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Research Article

Cattle Breeding Programs and Trait Preferences in Ethiopia

[1,2]Mohammed Endris Seid, [2]Kefelegn Kebede Kefenie, [3]Gebregziabher Gebreyohannes, [3]Selam Meseret, [3]Okeyo Mwai and [4]Enyew Negussie

[1]Afar Pastoral and Agro-Pastoral Research Institute (APARI), Samara, Ethiopia Semera, Ethiopia
[2]School of Animal and Range Sciences, Haramaya University, Haramaya, Ethiopia
[3]International Livestock Research Institute (ILRI), Nairobi, Kenya
[4]Natural Resources Institute (Luke), Jokioinen, Finland

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Corresponding Author:
Mohammed Endris Seid
Afar Pastoral and Agro-Pastoral Research Institute (APARI), Samara, Ethiopia Semera, Ethiopia; School of Animal and Range Sciences, Haramaya University, Haramaya, Ethiopia
Email: mohaend@gmail.com

Abstract: The success of livestock breeding programs depend on the active involvement of smallholder farmers, pastoralists, and agro-pastoralists in shaping breeding objectives and identifying key trait preferences based on specific production goals. This study aimed at assessing the relative importance of cattle-keeping objectives and trait preferences across mixed crop-livestock, pastoral, and agro-pastoral production systems in Ethiopia. We collected data from 180 households 90 from mixed crop livestock, 65 from pastoral, and 25 from agro-pastoral systems. The exploded logit statistical model was used and it provided a nuanced understanding of the different cattle-keeping objectives. In mixed crop-livestock systems, draft power and milk production were prioritized, whereas pastoral systems emphasized milk production and calf rearing. Data revealed that agro-pastoral systems demonstrated a more balanced set of preferences, with draft power and milk production being equally important. Trait preferences for male cattle were largely consistent across systems, with traction ability and body size being highly valued, while preferences for other traits, such as coat color and fertility, varied by context. Milk yield was the dominant trait across all production systems. The study outcomes offer crucial insights for the development of balanced breeding programs tailored to the needs of smallholder farmers, pastoralists, and agro-pastoralists, promoting sustainable cattle productivity.

Keywords: Cattle Breeding Program, Exploded Logit Model, Trait Preferences

Introduction

Cattle are essential to the livelihoods of smallholder farmers, pastoralists, and agro-pastoralists in Ethiopia (CSA, 2021). They provide essential products such as milk, meat, and manure, serve as a primary source of draft power for rural communities, and contribute to household income. As a result, cattle production is a central component of agricultural activities across the country. The vast majority (98.9%) of Ethiopia's national herd consists of indigenous cattle, which are maintained under extensive husbandry systems in rural areas (Tesfa *et al.*, 2022). These indigenous breeds are highly valued for their multipurpose uses, including milk and meat production, traction (draft power), and fulfilling social and cultural roles. Despite various breeding programs and genetic improvement strategies being introduced in developing countries, many have failed due to insufficient involvement of local beneficiaries. Lately, community-based breeding programs, which are better suited to low-input production systems, have gained recognition as a more sustainable approach. These programs require active participation from farmers throughout the implementation process. A key factor in the success of such programs is a clear understanding of the local production systems, selection criteria, and breeding goals. A well-defined breeding objective guides farmers in aligning their cattle management practices with the desired outcomes in terms of products and services. In conventional, market-oriented livestock systems, breeding objectives are often straightforward and economically driven. However, in traditional systems, where cattle serve multiple functions, defining breeding objectives is more complex. Therefore, analyzing farmers' preferred traits in cattle offers an indirect way to identify these objectives.

Previous studies have investigated cattle farmers' production systems and trait preferences in some tropical regions. For example, the preferences of Ankole cattle keepers in Uganda, Rwanda, and Tanzania were documented in Central and Eastern Africa (Ndumu *et al.*, 2008). In Ethiopia, research has focused on the breeding objectives of Sheko cattle keepers, breeding practices, and trait preferences (Elias *et al.*, 2018; Desta *et al.*, 2011; Zewdu *et al.*, 2018). Additionally, studies from West Africa have highlighted farmers' preferences for cattle traits, while more recent research in Gambia, Mali, and Nigeria has examined breeding objectives, practices, and preferences for cattle traits and breeds (Ejlertsen *et al.*, 2012; Traoré *et al.*, 2017; Yakubu *et al.*, 2019). These findings underscore the strong influence of farmers' characteristics and the local environment on production systems and breeding practices. Understanding the cattle-keeping objectives and trait preferences of smallholder farmers, pastoralists, and agro-pastoralists is essential for designing sustainable cattle genetic improvement programs. However, there is limited information on these objectives and preferences in Ethiopia's diverse production systems, making it difficult to develop effective breeding strategies. Therefore, we aimed to identify the relative importance of cattle-keeping objectives and trait preferences among smallholder farmers, pastoralists, and agro-pastoralists in Ethiopia, providing a foundation for designing sustainable breeding programs.

