N=371) N (%)	χ^2	P-value
	Pastoralist (N=215) N (%)	Agro-past. (N=62) N (%)	Mixed farm (N=94) N (%)			
Type of cattle mostly used for fattening					208.86	<0.001
Steers	95 (44.2)	5 (8.1)	6 (6.4)	106(28.6)		
Bulls	9 (4.2)	23(37.1)	19 (20.2)	51 (13.7)		
Oxen	33 (15.3)	34(54.8)	69 (73.4)	136 (36.7)		
Heifers and bulls	78 (36.3)	0	0	78 (21)		
Breed preferred for fattening					117.18	<0.001
Unknown indigenous	0	3 (4.8)	0	3 (0.8)		
Boran breed	46 (21.4)	35(56.5)	61 (64.9)	142 (38.3)		
Zebu breed	75 (34.9)	24(38.7)	33 (35.1)	132 (35.6)		
Borena and zebu breed	94 (43.7)	0	0	94 (25.3)		
Season of fattening					43.15	<0.001
Dry season	22 (10.2)	1 (1.6)	0	23 (6.2)		
Wet season	153 (71.2)	32(51.6)	49 (52.1))	234 (63.1)		
Transition period (wet-dry)	40 (18.6)	29(46.8)	45 (47.9)	114 (30.7)		
Months of animals kept for fattening					39.88	<0.001
Three months	43 (20)	3 (4.8)	5 (5.3)	51 (13.7)		
Four months	36 (16.7)	25(40.3)	42 (44.7)	103 (27.8)		
Five months and above	135 (62.8)	34(54.8)	47 (50)	216 (58.2)		
I don't have idea	1 (0.5)	0	0	1 (0.3)		
Do you have experience with weight record before fattening?					2.06	0.356
Yes	7 (3.3)	0	3 (3.2)	10 (2.7)		
No	208 (96.7)	62 (100)	91 (96.8)	361 (97.3)		
Do you get extension service?					64.23	<0.001
Yes	68 (31.6)	11(17.7)	32 (34)	111 (29.9)		
No	147 (68.4)	51(82.3)	62 (69)	260 (70.1)		
Do you get capacity improvement?					65.63	<0.001
Yes	17 (7.9)	11(17.7)	32 (34)	60 (16.2)		
No	198 (92.1)	51(82.3)	62 (69)	311 (83.8)		

N: Number of respondent.

and mixed farmers fatten cattle during both wet and transition periods. This seasonal variation ($\chi^2 = 43.15$, $P < 0.001$) is influenced by the availability of grazing resources and water during the wet season. Transition periods allow supplementary feeding before the dry season. These findings align with Shapiro *et al.* (2019), who found that feed availability greatly impacts fattening strategies in African pastoral systems.

Duration of Fattening: Most respondents across all systems fatten cattle for five months or more (58.2%). Mixed and agro-pastoral systems show a higher preference for fattening over four months (44.7% and 40.3%, respectively). Pastoralists typically fatten cattle for a longer period due to reliance on extensive grazing systems, which require more time for optimal fattening. These duration differences were statistically significant ($\chi^2 = 39.88$, $P < 0.001$). Studies suggest that pastoral systems require longer fattening periods due to slower weight gain from traditional grazing (Herrero et al., 2020).

Experience with Weight Records and Extension Services: Most farmers do not maintain weight records before fattening (97.3%) and do not receive extension services (70.1% and 83.8%). However, agro-pastoralists are more likely to receive extension services, reflecting the more intensive nature of their farming systems. This highlights the need for improved extension services to support better cattle fattening management practices. Extension services are critical for enhancing livestock productivity (Abdullah *et al.*, 2019).

Cattle fattening across farming systems, breed, type and season: Table 9 summarizes the types of cattle, breeds, and fattening seasons across three farming systems. The findings indicate significant differences in cattle selection and fattening seasons.

Type of Cattle Used for Fattening: Pastoralists mainly use oxen (15.3%) and a combination of heifers and bulls (36.3%) for fattening, while agro-pastoralists and mixed farmers primarily prefer oxen (54.8% and 73.4%, respectively). These differences are statistically significant (χ^2 = 208.86, P < 0.001), reflecting the labor-intensive role of oxen in mixed and agro-pastoral systems, where cattle are used both for draught power and meat production. Similar patterns were found in studies of mixed farming systems, where oxen are valued for both work and fattening (Koh *et al*., 2019).

