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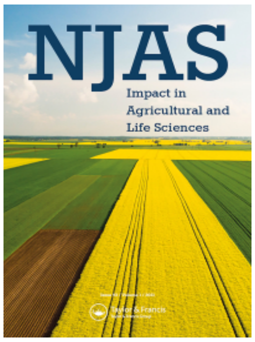

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Andualem Tenagne[a,b], Mengistie Taye[a,c], Tadelle Dessie[a,d], Bekalu Muluneh[a,e], Damitie Kebede[a,c] and Getinet Mekuriaw Tarekegn[a,c,f]

[a]Department of Animal Science, College of Agriculture and Environmental Sciences, Bahir Dar University, Bahir Dar, Ethiopia; [b]Department of Animal Science, Assosa University, Assosa, Ethiopia; [c]Institute of Biotechnology, Bahir Dar University, Bahir Dar, Ethiopia; [d]International Livestock Research Institute (ILRI), Addis Ababa, Ethiopia; [e]Department of Animal and Range Sciences, Wolaita Sodo University, Tarcha, Ethiopia; [f]Animal and Veterinary Sciences, Scotland's Rural College (SRUC), Roslin Institute Building, University of Edinburgh, Edinburgh, UK

ABSTRACT

Description of the production condition and level of performance is the first step in improving production performance. The study described the indigenous cattle reproductive performances, management practices and production limitations in north-western Ethiopia. Multistage purposive and random sampling methods were used to select the study sites/districts and households. A semi-structured questionnaire (320 interviewees), focus group discussions (12) and personal observations were used for data collection. Chi-square ($\chi 2$) test, the least squares mean and the ranking indexes were the statistical methods employed for data analysis. Livestock composition, reproductive performance and production constraints of cattle showed significant differences ($p < 0.001$) between agro-ecological zones. Cattle were the dominant livestock species, with mean numbers of 18.3 ± 9.9, 8.1 ± 3.2 and 5.4 ± 2.5 heads in the lowland, midland and highland agro-ecological zones, respectively. The mean ages at first mating of bulls, first service of heifers, first calving and calving interval of cows were best in the highlands, while the midland agro-ecology had the worst performance. Feed shortage (Index = 0.4) and disease prevalence (Index = 0.25) were the main cattle production problems. Natural pasture was the main feed source for cattle in the study areas. The study revealed a significant effect agro-ecology on landholding, cattle management practices, species composition; cattle herd structure, reproductive performances and cattle production constraints. This implies that the socioeconomic characteristics, management-level constraints for production and performance level of the livestock stock are important for developing improvement strategies for smallholder livestock production in different agro-ecological zones.

CONTACT Andualem Tenagne andualemtenagne@gmail.com; Mengistie Taye mengistietaye@gmail.com

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1. Introduction

Cattle are the most important livestock species that play a vital role for the livelihoods of millions of farmers, serving as a source of draft power for rural people and as a supplier of cattle products such as milk, meat, manure and cash income (Endalew & Ayalew, 2016). Cattle contribute almost all the traction power for crop production at the smallholder level in Ethiopia (Melaku, 2011). Ethiopia is home to a vast genetic resource of cattle with an estimated population of 70 million, making it the most populous country in Africa and the fifth largest in the world (CSA, 2021). Indigenous cattle are considered the backbone of relevant and sustainable livestock production (Okomo-Adhiambo, 2002), accounting for 97.4% of the total and being kept extensively, while crossbreds and exotic breeds account for only 2.3% and 0.31%, respectively, in Ethiopia (CSA, 2021). The reason for the high proportion of indigenous cattle is that they have various adaptive mechanisms that enable them to survive and reproduce under harsh environmental conditions and resist diseases (Hagos, 2016). Despite their vast resources and unique adaptability to local environmental conditions, cattle are not productive in most sub-Saharan African countries (Mwai et al., 2015; Renaudeau et al., 2012). In the mixed crop-livestock production systems, feed is one of the major constraints affecting smallholder cattle production (Njarui et al., 2021). Due to its rain-dependent nature of production, feed availability and quality vary with agro-ecological conditions and the season of the year (Kashongwe et al., 2017a). Generally, feed is more abundant in the highland and during the wet season, whereas it is scarce in the lowlands and during the dry season (L. Mburu et al., 2018; Onyango et al., 2019). For instance, crop residues are the most available during crop harvesting season (Anyango et al., 2018; Gakige et al., 2020; Mwendia et al., 2017). Seasonal feed availability and quality variations affect the production and reproduction performance of livestock (Kashongwe et al., 2017a; Schwendel et al., 2015), and low availability and quality of feed lead to reduced feed intake and affected performance when their nutritional requirements are higher than the nutrient intake from feeds (Colmenero & Broderick, 2006; Imaizumi et al., 2010).