Materials and Methods

Description of Study Areas

The study was conducted in the North Shewa zone of the Amhara National Regional State and Administrative Zone 1 (Lower Awash Valley) and Administrative Zone 3 (Middle Awash Valley) of the Afar National Regional State, which represents mixed-crop livestock, Pastoralists, and Agro-pastoralist production systems. Within administrative zones, six districts were selected Ang: Olelana Tera, Basona Worena, and Debrebirahan towns from the North Shewa zone of the Amhara regional state and Aysaita, Dubti, and Amibera districts from the administrative zones 1 and 3 of the Afar regional state. The description of each district is given (Figure 1) (CSA, 2021).

North Shewa zone: This is one of the ten zones of the Amhara National Regional State of Ethiopia. This zone shares borders with the Oromia region to the south and west, South Wollo and the Oromia zone to the north and northeast, and the Afar region to the east (Figure 1). Debre Berhan is the capital of the North Shewa zone located at 130 km northeast of Addis Ababa. The zone is made up of 22 rural districts and is situated from 8° 38'-10° 42' N and 38° 40'-40° 03' E (CSA, 2021). The zone covers a total surface area of approximately 16,193.6 square kilometers and is divided into two areas: Highlands in the west and lowlands in the east. The area's geography ranges from flat to undulating and hilly, with varied tropical, subtropical, and temperate climates. From the total of 22 districts and five town administrations, three districts, Angolelana Tera, Basona Worena, and Debrebirahan towns, were purposefully chosen based on the potential and accessibility of cattle production.

Administrative Zone 1 and 3 of the Afar region: The study was carried out in the Afar National Regional State's Zones 1 and 3 (Figure 1). With an estimated area of 95958 km^2, it is situated in northeast Ethiopia's rangeland, which is part of the Great Rift Valley. Cattle, goats, sheep, camels, and horses are among the many potential livestock resources that can benefit the area and the national economy. The area has 30-50^{0}C temperatures and 200-600 mm of rainfall annually. The location is between 100 and 1000 meters above sea level. Its latitude and longitude are 80 40' 13"-140 27' 29" N and 390 51' 13"-420 23' 03" E. Based on the potential and accessibility of livestock production, three districts, Aysaita, Dubti, and Amibera districts from the Afar regional state's administrative zones 1 and 3 were specifically chosen.

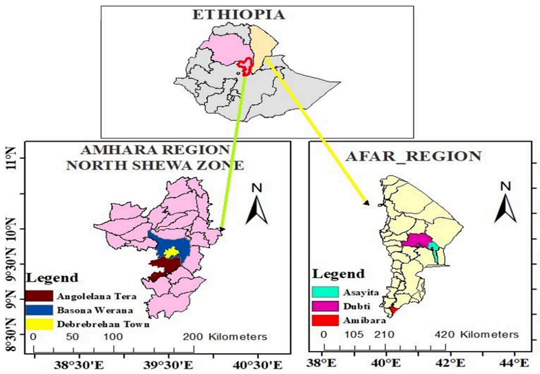

Fig. 1: Map of the study areas

The administrative structure in Ethiopia, from biggest to smallest, consists of regions, zones, districts, and Kebele. Stratified purposive sampling was employed (Gebbisa and Mulatu, 2020) in certain rural areas and districts from each regional administrative zone; this is determined by the distribution of cattle populations, the production system, accessibility, and potential. Purposive sampling was employed to identify three production systems in the study area: Mixed crop-livestock, pastoral and agro-pastoral.

Statistical Analyses

The Statistical Analysis System (SAS) JMP Pro version 18 (Kraft and Hinrichs, 2022) was used to analyze the categorical and continuous data. The data was primarily presented using least square analysis and descriptive tabular summaries and was carried out to assess statistical significance for particular comparison, as appropriate.