Breed Preferences for Fattening: The preferred breeds for fattening also vary across systems. Pastoralists favor Zebu, while agro-pastoralists and mixed farmers prefer Boran and Zebu breeds. Pastoralists often choose indigenous breeds like Zebu for their resilience to harsh conditions, whereas agro-pastoralists and mixed farmers favor Boran for higher productivity. These breed preferences were statistically significant (χ^2 = 117.18, P < 0.001), indicating that breed selection is influenced by environmental conditions and desired production outcomes. Previous research has highlighted the productivity and hardiness of Boran and Zebu breeds (Yami and Dadi, 2017).

Season of Fattening: Fattening is most common during the wet season (63.1%), with transition periods (30.7%) being the second most common time. Pastoralists predominantly fatten cattle during the wet season (71.2%), while agro-pastoralists and mixed farmers fatten during both wet and transition periods. This seasonal variation (χ^2 = 43.15, P < 0.001) is due to the availability of grazing resources and water, with transition periods allowing for supplementary feeding before the dry season. These findings align with Shapiro *et al*. (2019), who reported that seasonal feed availability influences fattening strategies in African pastoral systems.

Feed sources and feeding system management across the production process: Feed sources and management practices vary significantly across different farming systems, including Pastoralist, Agro-pastoral, and Mixed systems (Table 10). Pastoralists primarily rely on grazing (53%) for feed, with communal grazing land being a key resource. In contrast, agro-pastoralists and mixed farmers use a combination of grazing, fodder trees (11.7%), and agricultural by-products (12.9%), reflecting the integration of crop and livestock farming. These differences in feed sourcing are statistically significant (χ^2 = 93.62, P < 0.001), with crop-livestock integration being an essential feature of mixed farming systems (Rufael *et al*., 2021). Additionally, the location of feed sources differs across systems, with pastoralists utilizing extensive areas like dry communal lands and riverbanks (20.9%), while agro-pastoralists and mixed farmers take advantage of wetlands (24.5%) and dryland farmsteads (13.8%). These geographical variations are statistically significant (χ^2 = 79.65, P < 0.001), highlighting the impact of climate and geography on feed availability (Fasil *et al*., 2020).

Feeding systems also differ significantly across farming types. Pastoralists mainly use free-range grazing, an extensive system, while agro-pastoralists and mixed farmers tend to adopt more controlled practices such as tethering and zero grazing during dry periods. These practices reflect the more intensive management systems of agro-pastoral and mixed systems, and the differences in feeding systems are highly significant (χ^2 = 31.13, P < 0.001), indicating that the type of farming system influences feed management (Shapiro *et al*., 2019). Despite these varying practices, feed availability remains a concern. While 41.9% of pastoralists and 43.5% of agro-pastoralists report abundant feed, 73.4% of mixed farmers report feed shortages. This disparity is statistically significant (χ^2 = 7.33, P = 0.026), emphasizing the challenges in securing sufficient feed, especially in more intensive mixed farming systems.

Over the last five years, there has been a significant decline in feed availability across all farming systems, with the majority of pastoralists (71.6%), agro-pastoralists (98.4%), and mixed farmers (90.4%) reporting reduced feed resources. This decline is likely linked to climate change, land degradation, and overgrazing (Koh *et al*., 2019). Seasonal feed shortages are also common, with only 17.8% of respondents reporting year-round feed availability. Government recommendations to mitigate rising feed costs include support for irrigation-based feed cultivation and the plantation of agricultural by-products, emphasizing the need for sustainable feed production practices (Abdullah *et al*., 2019).

Traditional ethno-veterinary practices: The study highlights the diversity of traditional ethno-veterinary practices used by pastoral and agro-pastoral communities to manage cattle diseases (Table 11). Among the Nyangatom pastoralists, plant-based remedies such as Erieng plant roots and ebenyo tree leaves are used to treat conditions like Maliri (Heart Water), Green eye (conjunctivitis), and Etid (liver disease). Non-plant remedies, including hot iron applications, are used for treating wounds and conditions like mastitis. These practices reflect the deep cultural knowledge of these communities, which rely on locally available resources for disease management, as noted in studies emphasizing the importance of traditional knowledge in livestock health (Mekonnen *et al*., 2021; Fasil *et al*., 2020).

