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Description of cattle production systems in different agro-ecological zones of Narok County, Kenya

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Abstract

Cattle farming is an integral part of the livelihoods of farmers in Narok County. However, very few studies have been conducted to describe livestock production in different agroecosystems in Kenya. The objective of this study was to determine cattle production systems and characteristics under different agro-ecosystems. The study was conducted through the administration of semi-structured questionnaires to 817 farmers in three sublocations from Narok south sub-county. The main livestock production systems were pure pastoral, communal grazing and zero-grazing where indigenous cattle were the predominant breed kept (86.8%) with a few farmers keeping crossbreeds or exotic breeds. However, sheep (75.1%) goats (79.4%), chicken (68.6%) and donkeys (32.9%) were also kept. The mean lactation period for cattle was 9.5 months with average inter-calving interval of 14.1 months. More households (45.1%) grazed cattle within their own pastureland compared to pure pastoralism (12.5%), communal grazing (8.0%), zero grazing (0.9%), or combination (33.5%). Approximately 37.1% of the respondents herded their cattle, 13.1% were on free grazing, 36.6% both free grazing and herding whereas 13.2% used paddocks. The mean land area under pasture was estimated at 53.9 acres. The main source of drinking water was within the grazing field (63.6%) with 36.4% having had to take livestock elsewhere. Most households (85.7%) practicing mixed farming could easily access veterinary services compared to 57.2% and 55.1% in agro-pastoral and pure pastoral system respectively ($p<0.0001$). The main veterinary interventions were deworming, vaccination, and antibiotic administration. Most households (98.6%) had sprayed their livestock with 98.9% sourcing the products from agrovet outlets. More respondents (63.8%) in agro-pastoral compared to 61.5% and 49.7% from pastoral and mixed farming respectively were aware of East Coast Fever disease ($p<0.0001$). Cattle were principally fed on natural pasture either produced from owned or leased lands with farmers getting unequal access to veterinary services.

Keywords: *Cattle, Production system, Agro-ecosystem, Narok County, Kenya*

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Introduction

The livestock sector contributes an estimated 12% of Kenya's Gross Domestic Product (GDP) and 42% of the agricultural GDP and employs approximately half of the agricultural labor (Behnke & Muthami, 2011). The sector is a source of livelihood to a large proportion of rural

households and therefore it has a significant role to play in poverty reduction strategies for the rural populations (Jumba *et al.,* 2020). The urban population rely directly or indirectly on this sector through the sale of food animals or their products, or employment in livestock-related agro processing industries (Mugumaarhahama *et al.,* 2021). Among the different species of livestock kept in Kenya, cattle are the most economically important species in contributions to GDP and food security (Njarui *et al.*, 2016). They are kept as an important source of livelihood in many farming households whilst also having cultural and social value (Mugumaarhahama *et al.,* 2021). Cattle are raised either under intensive or semi-intensive systems within the highlands with high population densities mainly under highly intensive production systems (Njarui *et al.*, 2016). In other parts of Kenya, they are kept under semi-zero grazing or free-range systems (Njarui *et al*., 2016). Milk and meat are the two leading products from cattle that contribute immensely to the total gross value of livestock to the agricultural sector (Ikaal *et al*., 2020). Cattle are the main source of meat consumed in Kenya with over 80% of the red meat marketed which is reported to contribute about Ksh. 295 billion total capital value of pastoral livestock (Behnke and Muthami, 2011). More than 80% of the beef consumed in Kenya is produced by pastoralists, either domestically or from neighbouring countries (Behnke and Muthami, 2011). These cattle are kept in a free range grazing system where different herds move and interact freely at the grazing and watering points.

Veterinary or animal health services from both public and private sectors provide animal health and welfare interventions in Kenya to ensure the effectiveness of the veterinary service delivery system under the control of the veterinary authority (OIE, 2019). Effective, efficient, transparent, and credible animal health services are necessary to enhance the production and productivity of the livestock sector (OIE, 2019). Similarly, accessible, available and affordable essential veterinary services are important to mitigate animal disease risks, ensuring sustainable economic development of vulnerable producers, and limiting the public health risks posed by zoonotic diseases (OIE, 2019). Effective veterinary services also provide confidence for private sector investment from both individual farmers and livestock enterprises across the livestock value chains (Gizaw *et al.,* 2021).

Despite the immense contribution of the cattle to the Kenyan economy, production faces a number of challenges ranging from poor animal husbandry practices, inadequate quality and quantity of feed, high cost of production, climate change, low adoption of technologies, low milk value addition and animal diseases especially the tick-borne diseases like East Coast fever (Gachohi *et al*., 2012; Jumba *et al.,* 2020). Most pastoralists rely almost entirely on cattle for livelihood and this disease is no doubt an economic challenge retarding the development and improvement of livestock production in affected areas (Allan *et al*., 2021). Malnutrition has been reported as the major health issues in the marginalised communities which has been linked to limited dietary diversity, seasonal variability, and cultural practices especially in pastoral set up (KDHS, 2022). The goal of the longitudinal phase of this project is to assess the impact of ECF on nutritional status of vulnerable members of the pastoral communities.

Description and characterisation of livestock production systems have been done elsewhere in Kenya; central region (Gitau *et al*., 1994), Coastal region (Maloo *et al*., 1993), Western region (Thumbi *et al*., 2014), and Kajiado (Bekure *et al*., 1991) but there is scarce information on the characteristics of production systems in different agro-ecological zones in Narok County. This study was therefore designed to describe livestock production such as animal ownership, management practices, productivity, breeding, access to essential veterinary services, and knowledge on East Coast Fever (ECF) disease in Narok South sub-county. The generated preliminary description of cattle production in different agroecosystems will serve as a basis for design and implementation of a longitudinal study to estimate the incidence of ECF and *Theileria parva* infection, morbidity and mortality and the associated risk factors in cattle.