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An exploded logit model was used to analyze ranked data traits (i.e., the relative importance of the goal of cattle keeping and the traits that male and female cattle preferred in the breeding objectives) in order to find the significant differences across the different levels of a trait according to the approaches used by (Kebede and Usman, 2023). The GLIMMIX procedures of SAS and/or Proportional Hazards Regression (PHREG) can be used to implement the exploded logit model. In this model, a respondent i derives a certain utility U_{ij} from each item (i.e., the purpose of cattle keeping objective and trait preferences for male and female cattle) j, which is modeled as the sum of a systematic component μ_{ij} and a random component e_{ij}, that is:

$$U_{ij} = \mu_{ij} + e_{ij} \tag{1}$$

The error term e_{ij} is assumed to be independently and identically distributed with an extreme value distribution. The systematic component can be modeled as follows:

$$\mu_{ij} = \beta_j \, x_i \tag{2}$$

where, β_j is a row vector of coefficients and x_i is a column vector of explanatory variables that characterize the i^{th} respondent, each of the β_j vectors then describes how the respondent's attributes impact the log odds of selecting item j instead of the reference item. Significant mean differences were displayed by a letter display using the SAS macro % MULT (Piepho, 2012; Kebede and Usman, 2023).

Table 1: Characteristics of surveyed households in different production systems; N = number of households; MCL = Mixed-crop livestock; NV= Not valid

Characteristics	MCL		Pastoral		Agro-pastoral		Overall	
	N	%	N	%	N	%	N	%
Sex of respondents								
Female	13	14.44	4	6.15	3	12.00	20	11.11
Male	77	85.56	61	93.85	22	88.00	160	88.89
Head of households								
Female-headed	12	13.33	4	6.15	2	8.00	18	10.00
Male headed	78	86.67	61	93.85	23	92.00	162	90.00
Marital status								
Divorced	NV	NV	5	7.69	NV	NA	5	2.78
Married	78	86.67	44	67.69	24	96.00	146	81.11
Single	12	13.33	16	24.62	1	4.00	29	16.11
Educational level								
Illiterate	24	26.67	64	98.46	24	96.00	112	62.22
Literate (grade 4-6)	35	38.89	NV	NV	NV	NV	35	19.44
Read and writing	31	34.44	1	1.54	1	4.00	33	18.33
Main farming activity								
Cropping	60	66.67	NV	NV	NV	NV	60	33.33
Livestock	NV	NV	65	100.00	NV	NV	65	36.11
Both (livestock and cropping)	30	33.33	NV	NV	25	100.00	55	30.56

Results and Discussion

General Household Characteristics

The characteristics are presented as percentages in Table (1). The average age of respondents across the production systems is in Table (2). There was a significant ($p<0.04$) effect of the production system on household age structure. Family sizes were larger in pastoral and agro-pastoral households compared to those in mixed crop-livestock systems. Larger families typically require more resources for sustenance, which may drive individuals in such households to pursue multiple avenues of income generation. These findings are consistent with Gebbisa and Mulatu (2020). Additionally, family size can influence the availability of labor for tasks such as herding and farming. Agro-pastoral households had significantly ($p<.0001$) larger cropland sizes compared to those in mixed crop-livestock systems. While both production systems rely on crop and livestock farming for livelihood, the emphasis on each varies. No cropland was observed in the pastoral system, which is primarily characterized by livestock production with minimal crop cultivation. In contrast, agro-pastoralism features a balance of livestock and crop production, with a greater focus on livestock. Pastoral households, however, hold significantly larger communal grazing lands compared to the other systems. This reflects the need for extensive grazing areas to support their larger livestock herds, which are a key feature of pastoral livelihoods in the study area.

The majority of wheat, barley, beans, and oats were produced by households in the mixed crop-livestock system. In contrast, the agro-pastoral system used maize, mangoes, animal forage, date palms, lemons, cotton, and bananas (Figure 2). Notably, no crop production was observed within the pastoral community. This is due to the pastoralists' reliance solely on livestock husbandry for theirlivelihoods, as they migrate with their animals in search of grazing and water. Their food security is primarily ensured through livestock production and productivity. These findings are in line with the results reported by Regassa (2016).