Table 10: Feed sources and feeding system management throughout the production process.

Variables	Production system, N (%)			Overall (N=371) N (%)	χ^2	P value
	Pastoralist (N=215) N (%)	Agro-past. (N=62) N (%)	Mixed farm (N=94) N (%)			
Source of feed					93.62	<0.001
Grazing	114 (53)	12 (19.4)	10 (10.6)	136(36.7)		
Fodder trees and grasses	0	17 (11.7)	11 (11.7)	28 (7.5)		
Hay	0	0	1 (1.1)	1 (0.3)		
By-products	3 (1.4)	0	1 (1.1)	4 (1.1)		
Others (agricultural wastes)	44 (20.5)	8 (12.9)	26 (27.7)	78 (21.0)		
All	54 (25.1)	25 (40.3)	45 (47.9)	124 (33.4)		
Location of feed sources					79.65	<0.001
Homestead	2 (0.5)	0	1 (1.1)	3 (0.8)		
Dry communal grazing land	15 (7)	0	3 (3.2)	18 (4.9)		
Wetland and mountain area	31 (14.4)	1 (1.6)	23 (24.5)	55 (14.8)		
Dryland farmstead	11 (5.1)	0	13 (13.8)	24 (6.5)		
Omo and Woito river banks	45 (20.9)	0	1 (1.1)	46 (12.4)		
All	111(51.6)	61 (98.4)	53 (56.4)	225 (60.6)		
Current status of feed					7.33	0.026
Abundant	90 (41.9)	27 (43.5)	25 (26.6)	142 (38.3)		
Limited	125(58.1)	35 (56.5	69 (73.4)	229 (61.7)		
Trends of feed increment in last five years					31.13	<0.001
Increased	49 (22.8)	1 (1.6)	9 (9.6)	59 (15.9)		
Decreased	154(71.6)	61 (98.4)	85 (90.4)	300 (80.9)		
No change	12 (5.6)	0	0	12 (3.2)		
Is feed resources available year around?					15.77	<0.001
Yes	48 (22.3)	14 (22.6)	4 (4.3)	66 (17.8)		
No	167(77.7)	48 (77.4)	90 (95.7)	305 (82.2)		
Average feed price in local market					82.05	<0.001
10-50 birr/kg	100 (46.5)	14 (22.6)	4 (4.3)	118 (31.8)		
50-100 birr/kg	44 (20.5)	18 (29)	20 (21.3)	82 (22.1)		
More than 100 birr/kg	59 (27.4)	1 (1.6)	55 (58.5)	115 (31)		
Is price increased or decreased?					108.63	<0.001
Slightly increased	98 (45.6)	30 (48.4)	2 (2.1)	130 (35)		
Highly increased	85 (39.5)	2 (3.2)	76 (80.9)	163 (43.9)		
Slightly decreased	12 (5.6)	0	1 (1.1)	13 (3.5)		
Highly decreased	8 (3.7)	0	0	8 (2.2)		
No idea about price	1 (0.5)	0	0	1 (0.3)		
What government should do to provide lower price feed?					78.09	<0.001
Cultivating feed resources using irrigation	75(34.9)	39 (62.9)	17 (18.1)	131 (35.3)		
Introducing large demonstration site	0	0	6 (6.4)	6 (1.6)		
Plantation of by-products	5 (2.3)	11 (17.7)	14 (14.9)	30 (8.1)		
Provide concentrate feeds	1 (0.4)	0	0	1 (0.3)		
All	134(62.3)	12 (19.4)	57 (60.6)	203 (54.7		

N: Number of respondent.

In contrast, the Dasenech pastoralists use combinations like tobacco and water, while the Bodi and Dime agro-pastoralists rely on plants like garlic and chiligit grass for treating eye problems and wounds. The prevalence of non-

plant-based treatments, such as water restriction, further highlights the diversity of approaches to disease management. This variation suggests that each community has developed unique practices based on local environmental conditions and available resources. This diversity aligns with research by Haile *et al.* (2022), which documents the rich cultural heritage in ethno-veterinary practices across East African pastoral communities. Overall, the different remedies across these communities emphasize the cultural importance of traditional knowledge in maintaining livestock health and adapting to local environments.