Materials and methods

Study area

The study was carried out in Ololulung'a and Naroosura Maji Moto Wards of Narok South subcounty, Narok County, Kenya (Figure 1). Narok lies between 1500-2000 meters above sea level and has two rainy seasons with an average rainfall range of 500 to 1,800 mm per annum and temperatures of 12^{0}C to 28^{0}C. The human population of Narok South was estimated at 238,500 persons with the livestock population estimated at 701,900 cattle, 324,300 goats, and 599,900 sheep (KNBS, 2019). Administratively, Narok South sub-County has six wards: Naroosura Maji Moto, Ololulung'a, Melelo, Loita, Sogoo, and Sagamian. The main economic activities practiced by residents in the study area include livestock keeping, crop farming, beekeeping, and trade.

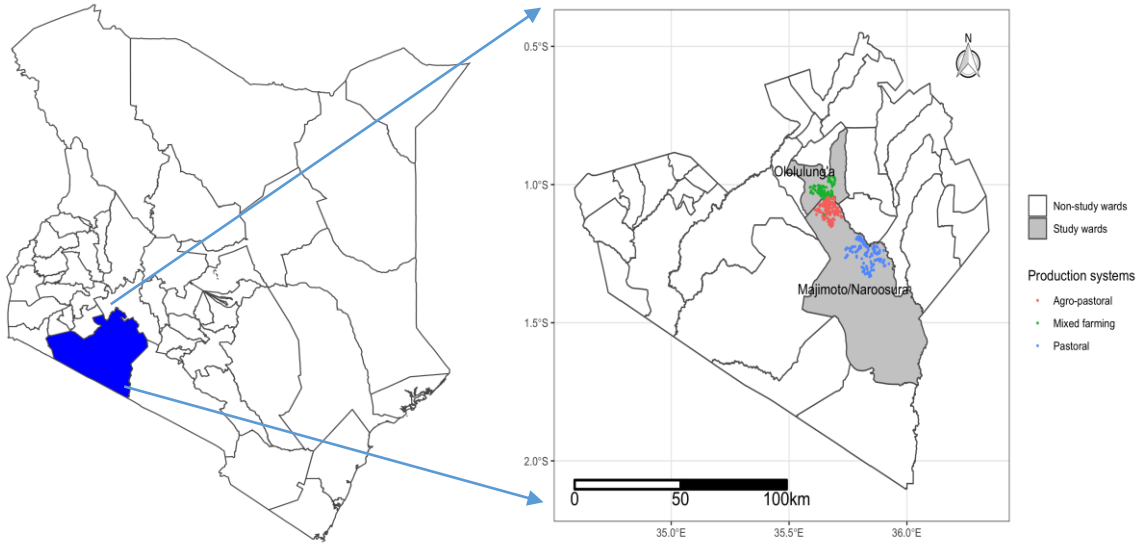

Figure 1

Map of Narok County showing the study wards with different production systems. The green represents the villages in the mixed production system, the red represents villages in Agro-pastoral system and blue represents the villages in the pastoral production system. The map was generated from the GPS coordinates captured during data collection process.

Sample size determination

The sample size was based on the formular for calculating sample size for longitudinal cluster randomized design for comparison of means in a two -arm trial with equal cluster sizes (Rutterford *et al.*, 2015). A design effect was used to account for randomization. An α of significant level was set at 95% CI = 0.05 and a β powered at 80% and delta Δ- mean difference between intervention and control groups hypothesized to be = 0.25 points and an intra-cluster correlation coefficient (ICC) *p* = a low ICC of 0.02 were assumed in the study county and variance of primary outcome measure, σ^2 = sigma = 1 and n = 50 households with a child less than two years per village. The sample size calculation was implemented in R statistical software using package "cluster Power" and function cluster with the above assumptions, a total of 12 villages were required with each village having an estimated 50 households meeting inclusion criterion and this would give a minimum of 600 households recruited to participate in the study.

Selection of Wards, sublocations and households

The study areas were selected based on the high levels of human malnutrition rates, reported high ECF prevalence and the different livestock production systems (Gachohi *et al.*, 2012; Njarui *et al.*, 2016). Two Wards were identified for this study, three sublocations were randomly selected that represented three different cattle production systems. Initially, all the sublocations in the two

wards were mapped and grouped into different production systems, the sublocations and villages were then randomly selected. The sublocations included Olenkuluo (pure pastoral), Olkiriaine (agro-pastoral) and Ololulung'a (mixed farming). Households in pastoral settings get more than 70% of household income directly from livestock kept on natural pasture depending heavily on livestock products (Njarui *et al.*, 2016; Steinfeld & Mäki-Hokkonen, 1995). Similarly, the setup is characterized by human and animal migration in search of sufficient pasture and water. On the other hand, agropastoral settings are households that practised both crop cultivation and livestock keeping and get more than 50% of the gross revenue from crop cultivation. Mixed cattle production systems practiced both crop cultivation and livestock keeping mainly in private lands. The households get more than 70% of their income from crop farming and there is neither human nor animal migration (Njarui *et al.*, 2016; Steinfeld & Mäki-Hokkonen, 1995). Three villages were randomly selected from Ololulung'a, four villages from Olkiriaine and five villages from Olenkuluo given that some had higher human/household density than others.

From the selected villages, households that met the inclusion criteria and consented to participate in the study were recruited. For a household to qualify to be recruited, it needed to have a Mother-child pair (child under 49 months), Dam-calf pair (calf under one month), presence of an adult person (18 years and above) and agreed to participate in the study. For the participating households, a consent form was given/read out to them detailing all the information required, respondents given opportunity to ask questions and time to make informed decision. For the ones that agreed, they were asked to sign and date two copies of the consent form and the enumerator also signed and dated the two forms. One form was given to the respondent and the other retained by the enumerator.

Data collection

The data collection was carried out between July and October 2022. Seven trained data collection research assistants were used for data collection. A semi-structured questionnaire was developed, digitalized, and uploaded onto CommCare software; a public utility data collection tool application compatible with Android cell phones. A pilot study was conducted prior to the start of the data collection. A field pre-test of the tool was conducted in a border village to Narosura-Maji Moto ward. The participants in the pilot study were recruited randomly. The data collection tools were tested on the 16 randomly selected households to check whether the respondents could understand the questions, appropriateness of different options provided, and the time taken to administer the questionnaires. The questionnaires were revised where applicable to produce the final version of the study.