In an integrated livestock production system, evaluating economic important traits related to reproductive efficiency and productivity is important for improvement of the sector (Fernandes Júnior et al., 2019; Soares et al., 2015). Among the reproduction traits, age at first calving (AFC) and calving interval (CI) play an important role in cattle production system and are relevant factors in the economic viability of the herd (Berry et al., 2014). Females calving early and regularly in their life tend to produce a larger amount of calves in a shorter time, increasing the females' reproductive life (Åby et al., 2012). To improve the productivity of indigenous cattle, the government of Ethiopia has been implementing cross-breeding of local cattle with commercial dairy cattle breeds for about six decades (Chebo & Alemayehu, 2012). The effort, however, is not visible in terms of the composition of crossbred animals at smallholder level and is leading to the erosion of indigenous genetic resources through poorly planned crossbreeding (Effa et al., 2011; Hagos, 2016). To properly plan sustainable breeding programmes, adequate information on the production and reproductive performance and production constraints of cattle are of paramount importance (Hagos, 2016; Haile, 2011; Mezgebe et al., 2017). Despite scattered efforts to characterize the cattle management system in various parts of Ethiopia, the detailed information required for planning a breeding programme is lacking and must be updated on a regular basis because animal populations and management styles will change with time. The results of this study will contribute to the literature on production system, reproductive performance and production constraints. Hence, literature is currently limited, particularly in the case of smallholder livestock production systems in Ethiopia and countries with similar production systems and agro-ecological zones. Understanding the production system, production constraints and stock performance in smallholder production systems can enable the design of a production improvement programme.

2. Materials and methods

2.1. Study sites

The study was conducted in six selected districts: Jawi, Enebsie Sarmidr, South Achefer, Mecha, Banja and Senan districts of north-west Ethiopia (Figure 1). Table 1 presents a description of the cattle populations, geographical locations, mean annual temperature, rainfall and altitude ranges of the study areas. Preliminary research and discussions with regional and zonal experts from livestock development offices on the potential and distribution of indigenous cattle in the study areas were conducted during site selection.

2.2. Cattle management system and livestock composition

The production system in the study sites is a mixed crop and livestock production system. Crop types grown in lowland areas include sorghum, finger millet, maize, rice, *gobe* and groundnut. In the midland, the common crops grown include wheat, maize, barley, finger millet and *teff*. In highland areas, wheat, maize, barley, oats and *teff* were the major crops grown in the

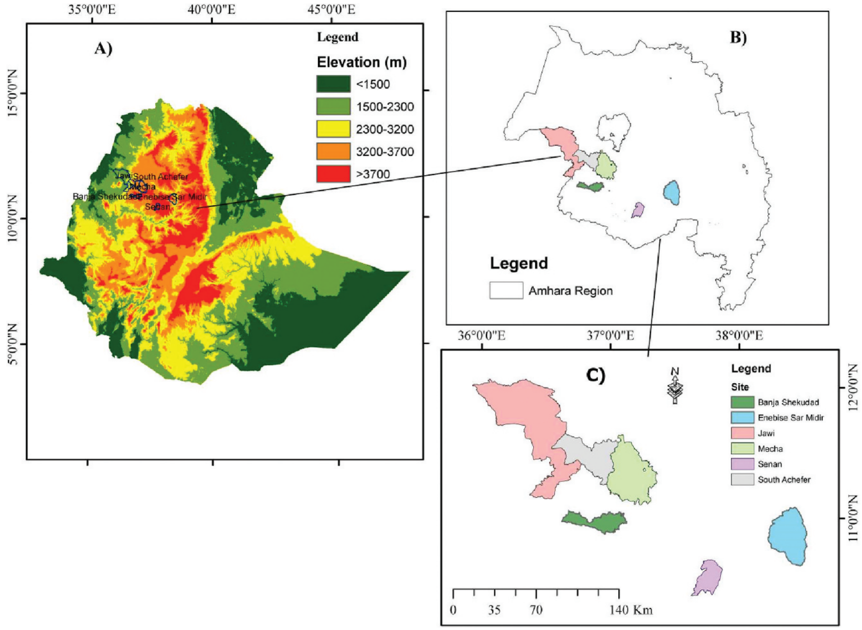

Figure 1. Map of Ethiopia (a), Amhara region (b) and six study districts (c) of Northwestern, Ethiopia.