Table 2: Least square means (mean ±SE) of household age (years), family size (member), land sizes for crops grown and communal grazing (ha) of the surveyed households in different production systems

Variables	MCL (N = 90)	Pastoral (N =65)	Agro-pastoral (N = 25)	Overall (N = 180)	P-value
Age (years)	47.14^{ab}±0.96	44.54^{b}±1.81	49.76^{a}±0.96	46.57±0.68	P<0.04
Family size (N)	6.24^{b}±0.16	8.71^{a}±0.19	8.48^{a}±0.96	7.44±0.15	p<.0001
Cropland size (ha)	2.79^{b}±0.13	NV	7.26^{a}±0.96	3.76±0.22	p<.0001
CG-land size (ha)	1.02^{b}±1.04	20.62^{a}±0.15	5.14^{b}±1.97	8.67±0.99	p<.0001

a,b,c Letters not connected by the same letter are significantly different at (p<0.05); N = number of households; SE=standard error; MCL = Mixed crop-livestock; CG-land size= Communal grazing land size.

Table 3: Least square means (LSM ± SE) of households holding livestock species and cattle herd structure in different production systems; a,b,c

Livestock species	MCL (N = 90)	Pastoral (N =65)	Agro-pastoral (N = 25)	Overall (N = 180)	P-value
Cattle	8.10^{a}±0.38	27.66^{b}±0.44	23.48^{c}±0.71	17.30±0.74	p<.0001
Sheep	11.91^{b}±0.73	18.40^{a}±0.87	16.08^{a}±1.39	14.80±0.56	p<.0001
Goats	3.15^{c}±1.95	27.58^{a}±1.08	18.96^{b}±1.74	21.12±1.21	p<.0001
Camel	NV	10.95^{a}±0.62	7.08^{b}±1.00	9.88±0.56	p<.0002
Donkey/Mules	2.34^{a}±0.08	1.38^{b}±0.11	1.10^{b}±1.18	1.77±0.08	p<.0001
Horses	1.57^{a}±0.07	NV	NV	1.57±0.07	p>0.05
Poultry	6.30^{a}±0.22	NV	NV	6.30±0.23	p>0.05
Cattle herd structure					
Cows	2.62^{a}±0.15	9.54^{b}±0.18	8.60^{c}±0.29	9.97±0.27	p<.0001
Heifers (post-pre calving)	1.85^{a}±0.17	5.97^{b}±0.19	3.38^{c}±0.32	3.65±0.19	p<.0001
Oxen (castrated adult male >3 years)	1.78^{b}±0.11	1.94^{ab}±0.11	2.32^{a}±0.18	1.93±0.07	p<0.03
Bulls (>3 years)	1.41^{a}±0.08	1.50^{a}±0.06	1.06^{b}±0.11	1.41±0.05	p<.0006
Immature males (<3 years)	1.26^{b}±0.15	5.18^{a}±0.14	5.80^{a}±0.23	2.62±0.19	p<.0001
Pre-weaners	1.48^{a}±0.15	2.80^{b}±0.24	1.48^{c}±0.15	2.66±0.13	p<.0001
Calves born in the last 12 months	1.51^{b}±0.13	3.14^{a}±0.16	2.78^{a}±0.23	2.26±0.11	p<.0001

a,b,c Letters not connected by the same letter are significantly different at (p<0.05); N = number of households; SE=standard error; MCL = Mixed-crop livestock; NV= Not valid

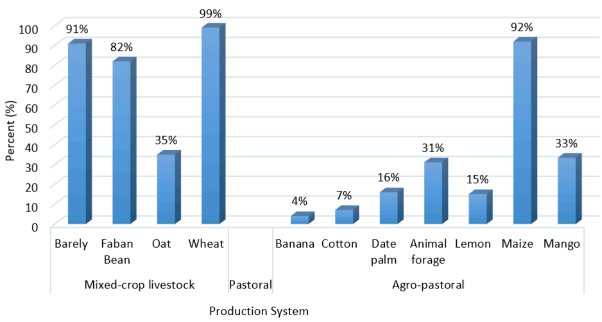

Fig. 2: List of crops grown by surveyed households in different production systems

Livestock Species and Cattle Herd Structure

The average number of livestock species and the cattle herd structures per household across different production systems are summarized in (Table 3). There were significant (p<.0001) differences between production systems in the number of cattle, sheep, goats, camels, and donkeys/mules per household. Cattle herd sizes were larger in pastoral and agro-pastoral households compared to mixed crop-livestock households. While goat flock sizes were similar across systems, the mean sheep flock size in mixed crop-livestock systems was significantly lower than in pastoral and agro-pastoral systems. Camels were present predominantly in pastoral and agro-pastoral systems, which is consistent with findings from Gebbisa and Mulatu (2020).