Questionnaires were administered to household heads via Computer-Assisted Personal Interviews (CAPI), a face-to-face data collection method in which the interviewer used a tablet or mobile phone to record answers given during the interview. The tool was used to capture information on the respondents' demographics, livestock species in the farm, herd structure, breeds of cattle kept, breeding method, feeding and feed resources, source of drinking water, milk production, lactation period, inter-calving interval and access to essential veterinary services. Other data included reported ECF occurrence, clinical signs recognised by the owners, tick control methods used and frequency of application. The responses were based on the farmer's recall within the last one year. The data were electronically recorded and submitted to a central server. Daily data quality checks were done, and feedback provided to the field team immediately and additional regular checks were carried out to ensure uniformity and that good quality data were collected.

Data analysis

Data were extracted from the main server and screened for errors and transferred to R statistical software (version R version 4.1.2, x86_64-apple-darwin17.0 (64-bit)). Descriptive analyses were used to determine the means, minimum, maximum for the continuous variables, and proportions and percentages for the categorical variables. A statistical (generalized linear model) comparison in different production systems was made to check for association for both continuous

and categorical variables using Odd ratios at 95% confidence interval ($p<0.05$).

Results

Household demographics

A total of 717 households participated in this study. The following were the summary demographics: About 28.3% from mixed farming, 38.8% from agro-pastoral and 32.9% from pastoral agroecosystems. A greater percentage (93.0%) of the household heads were married, 6.6% either single or widowed and less than one percent either divorced or separated. About 92.5% of the household heads were males while the other 7.5% were females. Slightly more than half (51.6%) of the household heads did not have formal education and only about 7.0% had attained university/tertiary level of education while the rest had education levels between the two. Regarding the primary occupation of the household heads, 44.2% practised mixed farming, 32.4% were pure pastoralists and only (23.4%) had additional occupation such as businesses or other forms of employment. Slightly more than half (51.7%) of the household heads were owners of the land where they had settled while the rest had other forms of land ownership such as extended family (clan), communal or leased lands. The mean household number was 7 with a minimum of two and maximum of 18 with each household owning an average of 22.4 acres of land (Table 1).

Table 1

Demographic characteristics of the respondents from Narok County from July-October 2022

Variable	**Category**	**Frequency (n=717)**	Percentage (%)
Categorical variables			
Marital status	Married	667	93.1
	Divorced	1	0.1
	Separated	1	0.1
	Single	12	1.7
	Widowed	36	5.0
Highest level of education	Informal	370	51.6
	Pre-school	1	0.1
	Primary	65	9.1
	Primary not completed	93	13.0
	Secondary	91	12.7
	Secondary not completed	32	4.5
	Technical/vocational	5	0.7
	Tertiary	50	7.0
	Tertiary not completed	10	1.4
Primary occupation	Pastoralist/ livestock only	232	32.4
	Mixed farmer	317	44.2
	Businessperson	84	11.7
	Employed full time	42	5.9
	Employed part time	16	2.2
	Other	26	3.6
Land ownership	Own land	371	51.7
	Do not own land	346	48.3
Continuous variables			
	Mean	Median	Range

Variable	Category	Frequency (n=717)	Percentage (%)
Age of household heads (years)	39.5	37	19-97
Number of family members	6.8	7	2-18
Farm size (acres)	22.4	4	1-83
No. of years keeping livestock	14.6	13	1-80

Table 2

Percentage of households owning different breeds of cattle and other animal species in Narok from July-October 2022.

Variable	Agroecosystem						
	Mixed farming (n=203)		Agro-pastoral (n=278)		Pastoral (n=236)		Total (%)
Categorical variables							
	Number	%	Number	%	Number	%	
Exotic cattle	0	0	0	0	0	0	0 (0)
Crossbreed cattle	12	5.9	6	2.2	0	0	18 (2.5)
Indigenous cattle	147	72.4	247	88.9	228	96.6	622 (86.8)
Exotic+ crossbreed cattle	2	1.0	1	0.4	0	0	3 (0.4)
Exotic+ indigenous cattle	2	1.0	2	0.7	0	0	4 (0.6)
Crossbreed+ indigenous cattle	40	19.7	18	6.5	7	2.97	65 (9.1)
All cattle breeds	0	0	4	1.4	1	0.42	5 (0.7)
Sheep	113	55.7	227	81.7	205	86.9	538 (75.0)
Goats	117	57.6	229	82.4	225	95.3	569 (79.4)
Chicken	116	57.1	192	69.1	184	78.0	492 (68.6)
Donkey	28	13.8	134	48.2	74	31.4	236 (32.9)
Continuous variables							
	Mean		Median		Range		
Exotic cattle	18.9		8		1-106		
Cross breeds cattle	11.9		5		1-100		
Indigenous cattle	19.4		10		6-264		

Breeds of cattle kept by households

The indigenous breed of cattle was the most predominant breed kept by households at 86.8% while the rest kept exotic breeds or crossbreeds with exotic breeds. Crossbreeds with exotics were considered as exotic breeds whereas crosses with indigenous breeds were considered as indigenous. The common indigenous breeds

were Zebu, Boran and Sahiwal breeds whereas Friesian, Ayrshire and Guernsey were the exotic breeds kept by some farmers. In addition to cattle, the households also kept other livestock on their farm which included sheep, goats, donkeys and chicken. About 79.4% of the households kept goats, while 75.1% kept sheep followed by chicken (68.6%) and donkeys (32.9%) (Table 2). Milk, meat and disposable income were reported as the main uses of sheep and goats whereas donkeys were mainly used for draught power.