Table 1. Summary of cattle population, annual temperature, rainfall, coordinate points and elevations of study districts in Ethiopia.

District/site	*kebele*	Latitude	Longitude	Altitude (m a s l)	Annual temp./°C	Annual RF/mm	Cattle population
Jawi	1	11°57′18″N	36°24′48″E	995	12–40	1250	252,121
	2	11°25′38″N	36°37′06″E	1365			
	3	11°33′40″N	36°31′50″E	1171			
Enebsie	1	10°41′35″N	38°30′35″E	1431	10–36	900–1200	67,791
	2	10°41′41″N	38°30′40″E	1207			
	3	10°42′03″N	38°30′40″E	1271			
Achefer	1	11°31′17″N	36°56′19″E	2052	15–23	1450–1594	337,467
	2	11°16′36″N	36°57′52″E	2000			
Mecha	1	11°19′28″N	37°14′05″E	2194	23–27	1500–2200	409,502
	2	11°22′26″N	37°04′32″E	1963			
Banja	1	10°54′39″N	36°58′04″E	2409	7–25	2200–2560	69,156
	2	10°56′48″N	36°52′08″E	2337			
	3	10°58′36″N	37°00′55″E	3028			
Senan	1	10°38′27″N	37°47′53″E	3192	0–15	900–1500	37,501
	2	10°35′03″N	37°49′43″E	3081			
	3	10°38′04″N	37°49′03″E	3214			

Source: Districts agricultural office, 2021; m a s l. = metre above sea level, Annual temp = the mean minimum and mean maximum annual temperature in Degree Celsius; and RF= mean annual rainfall in millimetres.

area. Cattle, sheep, goats, equines and chickens are the common livestock species in the study areas, and the main feed resources for livestock were natural pasture, crop residues, stubble grazing, private grazing land and conserved forage (CSA, 2021).

2.3. Sampling method and procedures

Preliminary studies and discussions were held with experts from the livestock development offices in the region and districts to know the husbandry systems, reproductive performances and major constraints of the indigenous cattle production in the study areas. Accordingly, a multi-stage sampling method was used. First, study areas where there is dearth of information were deliberately chosen and divided into three strata based on agro-ecology (lowland, midland and highland). In the second stage, two sites from each stratum (Jawi and Enebssie SarMidr from the lowlands; South Achefer and Mecha from the midland; and Banja and Sinan from the highlands) were selected based on cattle population potential and agro-ecological diversification. Finally, 320 cattle owners keeping more than two indigenous adult cattle were randomly selected for the household questionnaire survey. The sample size of the households was determined using the formula:

$n = \frac{N}{1+N\varepsilon^2}$, where: N = population size >1000000, ε = the degree of accuracy expressed as a proportion = 0.05; ρ = the number of standard deviations that would include all possible values in the range = 2; t = t-value for the selected alpha level or confidence level at 95% = 1.96. The minimum sample size is 267 households (Adam, 2021).

2.4. Data collection

A semi-structured questionnaire was used to collect information from the selected households on the socio-economic characteristics, management systems, production constraints, major feed sources and reproductive performance of indigenous cattle. The questionnaire was tested prior to the actual survey to ensure that all questions were sufficiently clear to respondents. The data were collected during the study period from February 2020 to March 2021 to obtain additional information and validate the data from the individual farmer interviews. In addition, two focus group discussions (FGD) were conducted at each site (a total of 12 FGD in the study), involving elders, knowledgeable farmers, livestock experts and veterinarians, each FGD with a group of 12 participants.

2.5. Data management and statistical analysis

Data collected from the sites were coded and entered into MS Excel for further analysis. Quantitative data, such as cattle reproductive performance traits, and livestock composition and herd structure were analysed using the general linear model procedures of the statistical analysis system (PROC GLM of SAS version 9.4) using the model:

Yij = μ+ Ai + εij; where Yij = the value of the respective variables; μ = overall mean of the respective variables; Ai = effect of the i^{th} agro-ecology (I = 3, highland, midland and lowland) on the respective variables; Ɛij = residual error term.