The smaller average livestock herd size observed in mixed crop-livestock households could be attributed to their engagement in crop farming activities, in contrast to pastoral and agro-pastoral areas where cattle are primarily used for draught power. The larger cattle herd sizes in pastoral and agro-pastoral households underscore the central role of livestock husbandry in these systems, where it forms the backbone of subsistence and is deeply intertwined with cultural and social practices. Pastoralist communities, in particular, tend to increase livestock numbers during favorable conditions to offset the losses incurred during periods of severe drought and disease outbreaks.

Purpose of Cattle Keeping Objective

The exploded logit model results of the purpose of keeping cattle in mixed-crop livestock, pastoralists, and agro-pastoralists are presented in Table (4). The analysis of the purpose of keeping cattle across three production systems—mixed-crop livestock, pastoral, and agro-pastoral—reveals distinct preferences for various attributes. The exploded logit model effectively captures these preferences, as evidenced by the significant ($p<.0001$) likelihood ratio statistics across all production systems. These results provide valuable insights into the priorities of cattle owners in different production systems.

In the mixed-crop livestock system, draft power was the most highly valued attribute, significantly surpassing other choices. This finding underscores the importance of cattle as a source of labor in mixed-farming systems, where animals are essential for plowing fields and transporting goods (Barrett & Upton, 2013). Milk production (0.53) was also a significant factor, reflecting the dual-purpose role of cattle in these systems, where both draught and dairy are critical to household livelihoods. Other attributes, such as live animal sale and meat, were less prioritized, indicating that these systems might focus more on subsistence rather than market-oriented production. The lower importance placed on dowry suggests that cultural practices, while still present, are less central in mixed-crop livestock systems compared to others. Similarly, social security and manure were not primary concerns, likely due to the availability of alternative sources of income and fertilizers.

In the pastoral system, milk production emerged as the most important attribute, reflecting the critical role of dairy products in pastoral livelihoods (Fratkin, 2021). The significant preference for calf sources highlights the importance of herd growth and sustainability, which are central to the survival of pastoral communities. Interestingly, dowry and live animal sales were more valued in this system compared to the mixed-crop livestock system, indicating the continued cultural and economic significance of cattle beyond subsistence. The relatively low value assigned to manure suggests that, unlike in agricultural systems, manure is less critical in purely pastoral contexts, where grazing land rather than cultivated fields predominates. Meat and social security were also less emphasized, further underscoring the pastoral systems' focus on milk and herd management.

Table 4: Purpose of keeping cattle in mixed-crop livestock, pastoral and agro-pastoral production systems

MCL	Likelihood Ratio Statistics							
Effect	DF		f-value			p-value		
Sample*Rank	449		8.72			<.0001		
Choice	8		48.50			<.0001		
Differences in estimates of LSM ± SE for the different choices								
CS	Dowry	Draft	LAS	Manure	Meat	Milk	MS	SS
$0.29^{d}\pm0.02$	$0.20^{e}\pm0.01$	$0.61^{a}\pm0.01$	$0.29^{d}\pm0.02$	$0.28^{d}\pm0.02$	$0.29^{d}\pm0.02$	$0.53^{b}\pm0.02$	$0.39^{c}\pm0.02$	$0.29^{d}\pm0.02$
Pastoral	Likelihood Ratio Statistics							
Effect	DF		f-value			p-value		
Sample*Rank	324		9.86			<.0001		
Choice	8		90.74			<.0001		
Differences in estimates of LSM ± SE for the different choices								
CS	Dowry	Draft	LAS	Manure	Meat	Milk	MS	SS
$0.35^{b}\pm0.02$	$0.28^{c}\pm0.02$	$0.30^{c}\pm0.02$	$0.40^{b}\pm0.02$	$0.20^{d}\pm0.02$	$0.30^{c}\pm0.02$	$1.18^{a}\pm0.03$	$0.26^{c}\pm0.02$	$0.27^{c}\pm0.02$
Agro-Pastoral	Likelihood Ratio Statistics							
Effect	DF		f-value			p-value		
Sample*Rank	124		7.77			<.0001		
Choice	8		13.80			<.0001		
Differences in estimates of LSM ± SE for the different choices								
CS	Dowry	Draft	LAS	Manure	Meat	Milk	MS	SS
$0.32^{c}\pm0.03$	$0.20^{d}\pm0.03$	0.46^{b} 0.04	$0.39^{bc}\pm0.03$	$0.20^{d}\pm0.03$	$0.23^{d}\pm0.03$	$0.58^{a}\pm0.04$	$0.44^{b}\pm0.04$	$0.33^{c}\pm0.03$