Feeding, housing and watering of cattle

The results showed that more households (45.1%) grazed cattle within their own pastureland or leased land compared to those who move animals elsewhere in search of pasture and water (12.5%) and/or communal grazing (8.0%). There was a statistical difference in grazing method amongst the different agroecosystems where agropastoral system (p=0.005) and mixed farming (p=0.001), were 2 and 2.6 times respectively more likely to practice private grazing in reference to the pure pastoral system. The farmers in mixed farming and agropastoral systems were 2.6 and 2 times respectively more likely to graze their herds in their own private lands compared to those in pure pastoral system. Approximately 37.1% of the respondents took their herds to pasture and herded them whereas 13.1% freely allowed the animals to roam the fields without a herder. The mean land under pasture was estimated at 53.9 acres with a median of 42 and a range of 1 to 200 acres. Most farmers (92.2%) would milk the lactating herd in the morning and allow the calves to interact with the herd and separate them in the evening with 63.4% of the respondents grazing both small and large ruminants together. About 65.8% of the households reported that their herds interacted with other herds/livestock during grazing or at watering points during the dry season. A higher percentage (80.2%) of the farmers used untreated wood and plain/barbed wire to make the *boma* (animal confinement at night) with only 1.5% using thatch.

Farmers reported the use of different sources of feed for their livestock with more than two-thirds (71.9%) sourcing the feed/pastures from the neighbourhood either as communal or leased lands. For those who had to purchase livestock feeds, the estimated mean cost per month was Ksh 11,134.00 with a median of Kshs 7,000.00 and range of Ksh 300.00 – Ks 100,000.00 depending on the herd size and the type of feed purchased.

The main sources of drinking water for cattle and other livestock were river/stream or dam for more than half (54.0%) of the households with 36.4% having had to take their herds for 1-2 kilometres to watering points (Table 3). The source of water was statistically different across the three agroecosystems with agropastoral system ($p<0.0001$, OR=2.0) and mixed farming ($p<0.0001$, OR=2.6) having their animals drink water from the dams within grazing area compared to the pure pastoral system that relied mainly on streams/river or communal watering points. The distance to water point was statistically significant across the three ecosystems where mixed farming ($p<0.0001$, OR=0.5) and agropastoral (p=0.001, OR=0.4) had water points closer to the grazing area compared to pure pastoral system.

Livestock productivity and breeding

Most of the households from the mixed farming (96.1%), agro-pastoral (94.6%) and pastoral systems (82.6%) had at least one lactating cow mainly the indigenous breeds. On the other hand, 38.1% and 17.0% of the households had lactating goats and sheep respectively. Cattle were the main source of milk consumed in the households and also sold. From this study, the estimated average milk yield for exotic breeds was 2.9 liter/cow/day, cross breed at 2.1 liter/cow/day and indigenous at 1.3 liter/cow/day. For animal breeding methods, most of the households (62.1%) in mixed farming compared to 52.9% in agro-pastoral and 52.1% in pastoral system had their own breeding bull in the farm. However, more households in pastoral (47.9%) and agro-pastoral (47.1%) compared to 37.9% in mixed farming system used a shared bull. However, there was no statistical difference in the breeding methods across the three agroecosystems ($p > 0.05$). The mean lactation period for most cows was 9.5 months with the median of 9 and a range of 7 to 24 months. The average inter-calving interval for most cows was 14.1 months with a median of 12 and a range of 11 to 36 months (Table 4). There was no statistical difference in the

average lactation and inter-calving periods across the three agroecosystems ($p > 0.05$).

Table 3

Descriptive statistics for cattle feeding, housing and watering variables in Narok County from July-October 2022.

Variable	Category	Number of households (n=590)	Percentage (%)
Categorical variables			
Grazing system	Private grazing	266	45.1
	Pastoralism	74	12.5
	Communal grazing	47	8.0
	Zero grazing	5	0.9
	Combination	198	33.5
Grazing/feeding	Herding	219	37.1
	Free grazing	77	13.1
	Paddocking	74	12.5
	Yard feeding	4	0.7
	Herding and free grazing	216	36.6
Calves grazing with adult animals	Yes	544	92.2
	No	46	7.8
Animal house material	Untreated wood only	60	10.2
	Untreated wood and wire	473	80.2
	Treated wood and wire	33	5.6
	Iron sheets	15	2.5
	Thatch	9	1.5
Source of animal feed	Grown within the farm	222	37.6
	From neighbourhood	424	71.9
	Purchased	181	30.7
	Other sources	13	2.2
Interspecies grazing	Yes	374	63.4
	No	216	36.6
Inter-herd grazing	Yes	388	65.8
	No	202	34.2
Source of drinking water	Pasture/grazing area	267	45.3
	River/stream/elsewhere	319	54.0
	Housing area	4	0.7

Variable	Category	Number of households (n=590)	Percentage (%)
Continuous variable			
Distance to the water point	<0.5 Km	70	11.9
	0.5-1 Km	169	28.7
	1-2Km	215	36.4
	2-3Km	102	17.3
	>3Km	34	5.8

Table 4

Number (percentage) of households with lactating animals in Narok County from July-October 2022

Lactating animal breed/species	Agroecosystem Mixed farming (n=203)	Agro-pastoral (n=278)	Pastoral (n=236)	Total (%)
Categorical variables				
	Frequency (%)	Frequency (%)	Frequency (%)	
Grade/exotic cattle	4 (2.0)	3 (1.1)	0 (0)	7 (1.0)
Crossbreed cattle (Exotic & indigenous)	41 (20.2)	18 (6.5)	5 (2.1)	64 (8.9)
Indigenous cattle	170 (83.7)	241 (86.7)	89 (37.7)	500 (69.7)
Sheep	17 (8.4)	39 (14.0)	66 (28.0)	122 (17.0)
Goat	37 (18.2)	81 (29.1)	156 (66.1)	274 (38.2)
Continuous variables				
		Mean	Median	Range
Exotic cattle	Lactating animals per farm	3.5	2.5	1-8
	Milk production/farm/day	10.3	5.5	5-24
Crossbreed cattle	Lactating animals per farm	4.7	2	1-40
	Milk production/farm/day	9.7	5	1-80
Indigenous cattle	Lactating animals per farm	3.4	2	1-40
	Milk production/farm/day	4.5	3	0.33-53
Lactating cattle	Inter-calving interval (months)	14.1	12	11-36
Lactating cattle	Lactation period (months)	9.5	9	7-24
Sheep	Lactating sheep per farm	4.8	4	1-60