Accessibility and availability of modern veterinary treatments: Table 12 presents data on the availability of modern veterinary treatments across different production systems, revealing significant gaps in access, particularly among pastoralist and agro-pastoralist groups. A majority of respondents, 61.4% of pastoralists and 56.5% of agro-pastoralists, reported that modern treatments were either "not yet" or "less available." Only 14.6% of respondents overall indicated that modern treatments were accessible, and even fewer reported efficient accessibility. These limitations may stem from infrastructural challenges or financial barriers, particularly in remote pastoral regions. Additionally, drug shops were reported as absent in many areas, with 71.6% of pastoralists and 59.7% of agro-pastoralists noting their lack in their districts. Even when available, drug supplies were often insufficient, with 95.7% of respondents reporting this issue. These findings highlight a significant challenge in the veterinary sector, where limited access to modern veterinary drugs and services hinders effective livestock health management (Mekonnen *et al.*, 2021; Fasil *et al.*, 2020).

Table 11: Traditional ethno-veterinary practices used in the study area.

Production System	Name of medical plant	Non-plant mate when fattening	Types of diseases
Nyangatom. pastoralist	Erieng plant roots, ebenyo tree leaves, ebey tree leaves and ekapelmon seeds	Hot- iron Witch doctor or ritual specialists	Maliri (Heart Water or cowdrosis), Green eye and any eye disease (conjactivitis), Etid or liver disease (Liver Fluke), Nakowukeng (PPR)
		Hot water	Ewuko or lowuko lung disease(CBPP)
	Emuus or lomosingo roots		Longolhei (Blackleg), Lotayen, ekiriyont (Trypanasomiais), Ekutowo or lokejen (footroot)
	Muruda leguminous plant roots	Birds house burning below teats	Swelling of cow teats (Mastitis)
		Water restriction	Ekutowo disease, 4-5 days water restriction
	Lopariyang climbing tree roots (drinking once amonth)		For Barren cow (cow do not give birth)
	Apongaye (its steam cover) (herbatious tree)		For retained placenta
Dasenech. Pastoralist	Tobacco+ water?	Urine of sheep+ white makado	Mix with water given to unhealthy cattle
		Qanqo+White makado?	
		Qanqo?	
		Cattical areqe	Lesnech disease
Bodi and Dime, agro-pastoralist	Boiling coffee		
	Garlic and Chiligit grass		For eye problem
	Shodit and dampo plant		For wound
	Choboch tree		Its barks used for snake bite
		Boiled salts	For cattle with bloody diaharea
		Pig meat soup	For Swelling of stomach
Mixed farming and agro-pastoralist	Tobacco leaves		For external parasites
	Kutata plant leaves		Eye disease
	Roots of moringa trees		For legs pain disease
	Ditata plant leaves		Internal parasites

Table 12: Traditional ethno-veterinary practices utilized by various tribes to manage cattle diseases throughout the production system.

Variables	Production System			Overall (N=371) N (%)	χ^2	P-value
	Pastoralist (N=215) N (%)	Agro-past. (N=62) N (%)	Mixed farm (N=94) N (%)			
Is the modern disease treatment available?					303.84	< 0.001
Not yet	132 (61.4)	35 (56.5)	1()	133(35.8)		
Less available	56 (26)	23 (37.1)	64 (68.3)	178 (48)		
Available	26 (12.1)	4 (6.5)	24 (25.5)	54 (14.6)		
Efficiently available	1 (0.5)	0	5 (5.3)	6 (1.6)		
Drug shops available in the district or kebeles?					186.66	<0.001
Yes	61 (28.4)	25 (40.3)	92 (97.9)	178 (48)		
No	154 (71.6)	37 (59.7)	2 (2.1)	193 (52)		
Are drugs supply fulfilled?					9.01	0.001
Less fulfilled	210(97.7)	60 (96.8)	85 (90..4)	355 (95.7)		
Moderately fulfilled	5 (2.3)	2 (3.2)	9 (9.6)	16 (4.3)		

N: Number of respondent.

Table 13: Various cattle marketing strategies used in different production systems.