^{a,b,c,d,e}*letters not connected by the same letter within a row are significantly different (p<0.05); CS = calf source, LAS = live animal sale; MS = milk sale; SS = social security*

In agro-pastoral systems, milk production was again a primary attribute, albeit with a slightly lower estimate than in the pastoral system. This may reflect the dual focus on both agriculture and pastoralism in these systems, where cattle must fulfill multiple roles (Jun *et al.*, 2019). Draft power was the second most important attribute, aligning with the need for labor in crop production. Live animal sales were also highly valued, indicating the importance of cattle as a source of income. Calf source and dowry were less prioritized, suggesting that while herd growth and cultural practices are still relevant, they are not as critical as in purely pastoral systems. The lower emphasis on manure and meat reflects the diverse nature of agro-pastoral systems, where cattle are used for various purposes rather than solely for subsistence or market production.

The results of the exploded logit model provide a detailed understanding of the varied purposes for keeping cattle across different production systems. In mixed-crop livestock systems, draft power and milk production are paramount, while in pastoral systems, milk production and calf source are prioritized. Agro-pastoral systems exhibit a more balanced set of preferences, with milk production and draft power being the most important. These findings have significant implications for breeding programs and livestock management strategies, as they highlight the need for tailored approaches that consider the specific priorities of each production system. Future research should explore how these preferences evolve with changing environmental and economic conditions, particularly in the context of climate change and market integration.

Male Cattle Trait Preferences

The exploded logit model results of trait preferences for male cattle in mixed-crop livestock farmers, pastoralists, and agro-pastoralists are presented in (Table 5). The results of the exploded logit model to evaluate trait preferences for male cattle across three production systems revealed significant differences in trait preferences, as indicated by the highly significant ($p<0.0001$) statistics. These findings provide valuable insights into the specific attributes prioritized by farmers in different production systems, which has implications for breeding strategies and livestock management.

Table 5: Trait preferences for male cattle in mixed-crop livestock, pastoral and agro-pastoral production systems

MCL	Likelihood Ratio Statistics						
Effect		DF		f-value		p-value	
Sample*Rank		446		5.81		<.0001	
Choice		7		24.04		<.0001	
Differences in estimates of LSM ± SE for the different choices							
BS	CC	DR	DT	Fertility	HS	Temperament	TA
$0.40^{b}\pm0.02$	$0.34^{cd}\pm0.01$	$0.33^{de}\pm0.02$	$0.23^{f}\pm0.02$	$0.39^{bc}\pm0.02$	$0.29^{e}\pm0.02$	$0.25^{f}\pm0.02$	$0.54^{a}\pm0.02$
Pastoral	Likelihood Ratio Statistics						
Effect		DF		f-value		p-value	
Sample*Rank		322		4.46		<.0001	
Choice		7		43.70		<.0001	
Differences in estimates of LSM ± SE for the different choices							
BS	CC	DR	DT	Fertility	HS	Temperament	TA
$0.55^{b}\pm0.03$	$0.84^{a}\pm0.04$	$0.27^{e}\pm0.02$	$0.47^{c}\pm0.03$	$0.39^{d}\pm0.02$	$0.25^{e}\pm0.02$	$0.27^{e}\pm0.02$	$0.37^{d}\pm0.02$
Agro-pastoral	Likelihood Ratio Statistics						
Effect		DF		f-value		p-value	
Sample*Rank		124		4.99		<.0001	
Choice		7		25.72		<.0001	
Differences in estimates of LSM ± SE for the different choices							
BS	CC	DR	DT	Fertility	HS	Temperament	TA
$0.65^{b}\pm0.05$	$0.59^{b}\pm0.05$	$0.23^{d}\pm0.03$	$0.35^{c}\pm0.04$	$0.43^{c}\pm0.04$	$0.25^{d}\pm0.03$	$0.23^{d}\pm0.03$	$0.85^{a}\pm0.06$

^{a,b,c,d,e,f}*letters not connected by the same letter within a row are significantly different (p<0.05); BS = body size, CC = coat color, DR = disease resistance, DT = disease tolerant, HS = hump size and TA = traction ability*

In the mixed-crop livestock system, traction ability emerged as the most important trait. This preference underscores the critical role of male cattle in providing labor for agricultural activities, particularly in systems where mechanization is limited (Starkey, 2010). The significance of body size and fertility further highlights the dual-purpose role of cattle in these systems, where they contribute to both labor and reproduction. Coat color and disease resistance were moderately important, suggesting that while these traits are valued, they are secondary to functional attributes such as traction and fertility. Disease tolerance and temperament were less emphasized, indicating that these traits may be less critical in mixed-crop livestock systems, possibly due to the lower disease pressures or the use of other management practices to mitigate these risks.