Lactating animal breed/species	Agroecosystem Mixed farming (n=203)	Agro-pastoral (n=278)	Pastoral (n=236)	Total (%)
Goat	Lactating goats per farm	4.4	3	1-40

Access to essential veterinary services

Most households (85.7%) in mixed farming system could access veterinary services (office, agrovet, animal health assistant, veterinarian) within five kilometres whereas 57.2% in agro-pastoral system had the nearest veterinary service provider between 5-10 kms distance. However, more than half (55.1%) of the households in the pure pastoral set up had to travel for more than 10 kilometres to reach to the nearest service provider. The distance to the nearest veterinary service provider was statistically significant across all the three agroecosystems: pure pastoral ($p<0.0001$, OR= 28.5), agro-pastoral ($p<0.0001$, OR= 0.2) and mixed farming ($p<0.0001$, OR=0.006) systems. The farmers in the pastoral system were 28.5 times more likely to travel far to get veterinary services compared to those in the mixed farming system. The reasons given for seeking veterinary services (either from public or private entities) were for clinical/sick animals and disease prevention measures (mainly vaccination). Most households in the three production systems had received at least one veterinary intervention within the last one month from the date of interview with agro-pastoral recording the highest at 69.1% followed by pastoral at 61.9% and mixed farming at 53.2%. The veterinary intervention in pure pastoral system ($p= 0.0003$, OR=1.7) was statistically different compared to agro-pastoral ($p= 0.09$, OR=1.4) and mixed farming ($p= 0.07$, OR=0.7) systems. The main veterinary interventions were deworming, vaccination, antibiotic administration either separately or in combination (Table 5).

Table 5

Reasons for seeking veterinary services and interventions provided within the last one month in Narok County from July-October 2022.

Seeking vet services	**Agroecosystem Mixed farming Frequency (%)**	**Agro-pastoral Frequency (%)**	Pastoral Frequency (%)
Regularly	18 (8.9)	5 (1.8)	13 (5.5)
For clinical cases	62 (30.5)	50 (18.0)	35 (14.8)
Vaccination	21 (10.3)	38 (13.7)	45 (19.1)
Regularly and clinical cases	26 (12.8)	40 (14.4)	12 (5.1)
Regularly and vaccination	4 (2.0)	2 (0.7)	4 (1.7)
Clinical cases and vaccination	60 (29.6)	109 (39.2)	86 (36.4)
Regularly, clinical and vaccination	11 (5.4)	28 (10.1)	17 (7.2)
Never	1 (0.5)	6 (2.1)	24 (10.2)
Total	203 (100)	278 (100)	236 (100)
	Veterinary interventions received		
Deworming	27 (25.0)	39 (20.3)	36 (24.7)
Vaccinations	15 (13.9)	30 (15.6)	22 (15.0)
Antibiotics	30 (27.8)	54 (28.1)	18 (12.3)
Deworming and vaccination	9 (8.3)	10 (5.2)	16 (11.0)
Deworming and antibiotics	15 (13.9)	33 (17.2)	33 (22.6)
Vaccination and antibiotics	2 (1.9)	7 (3.7)	0 (0)

Seeking vet services	Mixed farming Frequency (%)	Agroecosystem Agro-pastoral Frequency (%)	Pastoral Frequency (%)
Deworming + vaccination + antibiotics	5 (4.6)	15 (7.8)	20 (13.7)
Other interventions	5 (4.6)	4 (2.1)	1 (0.7)
Total	108 (100)	192 (100)	146 (100)

Regarding the animal species that received veterinary intervention, more households reported to have dewormed their cattle in mixed farming (16.6%) and agro-pastoral (11.2%) compared to pastoral system where only 3.4% had done so (Table 6). However, more households in the pastoral area (16.1%) reported to have administered dewormer to sheep and goats compared to only 2.0% and 2.5% in mixed farming and agro-pastoral systems, respectively. Households in mixed farming reported to have vaccinated their cattle herds at slightly higher level of 11.8% compared to 9.0% and 8.9% from agro-pastoral and pastoral systems respectively. More households had vaccinated their goats in pastoral (8.5%) when compared to agro-pastoral (5.8%) and mixed farming (1.5%). About 19.1% of the households in agro-pastoral area reported that their cattle herds received antibiotic treatment, followed by 16.8% in mixed farming and only 3.0% in pastoral. However, more households had treated their goats with antibiotics in pastoral (11.9%) compared with 4.7% and 0.5% in agro-pastoral and mixed farming systems respectively. The veterinary intervention received by the respondents was statistically significant across the three agroecosystems; pastoral ($p<0.0001$, OR= 18.7), agro-pastoral ($p=0.0008$, OR=0.3) and mixed farming systems ($p=0.005$, OR=O.4). The farmers in the pastoral system were 18.7 times more likely to receive veterinary interventions in reference to the other agroecosystems.

Table 6

Number of households that received veterinary interventions for specific species of livestock from different agroecosystems in Narok County from July-October 2022

Veterinary intervention	Animal species	Mixed farming (n=203)	Agroecosystem Agro-pastoral (n=278)	Pastoral (n=236)
		count (%)	count (%)	count (%)
Deworming	Cattle	34 (16.8)	31 (11.2)	8 (3.4)
	Sheep	2 (1.0)	8 (2.9)	13 (5.5)
	Goats	1 (0.5)	6 (2.2)	12 (5.1)
	Sheep and goats	4 (2.0)	7 (2.5)	38 (16.1)
	Cattle and sheep	2 (1.0)	10 (3.6)	3 (1.3)
	Cattle and goats	3 (1.5)	8 (2.9)	8 (3.4)
	Cattle, sheep and goats	10 (4.9)	27 (9.7)	23 (9.8)
	Total	56 (27.7)	97 (35.0)	105 (44.6)
Vaccination	Cattle	24 (11.8)	25 (9.0)	21 (8.9)
	Sheep	0 (0)	4 (1.4)	2 (0.9)
	Goats	3 (1.5)	16 (5.8)	20 (8.5)
	Sheep and goats	1 (0.5)	6 (2.2)	11 (4.7)
	Cattle and goats	1 (0.5)	4 (1.4)	1 (0.4)
	Cattle, sheep and goats	2 (1.0)	7 (2.5)	3 (1.3)
	Total	31 (15.3)	62 (22.3)	58 (24.7)