Variables	Production system, N (%)			Overall (N=371) N (%)	χ^2	P-value
	Pastoralist (N=215) N (%)	Agro-past. (N=62) (%)	Mixed farm (N=94) N(%)			
Why they marketing traditionally?					60.56	<0.001
To expand livestock herd	43 (20)	0	3 (3.2)	46 (12.5)		
For wealth purpose	3 (1.4)	0	7 (7.6)	10 (2.7)		
For buying livestock medicine	10 (4.7)	0	11(12)	21 (5.7)		
For income generation	4 (1.9)	2 (3.3)	9 (9.8)	15 (4.1)		
All	155 (72.1)	59 (96.7)	62 (67.4)	276 (74.4)		
How they have been marketing beef cattle and meat?					134.11	<0.001
Simply by taking animals to urban market	76 (35.3)	43 (69.4)	76 (80.9)	195 (52.6)		
By contacting the buyers before taking to market	4 (1.9)	11 (17.7)	17 (18.1)	32 (8.6)		
By exchanging animals with properties	130 (60.5)	8 (12.9)	1 (1.1)	139 (37.5)		
All	5 (2.2)	0	0	5 (1.3)		
Is market place accessible?					123.55	<0.001
No, there is no infrastructure	148 (68.8)	38 (61.3)	23 (24.5)	209 (56.3)		
There is but not in the correct place	56 (26)	22 (35.5)	46 (48.9)	124 (33.4)		
There is but not standardized	10 (4.7)	0	24 (25.5)	34 (9.2)		
Yes, modernized	1 (0.5)	2 (3.2)	1 (1.1)	4 (1.1)		
Is there official cross border trade between neighbor countries?						
No	215 (100)	62 (100)	94 (100)	371 (100)		
Did you consider weight loss?					37.06	<0.001
Yes	39 (18.1)	2 (3.2)	35 (37.2)	76 (20.5)		
No	170 (79.1)	58 (93.5)	50 (53.2)	278 (74.9)		
I have ideas about weighing animal	6 (2.8)	2 (3.2)	8 (8.5)	16 (4.3)		

N: Number of respondent.

Current Status, Indigenous Knowledge, Opportunities and Challenges of Beef Cattle Marketing

Beef cattle marketing strategies and cattle commercialization: Table 13 shows the marketing strategies employed by communities to sell cattle and beef.

Table 14: Marketing linkage distribution of cattle across production systems.

Variables	Production System			Overall (N=371) N(%)	χ^2	P- value
	Pastoralist (N=215) N (%)	Agro-past (N=62) N (%)	Mixed farm (N=94) N (%)			
Marketing linkage with central part of country					28.84	<0.00
No linkage between producer and buyer	79 (36.7)	20 (32.3)	37 (39.4)	136 (36.7)		
Through brokers	67 (31.2)	29 (46.8)	43 (45.7)	139 (37.5)		
Wholesalers buy sometimes from village	63 (29.3)	12 (19.4)	13 (13.8)	88 (23.7)		
Owner transport directly to industry	1 (0.5)	1 (1.6)	1 (1.1)	3 (0.8)		
Brokers and wholesalers	5 (2.3)	0	0	5 (1.3)		

N: Number of respondents.

Traditional methods, such as taking animals directly to urban markets or exchanging livestock for property, were commonly used, especially by pastoralists (60.5%) and agro-pastoralists (69.4%). This indicates a reliance on traditional practices over formalized marketing channels. However, there were significant differences in market infrastructure across the production systems. While 68.8% of pastoralists reported a lack of infrastructure, 61.3% of agro-pastoralists faced similar challenges. Mixed farming systems had better access to standardized markets, with 25.5% of respondents reporting available but non-standardized markets. A lack of official cross-border trade was noted across all systems, limiting international cattle trade (Muriuki *et al*., 2015; Saxena and Verma, 2017; Kassa *et al*., 2023).

The commercialization of cattle has slightly increased in agro-pastoral and mixed farming systems, with 47.2% of respondents reporting a rise in commercialization. However, pastoralists were more likely to report a decrease (6%) or stagnation (44.7%) in commercialization, likely due to limited market access and infrastructure (Hussain *et al*., 2021; Zhang *et al*., 2023). Weight loss in cattle was also more significant in pastoralist systems, with 18.1% of pastoralists reporting noticeable weight loss, compared to just 3.2% in agro-pastoral systems. This difference may be attributed to varying feeding practices, environmental stressors, and the longer distances pastoralists' cattle travel to find grazing areas (Pagiola *et al*., 2020; Hussein *et al*., 2022).