In pastoral systems, coat color was the most highly valued trait, significantly exceeding other attributes. This finding reflects the cultural and social importance of coat color in pastoral communities, where certain colors may be associated with specific cultural beliefs or market preferences (Fratkin, 2021). Body size remained a critical trait, reflecting the importance of larger animals for social status and economic transactions, such as dowries and sales. Traction ability and disease tolerance were also important but to a lesser extent, highlighting the need for animals that can endure the harsh environmental conditions typical of pastoral areas. Fertility and disease resistance were less prioritized, indicating that while these traits are important, they may be considered secondary to physical characteristics like coat color and body size.

The agro-pastoral system exhibited a somewhat balanced set of trait preferences, with traction ability again emerging as the most critical trait. This high value reflects the dual reliance on cattle for both agricultural labor and mobility, which is characteristic of agro-pastoral systems (Jun *et al.*, 2019). Body size and coat color were also significantly valued, indicating a preference for larger, well-appearing animals that are likely seen as symbols of wealth and productivity. Fertility and disease tolerance were moderately important, which suggests that while these traits contribute to the overall utility of cattle, they are balanced against other considerations such as traction and body size. Disease resistance and temperament were less emphasized, similar to the other systems, indicating that these traits are not the primary focus in agro-pastoral contexts. The results of this study provide a nuanced understanding of trait preferences for male cattle across different production systems in question. Traction ability and body size were consistently important across all systems, with variations in the importance of other traits, such as coat color and fertility, depending on the specific context. These findings have significant implications for cattle breeding programs, which should consider the unique priorities of farmers in different production systems to enhance the effectiveness of livestock management and breeding to improve productivity.

Female Cattle Trait Preferences

The exploded logit model results of trait preferences for male and female cattle in mixed-crop livestock farmers, pastoralists, and agro-pastoralists are presented in (Table 6). The likelihood ratio statistics indicated that the model was highly significant ($p<.0001$) across all production systems, demonstrating distinct preferences for specific traits in female cattle. The variation in trait preferences across these systems offers valuable insights for targeted breeding programs and livestock management strategies.

In the mixed-crop livestock system, milk yield was identified as the most important trait. This preference underscores the crucial role of milk production in mixed-crop livestock systems, where dairy products are a key source of income and nutrition (Thornton, 2020). Body size was highly valued, reflecting the dual emphasis on productive efficiency in these systems. Calving interval, coat color, and disease resistance exhibited similar levels of importance. The preference for these traits highlights the need for cattle that are both visually appealing and resistant to diseases while also producing milk of desirable quality (Haile *et al.,* 2009). In contrast, butterfat, mothering ability, teat, and udder size, as well as temperament, were less emphasized. This suggests that while these traits are recognized, they are secondary to milk production and overall body size in mixed-crop livestock systems.

In pastoral systems, milk yield remained the most highly valued trait. This result aligns with the central role of dairy production in pastoral livelihoods, where milk serves as a primary food source and a significant economic asset (Roth & Fratkin, 2005). Coat color was the next most important trait (0.44), reflecting the cultural significance and market preferences associated with specific coat colors in pastoral communities. Body size, disease tolerance, and temperament were moderately important, indicating a balance between the need for cattle that are both physically robust and capable of withstanding harsh environmental conditions. Butterfat and calving interval were less emphasized, suggesting that while these traits contribute to overall productivity, they are not the primary focus in pastoral systems. The relatively lower importance of mothering ability and teat and udder size further underscores the prioritization of traits that directly influence milk production and market value in these systems.

In agro-pastoral systems, milk yield was again the most critical trait, significantly higher than in the other systems. This finding highlights the importance of dairy production in agro-pastoral economies, where milk is a key source of income and nutrition, particularly during the dry season when crop production is limited (Jun *et al.*, 2019). Coat color and body size were also highly valued, indicating a preference for cattle that are both productive and culturally valued. Disease tolerance and calving interval were moderately important, suggesting that these traits are critical for maintaining a sustainable breeding program in agro-pastoral contexts. The lower emphasis on butter fat, mothering ability, teat, and udder size, and temperament reflects a more balanced approach, where the primary focus is on maximizing milk production and ensuring the resilience of cattle in challenging environments. The results of this study reveal distinct preferences for traits in female cattle across different production systems, with milk yield consistently emerging as the most critical trait across all systems. However, the importance of other traits, such as coat color, body size, and disease tolerance, varied depending on the production system, reflecting the unique environmental, economic, and cultural factors that influence cattle management practices. These findings have significant implications for breeding programs, suggesting the need for tailored approaches that consider the specific priorities of farmers in different contexts.