Veterinary intervention	Animal species	Mixed farming (n=203)	Agroecosystem Agro-pastoral (n=278)	Pastoral (n=236)
		count (%)	**count (%)**	count (%)
Antibiotics	Cattle	34 (16.8)	53 (19.1)	7 (3.0)
	Sheep	2 (1.0)	14 (5.0)	11 (4.7)
	Goats	1 (0.5)	13 (4.7)	28 (11.9)
	Sheep and goats	7 (3.5)	5 (1.8)	13 (5.5)
	Cattle and goats	3 (1.5)	9 (3.2)	4 (1.7)
	Cattle and sheep	2 (1.0)	6 (2.2)	2 (0.9)
	Cattle, sheep and goats	3 (1.5)	9 (3.2)	6 (2.5)
	Total	52 (25.8)	109 (39.2)	71 (30.2)

More than half of the households whose animals received intervention treated the animals themselves. More (44.9%) household heads in pastoral system treated their animals when they were reported sick compared to 29.1% doing so in mixed farming and 37.4% in agro-pastoral systems. However, more respondents (30.9%) in agropastoral system sought intervention from animal health specialists compared to the other systems. Regarding the sources of veterinary drugs and products, most households (more than 95%) got them from agrovets with a few reporting that veterinarians or animal health assistants provided the drugs and products. On average, the cost incurred by the farmers on veterinary interventions in a month was Kshs 2251 with a median of Kshs 1500, maximum of Kshs 25000 with no cost incurred by farmers who received interventions such as vaccinations from the government.

Tick control practices

Most of the households (98.6%) had applied acaricide on their livestock with 98.9% sourcing the products from the nearby agrovet outlets and the remaining 1.1% getting them either from local shops or animal health specialists. Generally, during the normal season (no extreme weather conditions) of the year with moderate precipitation, 47.0% of the households did not have a specific pattern of tick control with only 8.6% spraying their animals weekly. However, during the dry season, 51.5% of the households sprayed their animals weekly with 36.1% spraying every two weeks and only 5.9% doing it once a month. Similarly, during the rainy season, 46.7% of the households sprayed their animals every two weeks with 37.3% doing it weekly and only 6.2% not having a specific pattern on when to apply acaricide on their animals. A higher percentage (85.3%) indicated that they followed manufacturers' recommendations on safety, handling, dilution and use of the acaricides. The common method of tick control used by most of the households (88.8%) was hand spraying the whole-body parts of the animal while remaining 11.2% used a combination of different methods such as hand picking of ticks, pour on or use of injectable drugs.

Herd dynamics

For the animals that joined the herd one month prior to the study, most of them (65.7%) were births in the farms with pastoral area recording the highest of 79.7%. However, more households in mixed farming (36.0%) reported having purchased animals compared to 18.6% and 9.4% in pastoral and agro-pastoral systems respectively. On the other hand, 23.7% of the households in agro-pastoral received cattle into their herds either as gifts, dowry or settling debts compared to 12.3% and 9.8% in mixed farming and pastoral respectively. For the animals that left the herd, more than half of the households (57.5%) had sold the animals with others reporting deaths (38.2%), given away (28.6%), slaughtered (17.3%) and lost/stolen (12.8%). More households in pastoral (45.3%) reported animal deaths compared to 36.0% and 33.0% in agro-pastoral and mixed farming respectively.

Household awareness and knowledge on East Coast fever

From all the agroecosystems, most of the respondents (91.8%) reported to be aware of ECF especially in the local name Oltikana/malaria (Table 10). For the specific animals affected by ECF, 53.0% reported that the disease only affects cattle whereas the remaining thought that it can also affect small ruminants (28.7%) and humans (28.9%). The respondents were asked to mention the clinical signs associated with ECF in cattle from the six signs in the questionnaire. These signs were fever, swollen lymph nodes, nasal discharges, petechiation, corneal opacity and difficulty breathing. Those who mentioned at least three signs were considered to know ECF. About 63.8% of the respondents in agro-pastoral were considered to know ECF as they mentioned more than half of the specific signs. However, 61.5% of respondents from pastoral and 49.7% from mixed farming were considered to know ECF as they mentioned three or more specific clinical signs. Other details are shown in Table 7.

Table 7

Knowledge on East Coast Fever disease and the animals affected in Narok County from July-October 2022

	Category	Frequency	Percentage
Knew ECF (n=717)	Yes	658	91.8
	No	59	8.2
Animals affected with ECF (n=717)	Cattle	380	53.0
	Small ruminants	189	28.7
	Humans	190	28.9
Knew ECF clinical signs (n=658)	Yes	389	59.1
	No	269	40.9
Source of knowledge (n=658)	Neighbour	450	68.4
	Death of an animal	229	34.8
	Vet/paravet	179	27.2
	Media	163	24.8
	Extension officer	33	5.0
	Local baraza	27	4.1
How cattle acquire ECF (n=658)	Ticks	251	38.2
	Other animals	174	26.4
	Environment	70	10.6
	Other	163	24.8
Ticks (n=252)	Brown ear	73	29.1
	Red spotted	99	39.4
	Blue tick	69	27.5
	Other ticks	10	3.98

The respondents gave various ways on how cattle get infected with ECF ranging from ticks (38.2%), animal-to-animal interaction (26.4%), environment (10.6%) or other routes (24.8%). On the type of tick that is responsible for ECF infection, more respondents (39.4%) reported red spotted ticks compared to 29.1% that reported brown ear ticks and 27.5% reporting blue ticks (Table 7). Despite 48.1% of the respondents reported having heard of ECF sick animals in the village, there were no statistical differences in the cases of ECF reported from the neighborhood of the respondents in the three production systems. However, within their herds, fewer farms (27.6%) reported that ECF affected their cattle herds. Statistically, households in mixed farming

systems (p=0.01) were 1.7 times more likely to have reported ECF cases in their herds within the last four months compared to those in pure pastoral production system. On the other hand, when the reference period was extended to the past 12 months, households in mixed farming (p=0.001) and agro-pastoral (p=0.02) were 1.9 and 1.6 times respectively more likely to report ECF compared to those in pure pastoral system.