Marketing linkages and price variations: Table 14 shows that marketing linkages in pastoral systems were largely informal, with 36.7% of respondents indicating no linkage between producers and buyers. In contrast, agro-pastoralists and mixed farmers had better connections, often involving brokers or wholesalers. The lack of structured marketing linkages in pastoralist systems is a barrier to optimizing livestock sales and maximizing profits. Price analysis, as presented in Table 16, also shows significant variation in cattle prices across production systems. Pastoralists received the lowest prices for fattened cattle in both the wet and dry seasons. In the wet season, the price for fattened cattle among pastoralists was 24,324.65±641.41 ETB, while agro-pastoralists and mixed farmers received significantly higher prices (42,612.90±1980.25 ETB and 47,191.5±3618.7 ETB, respectively). This price discrepancy could be attributed to the higher quality of livestock from agro-pastoral and mixed farming systems, which likely have better access to veterinary care and feeding practices (Saxena and Verma, 2017; Muriuki *et al*., 2015; Hussein *et al*., 2022).

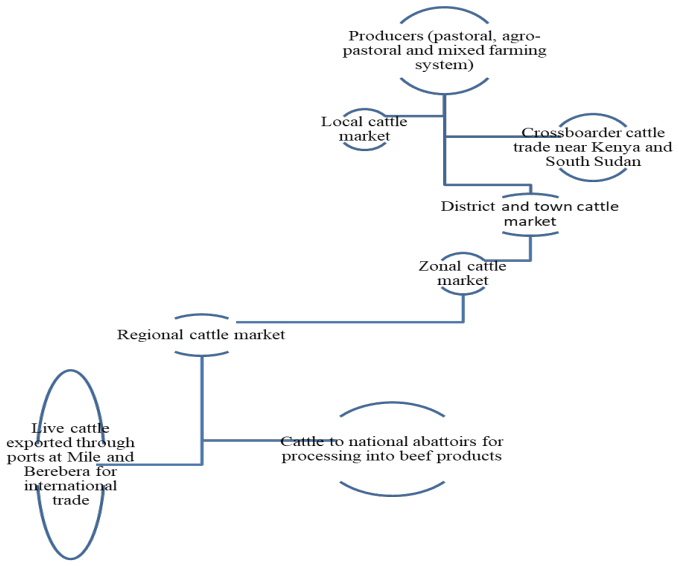

Figure 2: Cattle flow chain: from producers to different markets, and then to export from the research regions.

Beef cattle flow chain: Figure 2 illustrates the cattle flow chain, outlining the movement of cattle from producers to local markets and, in some cases, to export destinations. The flow varies significantly across production systems, including pastoralist, agro-pastoralist, and mixed farming. Pastoralists, who typically manage larger herds, face challenges with limited infrastructure and market access. Their cattle are often moved from remote grazing areas to local or district markets, where they are sold to traders or brokers who transport them to urban markets or wholesalers. However, pastoralists have limited access to export markets due to logistical and regulatory barriers,

Table 15: The status of live fattened cattle commercialization in the production system.

Variables	Production System			Overall (N=371) N (%)	χ^2	P-value
	Pastoralist (N=215) N (%)	Agro-past. (N=62) N (%)	Mixed farm (N=94) N (%)			
Status of cattle meat commercialization					93.38	0.000
Decreased	13 (6)	11 (17.7)	16 (17)	40 (10.8)		
Slightly increased	75 (34.9)	41 (66.1)	59 (62.8)	175 (47.2)		
Highly increased	31 (14.4)	8 (12.9)	19 (20.2)	58 (15.6)		
At the same margin	96 (44.7)	2 (2.3)	0	98 (26.4)		
Which market is more attractive for live animals?					30.69	0.000
Local level market	29 (13.5)	12 (19.4)	0	41 (11.1)		
District town market	168 (78.1)	50 (80.6)	85 (90.4)	303 (81.7)		
Zonal town	5 (2)	0	0	5 (1.3)		
Cross-border trade between Kenyan	4 (1.9)	0	0	4 (1.1)		
Central market within country	9 (4.2)	0	9(9.6)	18 (4.9)		

N: Number of respondent.

restricting their ability to capitalize on higher-value international sales (Saxena and Verma, 2017). Agro-pastoralists, with better transportation access, experience more efficient cattle movement to district markets, where they can connect with wholesalers or retailers. Their increased access to export routes improves their chances of selling cattle internationally, enhancing income opportunities (Hussain *et al*., 2021).