Table 6: Trait preferences for female cattle in mixed-crop livestock, pastoral and agro-pastoral production systems

MCL	Likelihood Ratio Statistics								
Effect	DF			f-value			p-value		
Sample*Rank	449			11.81			<.0001		
Choice	9			63.49			<.0001		
Differences in estimates of LSM ± SE for the different choices									
BS	BF	CI	CC	DR	DT	MY	MA	TUS	Temperament
$0.49^{b}\pm0.02$	$0.26^{d}\pm0.01$	$0.32^{c}\pm0.01$	$0.32^{c}\pm0.02$	$0.32^{c}\pm0.02$	$0.20^{e}\pm0.01$	$0.73^{a}\pm0.02$	$0.25^{d}\pm0.01$	$0.25^{d}\pm0.01$	$0.23^{de}\pm0.01$
Pastoral	Likelihood Ratio Statistics								
Effect	DF			f-value			p-value		
Sample*Rank	324			11.24			<.0001		
Choice	9			33.14			<.0001		
Differences in estimates of LSM ± SE for the different choices									
BS	BF	CI	CC	DR	DT	MY	MA	TUS	Temperament
$0.30^{cd}\pm0.02$	$0.29^{ce}\pm0.02$	$0.27^{ce}\pm0.02$	$0.44^{b}\pm0.02$	$0.25^{c}\pm0.02$	$0.31^{c}\pm0.02$	$0.67^{a}\pm0.03$	$0.20^{f}\pm0.02$	$0.24^{ef}\pm0.01$	$0.30^{cd}\pm0.02$
Agro-Pastoral	Likelihood Ratio Statistics								
Effect	DF			f-value			p-value		
Sample*Rank	124			12.69			<.0001		
Choice	9			35.24			<.0001		
Differences in estimates of LSM ± SE for the different choices									
BS	BF	CI	CC	DR	DT	MY	MA	TUS	Temperament
$0.41^{bc}\pm0.03$	$0.21^{e}\pm0.02$	$0.27^{de}\pm0.03$	$0.48^{b}\pm0.03$	$0.27^{de}\pm0.03$	$0.33^{cd}\pm0.03$	$1.07^{a}\pm0.05$	$0.20^{e}\pm0.04$	$0.25^{e}\pm0.02$	$0.22^{e}\pm0.02$

^{a,b,c,d,e,f}letters not connected by the same letter within a row are significantly different (p<0.05). BS = body size, BF = butter fat, CI = calving interval, CC = coat color, DR = disease-resistance, DT = disease tolerance, MY = milk yield, MA = mothering ability and TUS = teat & udder size

Conclusion

Breeding decisions of smallholder farmers, pastoralists, and agro-pastoralists of cattle producers in mixed-crop livestock, pastoral, and agro-pastoral production systems adhere to the various goals of the cattle producers. These factors include the purpose of keeping cattle and the methods used to choose male and female cattle in their production environments. In order to develop livestock policies that can enhance the lives of smallholder farmers, pastoralists, and agro-pastoralists and satisfy the demands of customers who utilize livestock products, it is essential to comprehend these breeding decisions. Consequently, the community's breeding goals and customs should be taken into account in any breed development plans that are meant to be used in the study area and elsewhere. The use of the exploded logit model provided a clear distinction and unambiguously identified farmers' choices in the selection of attributes. There were major variances between them, as seen by the strong indications supporting the utility value discrepancies. According to the current study, there is variation among smallholder farmers, pastoralists, and agro-pastoralists in trait preferences across production systems. Therefore, when designing breeding programs in the tropics, the use of farmers' livestock-keeping objectives and trait preferences as identified by the exploded logit model is critically important for deciding on relevant breeding goal traits.

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Author's Contributions

All authors are equally contributed to this research study.

Ethics

This study is original and includes unreleased content. The corresponding author confirms that all of the other authors have reviewed and approved the article and there are no ethical concerns are involved. Furthermore, the authors declare that there are no conflicts of interest related to this research, ensuring transparency and integrity in the findings presented. This commitment to ethical standards reinforces the credibility of the study and its contributions to the field.

Conflict of Interest

The authors declare no competing interest.

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