Herds interacting with wildlife

More cattle herds (85.2%) from the pastoral production system interacted with wildlife during grazing followed by agro-pastoral at 56.8% and mixed farming at 19.7%. The interaction of the herds with wildlife was statistically different across the three sublocations, pastoral ($P < 0.0001$), agro-pastoral ($p<0.0001$) and mixed farming ($p < 0.0001$). However, herds in pastoral system were 5.7 times more likely to interact with wildlife compared to herds in other agroecosystems. The herds were reported to interact with wild animals mostly during the dry seasons when animals would move to search for pasture and water. Zebras, wildebeests and gazelles were reported to be the most common wild animals interacting with cattle in these areas.

Discussion

The two selected wards for this study had different agroecosystems ranging from mixed farming, agro-pastoral and pure pastoral production systems as described by Njarui *et al.* (2016). The above characteristic was relevant to allow comparison of livestock production systems from different agro-ecological zones. Livestock are kept as an important source of livelihood in many farming households whilst also having cultural and social value.

Indigenous breeds of cattle (Zebu, Boran & Sahiwal) were predominantly kept by most households in Narok County and were the main source of milk consumed and sold by the households. The observation agrees with other studies by Dabbaso *et al.* (2021) that indigenous breeds of cattle was the predominant breed kept in Tana River and Narok counties and Mwangi *et al.* (2020) in Laikipia, Kenya. Similarly, Mwangi and Ilatsia (2021) indicated that sahiwal cattle was the most preferred breed amongst the pastoralists in Kajiado, Narok and Transmara because of high milk production, growth rate and reproductive ability. Elsewhere, the feedlots operators in Shoa region of Ethiopia (Teklebrhan & Urge, 2013) and pastoralist in Botswana kept indigenous cattle breeds (Engelen *et al.,* 2013). The extreme erratic and unpredictable rainfall patterns in rangelands have exacerbated the vulnerability of crop production leaving rearing of adaptable livestock (indigenous breeds) as the most viable enterprise. Similarly, the local breeds can utilize low quality feed resources and tolerate several infections making them the appropriate breed in Arid and Semi-arid lands. In the wake of climate change, indigenous breeds are efficient, robust and multi-purpose animals that would reduce the stocking rate hence the amount of methane gas produced which has a net effect of reducing the negative impact of animals' contribution to global warming (Mwangi & Ilatsia, 2021). From this study, the estimated average milk yield for exotic breeds was 2.9 liter/cow/day, cross breed at 2.1 liter/cow/day and indigenous at 1.3 liter/cow/day. These levels, especially for the indigenous cattle breeds, were slightly higher than what was estimated by Ayza *et al.,* (2013). of 1.09 liter/day/cow and Ahmed (2019) of 1.0 liter/cow/day as the average milk yield from local Arsi cows in Ethiopia. The observed difference might be attributed to the fact that for this project, the estimates were from the milking herd (recently calved animals) which was left in the homestead as the other herd (including animals in late lactation) had migrated in search of pasture and water. Generally, the low production levels for indigenous breeds have been attributed to genetic make-up, short lactation period and shortage of feed (Engelen *et al.,* 2013). From the Maasai pastoralists, average milk yield of 1.09 and 0.79 litres/cow/day in the wet and dry season respectively has been documented by Ahmed (2019). However, the current study was carried out immediately after the long rains of April/June season and so that can explain the higher production levels. The average lactation period of 9.5 months reported in the current study was but slightly longer than 6 months reported by Ahmed, (2019) reported in Ethiopia.

From the current study, 71.9% of the respondents indicated that livestock were fed principally on pasture grown within the farm or from neighborhood which is slightly lower than 87.5% reported by Ahmed (2019). The findings agree with other studies which reported that natural pasture and crop residues are the major feed resources used as a basal diet in rural and peri-urban cattle production systems (Omollo *et al.,* 2018). However, from this study, there was little practice of supplementary feeding of animals but only for lactating/milking herd and during the dry season. Similar findings were reported elsewhere (Engelen *et al.,* 2013; Mugumaarhahama *et al.,* 2021; Paul *et al.,* 2020) that the use of improved forage and supplementary feed by the pastoralists is insignificant, as the primary feed sources of livestock were the indigenous species of grasses, shrubs and fodder trees. In Rwanda, Eugene (2017) reported that only 3.6% of the interviewed farmers practiced supplement feeding otherwise most of them fed their animals principally on pasture without any supplementation.

The common method of tick control used by most of the households (88.8%) was hand spraying while the remaining 11.2% used a combination of different methods like hand picking, pour on or use of injectable drugs. This observation was in contrast with a study by Wangila (2016) in smallholder farming system where more than half (51%) of the farmers did home spraying, 46.5% used public dips and only 2.5% used private dips. The results showed that 47.0% of the households did not follow a specific time period in spraying their herds, although 51.5% sprayed weekly during the dry period and every two weeks (46.7%) during the wet season. However, Wangila (2016) reported that more farmers (77.3%) from Nandi and Uasin Gishu counties would spray their herds weekly, with 9.8% doing it after every two weeks, 3.9% once a month, and 1.6% every three weeks. The weekly acaricide application was based on the reasoning that during the wet season the rain would wash away the acaricide/chemical from the body of animals.