In mixed farming systems, the cattle flow is more organized, benefiting from market integration and greater access to centralized markets. These systems see more frequent sales in larger markets, with a higher concentration of buyers, including exporters, who can directly engage with producers or brokers. As a result, mixed farmers tend to receive better prices and have more opportunities for cross-border trade compared to pastoralists (Pagiola *et al*., 2020). Brokers and wholesalers play a crucial role in linking producers with larger markets, particularly in pastoralist and agro-pastoralist systems. Despite this, regulatory and logistical challenges still hinder the flow of cattle to export destinations, limiting the potential for cross-border trade in some regions (Muriuki *et al*., 2015).

Commercialization status of live fattened cattle: Table 15 presents data on the commercialization of cattle meat across various farming systems. The findings reveal significant differences in the level of commercialization between pastoralist, agro-pastoral, and mixed farming systems. Overall, 47.2% of respondents reported a slight increase in cattle meat commercialization, with the highest increase observed in agro-pastoral (66.1%) and mixed farming systems (62.8%). In contrast, only 34.9% of pastoralists reported a slight increase. This suggests that agro-pastoralists and mixed farmers are more actively involved in the commercialization of fattened cattle, likely due to improved access to markets and better infrastructure, a finding that aligns with research by Shiferaw and Gebremedhin (2021), who noted that agro-pastoral systems have a stronger market orientation due to better infrastructural development. On the other hand, pastoralists face significant challenges, including limited market access and veterinary care, which impede their commercialization efforts (Hussein and Stotz, 2020).

A notable portion of pastoralists (44.7%) reported that commercialization of cattle meat remained unchanged, with just 6% noting a decrease. This stagnation can be attributed to the lack of sufficient market opportunities, poor infrastructure, and inadequate veterinary services in pastoralist regions, which hamper livestock productivity and marketability. This observation is consistent with findings by Saxena and Verma (2017), which highlighted that limited market integration and poor infrastructure contribute to stagnation in pastoralist areas. Conversely, only 2.3% of agro-pastoralists and none of the mixed farmers reported no change in commercialization levels, underscoring more dynamic markets in these systems.

Market attractiveness for live animals: When respondents were asked about the most desirable markets for live animals, the district town market emerged as the preferred choice across all production systems, with 81.7% of respondents selecting it. Both pastoralists (78.1%) and agro-pastoralists (80.6%) favored district town markets, while mixed farmers (90.4%) also preferred these markets, likely due to better access and infrastructure. These findings support the work of Shiferaw and Gebremedhin (2021), who emphasized that district town markets are more attractive due to the concentration of buyers and improved infrastructure, particularly in mixed and agro-pastoral systems. In contrast, local markets were less appealing, with

Table 16: Average (Mean ± SE) distance to market place, weight loss, and price of live and fattened cattle in livestock production systems.

Parameter (variables)	Production systems			Overall (N=371) (Mean ± SE)	P value
	Pastoralists (N=215) (Mean ± SE)	Agro-pastoralists (N= 62) (Mean ± SE)	Mixed farm (N=94) (Mean ± SE)		
Distance to market	15.93 ± 1.73[a]	7.81±0.45[b]	6.93 ± 1.05[c]	12.34 ± 1.1	<0.001
Weight loss (kg)	3.503 ± 0.38[a]	2.00 ± 0.00[b]	1.57 ± 0.17[c]	2.77 ± 0.3	0.001
Price of fattened ox or steer					
Wet season	24324.65±641.41[c]	42612.90±1980.25[b]	47191.5±3618.7[a]	33174.7 ± 1173.6	0.000
Dry season	19227.91±511.45[c]	37260.6±1438.2[b]	43056.45±3425.42[a]	29450.1 ± 999.9	0.000

[abC]Different superscripts denote significant differences at P<0.05 between means within rows; **N:** number of respondent; **SE:** standard error.

only 13.5% of pastoralists and 19.4% of agro-pastoralists choosing them, possibly due to lower prices and fewer buyers.

These results suggest that while the district town market is the most attractive due to its higher concentration of buyers, local markets still serve a role, particularly for pastoralists who may face challenges in accessing larger markets. The lack of cross-border trade and limited access to central markets further highlight the infrastructural and regulatory constraints that pastoralists face (Tadesse, 2017).