The findings further revealed that the access to essential veterinary services by livestock keepers varied substantially across livestock production systems with relatively better access in the mixed system compared to agro-pastoral and pastoral systems. This was contributed by the relative concentration of the veterinary establishments and better basic infrastructure and amenities. Gizaw *et al.,* (2021) reported similar findings in Ethiopia where livestock keepers in the crop-livestock system had 5.5 times more access to veterinary services compared to the pastoral system. Studies that have been done elsewhere have indicated that farmers practising crop and livestock keeping do so in high population density areas and have better access to veterinary services compared to those who solely depend on livestock. Bosche *et al.,* (2004) in their study on analytical approach on provision of animal care to livestock farmers in Africa reported similar findings. However, from different African countries, studies have reported significant differences in how livestock keepers access veterinary services across different production systems such as in Zimbabwe (Chatikoboa *et al.,* 2012), South Africa (Busisiwe *et al.,* 2019), border of South Africa and Namibia (Oladele *et al.,* 2013), Namibia (Vetjaera *et al.,* 2020), northern Kenya (Onono *et al.,* 2013) and Baringo Kenya (Shivairo, 2013). Therefore, efficient delivery of essential veterinary services will not only return positive economic value but can also prevent and contain animal health crises and save human lives which align to the United Nation's sustainable development goals.

The distance to the nearest veterinary establishment and the unpredictable rains were the main factors reported as barriers to accessing essential veterinary services in the current study. The main reason for insufficient access can be attributed to the long distance to the veterinary establishments especially in the pure pastoral setting where farmers had to travel for more than 10 kilometres to get the services. Similarly, related findings like poor infrastructure, remoteness and inconsistent rainfall have been reported elsewhere (Vetjaera *et al.,* 2020). A study by Delia *et al.* (2017) and FAO (2020) reported that factors such as education level, economic status and political marginalisation of the pastoral communities can influence seeking and access to essential veterinary service however there was no significant difference between these and access to veterinary services in the current study. Chong

(2002) reported several causes of underdeveloped private veterinary services in pastoral setting in Kenya such as poor infrastructure, insecurity, high cost of service delivery, high mobility and low economic status of the communities. However, with major development changes in Kenya during the last two decades, the above observations may have significantly changed.

The findings from this study indicated that vaccination, deworming and treatment of clinical cases with antibiotics were the three main veterinary interventions sought for by the farmers. However, in a study done in Ethiopia with similar production systems, additional essential services such as disease outbreak investigations, herd health and training were reported (Gizaw *et al*., 2021). Most of the respondents got veterinary drugs and products from agrovet outlets which is similar to what was reported in Ethiopia by Gizaw *et al.* (2021). Some of the drugs bought from the agrovets include antibiotics such as oxytetraxycline. Unregulated access to above drugs has been known to contribute to Antimicrobial Resistance (Haftay *et al.,* 2018; Kalayu *et al.,* 2020; Walkite, 2018).

More farmers were reported to know how ECF manifests clinically in cattle as more than half (59.1%) could tell the specific signs of the disease. However, in a study done in smallholder cattle keepers in Nandi and Uasin Gishu counties of Kenya, it was reported that only 24.5% of the respondents were able to list at least two signs specific to ECF (Wangila, 2016). The ability of many farmers to recognise East Coast fever is a major advantage as the disease is the most economically important in cattle in sub-Saharan African countries (Gachohi *et al.,* 2012; Nene *et al*., 2016). From this study, 38.2% of the respondents attributed source of ECF infection in cattle to ticks with 26.4% to cattle interaction with other cattle and 24.8% to livestock-wildlife interaction. However, Wangila (2016) reported other factors like communal grazing (32.6%), uncontrolled animal movement (animal interaction) (27.5%), proximity to trade routes (18.9%), purchased animals (16.7%) and livestock-wildlife interaction at 3%. The wide difference on the perception of the respondents to livestock-wildlife interaction between this study and Wangila (2016) can be attributed to the differences in the study sites. This study was carried out in a pastoral system adjacent to the Masai Mara national park whereas Wangila did his study in the highly populated areas of Nandi and Uasin Gishu with limited livestock-wildlife interaction. On the other hand, respondents from Baringo and West Pokot counties of Kenya reported grass/open grazing as the main source of ECF infection (Kiprono *et al.,* 2011). Different cattle productions have been significantly associated with ECF infections in agreement with the results of this study cattle (Gachohi *et al.,* 2012; Gizaw *et al.,* 2021).

Conclusion

From this study, we conclude that indigenous breed of cattle was an important source of household income and most of these cattle were raised on natural pasture. The estimated average milk yield for exotic breeds was 2.9 liter/cow/day, cross breed at 2.1 liter/cow/day and indigenous at 1.3 liter/cow/day. The mean lactation period for cattle was 9.5 months with average inter-calving interval of 14.1 months. Natural mating with either own or borrowed bull was the main breeding method. Accessibility to veterinary services in these production systems was not the same with tick control, vaccination, deworming and antibiotic use being the veterinary interventions practiced by the farmers. Most of the households (98.6%) did hand spraying of their herds sourcing the products mainly from the agrovet outlets (98.9%). More respondents from agro-pastoral knew ECF compared to those from mixed farming and pure pastoral systems.

The three production systems especially pure pastoral require more input and improved feed resources (feed value chain) to ensure continued supply of feed even during the dry period. Public and private veterinary service delivery systems should be established in the study area (like mobile clinics and extension services) to increase availability and accessibility of essential veterinary services to livestock keepers. Similarly, with the reports of ECF infection and the challenges associated thereto, modern technologies on control and prevention should be provided and farmers encouraged to adopt them.

There is also a need to educate livestock farmers on early detection and reporting of ECF cases to reduce both direct and indirect economic losses. Similarly, there is need to investigate the incidence of ECF in different production systems and determine the associated risk factors to confirm the verbal reports by the respondents.

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Ethical approval

The study protocols and procedures were approved by the Faculty of Veterinary Medicine's Biosafety, Animal use and Ethics committee (**REF: FVM BAUEC/2021/316**) of the University of Nairobi.

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