Distance to market, weight loss and price of fattened cattle: Table 16 reveals significant differences in livestock production parameters across farming systems. Pastoralists reported the longest average distance to market (15.93 ± 1.73 km), which limits their ability to access markets regularly. In contrast, agro-pastoralists (7.81 ± 0.45 km) and mixed farmers (6.93 ± 1.05 km) had much shorter distances, enabling them to engage more effectively in cattle sales and achieve better commercialization outcomes. This disparity in market access plays a critical role in the economic outcomes for these systems, supporting the findings of Saxena and Verma (2017), who noted that distance to market, is a major determinant of livestock commercialization success.

Additionally, weight loss in cattle was more pronounced in pastoralist systems (3.503 ± 0.38 kg) compared to agro-pastoralists (2.00 ± 0.00 kg) and mixed farmers (1.57 ± 0.17 kg), likely due to longer travel distances and suboptimal feeding conditions. This impacts livestock quality and marketability, as suggested by Tadesse (2017). Price analysis revealed that, in both the wet and dry seasons, pastoralists received the lowest prices for fattened cattle (24,324.65 ± 641.41 ETB and 19,227.91 ± 511.45 ETB), while mixed farmers received the highest prices (47,191.5 ± 3618.7 ETB and 43,056.45 ± 3425.42 ETB). These price differences reflect better market access, livestock quality, and management practices in agro-pastoral and mixed farming systems, consistent with the observations of Hussein and Stotz (2020), who found that better market access correlates with higher prices for livestock.

CONCLUSIONS AND RECOMMENDATIONS

The socio-economic characteristics of respondents in this study varied significantly across farming systems, highlighting the need for context-specific interventions to address unique challenges. Policymakers should focus on improving literacy, promoting gender equity, and leveraging indigenous knowledge to enhance agricultural productivity and sustainability. Livestock ownership remains widespread, though cattle, sheep, and goat populations have declined over the past decade, suggesting the need to explore factors such as climate change, market dynamics, and shifts in farming practices. These trends emphasize the complexity of livestock management, particularly in pastoral and agro-pastoral regions, requiring targeted strategies to improve sustainability. Cattle fattening practices, shaped by economic factors, cultural beliefs, and market access, need modern integration while preserving indigenous knowledge. Feed sourcing and pricing vary, with pastoralists relying on natural grazing, while agro-pastoralists and mixed farmers face higher feed costs. Government interventions in feed production and by-product utilization could help. Improved veterinary care, market access, and infrastructure are vital for enhancing livestock health and commercialization, especially for pastoralists, who face barriers limiting their economic potential.

Promoting land rights protection through laws and pilot programs can support sustainable use and communal tenure systems, integrating traditional governance. Implementing land management practices like rotational grazing and agroforestry can balance modern agricultural demands with traditional practices. Governments could stabilize market prices by establishing pastoralist cooperatives or price stabilization funds. Financial support, such as microloans or grants, alongside technical training, would en-

hance smallholder productivity and resilience. Documenting and sharing traditional cattle-fattening knowledge via participatory research or digital platforms is essential for modern livestock management integration. Community-led conservation projects and drought-resistant fodder crops can improve natural grazing management. Mobile clinics or subsidized veterinary services can ensure better access to care for remote communities.

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NOVELTY STATEMENTS

In tropical regions, including Ethiopia, cattle fattening practices, marketing channels, and the availability of feed resources for livestock are highly influenced by climatic conditions, seasons, agricultural production systems, and agro-ecological zones. Although the Southern Ethiopian Rift Valley features distinct production systems—pastoral, agro-pastoral, and mixed farming—there is a significant research gap regarding the dynamics of small-scale cattle fattening practices, local feed resource utilization, and marketing strategies within these systems. The novelty of this study lies in addressing these gaps by exploring these critical aspects in the unique context of the region.

AUTHOR'S CONTRIBUTIONS

Tesfaye Edjem: conceptualized the study, curated the data, conducted formal analysis and investigation, designed the methodology, managed the project, and drafted the original manuscript.
Yisehak Kechero: secured funding, performed formal analysis, provided supervision, and reviewed and revised the manuscript.
Asrat Guja: contributed to supervision and formal analysis.

Limitations and Future Research

Future research could explore region-specific challenges and evaluate the long-term impacts of integrating indigenous knowledge with modern cattle management techniques. Investigating innovative policy frameworks to balance communal and private land use rights would further inform sustainable land management strategies.

Conflict of Interest

The authors have declared no conflict of interest.

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