SPSS (Statistical Package for Social Sciences) version 26 was also used for the chi-square (χ2) statistic to test the independence of categories from livestock trends and to assess the association between farmer demographic characteristics and cattle management practices. Finally, for the frequency calculations, we determined the respondents' percentages of demographic characteristics, overall management system, milking frequency and farmer milk utilization. Ranking indices were calculated to determine the ranking of key cattle feed resources and production constraints using the formula (Kosgey, 2004).

$$Index = \frac{\sum[(3 \times rank1) + (2 \times rank2) + (1 \times rank3)]\mathit{individual}\,\mathrm{variable}}{\sum[(3 \times rank1) + (2 \times rank2) + (1 \times rank3)]\mathit{overall}\,\mathrm{variables}}$$

3. Result and discussions

3.1. Demographic characteristics of the respondents

Table 2 shows the socio-economic characteristics of cattle-owning households in the study areas. The majority of the respondents were males (97.2%). It is a common trend in Africa that large animals such as cattle are difficult to be handled by females (Duguma, 2020; Nguyen et al., 2021; O. Mapiye et al., 2018). From the sample households, 45.4% of them were within the range of 46–64 years old, followed by 31–45 years old (45.3%). This shows that the proportion of youth in the study area was very rare from the total cattle owners, which has been repeatedly reported in most African countries (Mazimpaka et al., 2017; Taruvinga et al., 2022). The possible reason for the lower participation of youth in cattle production is that they have relatively small plots of land and less capital available for cattle production compared to older households. However, such distribution could slow down the adoption and application of new agricultural technologies. In terms of education level, most of the farmers (95.9%) had no regular education, and only 4.2% of them had completed 10th grade. This low level of education may negatively affect the rate of adoption for new technologies and the use of veterinary services. Therefore, education plays an important role in introducing technologies and shaping the demographics, health status and socioeconomic status of the family (Kassahun, 2004). The overall mean landholding per household was 2.86 hectares, and 71.5% of farmers owned <2.0 hectares of

Table 2. Household's characteristics of cattle owners and management practice in the three agro-ecology zones of north western Ethiopia.

Household characteristics	Agro-ecological zones (%) Lowland, %	Midland, %	Highland, %	Overall, %
Sex of respondent		$X^2 = 285.0$***		
Male	95	97.5	99.2	97.2
Female	5	2.5	0.9	2.8
Age of respondent		$X^2 = 193.8$***		
≤30 years	4.2	2.5	0	2.2
31–45 years	49.2	37.5	49.15	45.3
46–64 years	44.2	51.3	40.9	45.4
>64 years	2.5	8.8	10	7.1
Marital status of respondent		Ns		
Single	1.7	0.0	0.8	0.8
Married	94.2	95.0	99.2	96.1
Widowed	1.7	1.3	0.0	1.0
Divorced	2.5	3.8	0.0	2.1
Religion of respondent		$X^2 = 193.8$***		
Orthodox Christian	100	100	100	100.0
Muslim	0.0	0.0	0.0	0.0
Protestant	0.0	0.0	0.0	0.0
Others	0.0	0.0	0.0	0.0
Education level of respondent		$X^2 = 136.8$***		
Illiterate	60	15	35.9	37.0
Read and write	35	81.2	60.9	59.0
10th or 12th complete	5	3.8	3.4	4.0
Land owned classes		$X^2 = 250.7$***		
≤1 hectare	15.9	26.3	59	33.7
1.1–2 hectares	14.2	60	39.4	37.8
2.1–3 hectares	6.7	12.5	1.7	6.9
3.1–4 hectares	5.6	1.3	0	2.4
>4 hectares	57.5	0	0	19.2
Grazing land 1 ≤ 0.5 hectare	80.9	96.3	95	90.1
Cattle management system		$X^2 = 166.5$***		
Extensive	85.1	26.4	50	53.8
Semi extensive	14.1	73.7	50	45.9
Intensive	0.9	0	0	0.3
Grazing land ownership		$X^2 = 222.6$***		
Communal only	75	6.3	0	27.1
Private only	0	1.3	2.5	1.3
Both	25	92.5	97.5	71.4
Grazing system		$X^2 = 35.1$***		
Free	96.7	27.5	62.5	62.2
Control	3.4	72.5	37.5	37.8
Milking frequency		$X^2 = 277.5$***		
Once per day	58.3	0	0	19.4
Twice per day	41.7	100	100	80.6
Milk utilization		$X^2 = 132.6$***		
Family consumption only	24.2	20.8	20.8	16.7
Both family consumption and income sources	75.8	79.2	79.2	83.3

Key: *** = $p < 0.00$ and Ns is not significant.

land, even though in lowland agro-ecology, 57.5% of farmers have >4 hectares of land (Table 2). The overall mean landholding per household was comparable to Y. Alemayehu et al. (2016). The relatively larger land area in the lowland agro-ecological zone indicates its better potential for cattle production with pasture cultivation and fodder development than other sites. Surprisingly, more than 90% of the respondents in the study area had no or less than 0.5 hectares of cultivated pasture land for their livestock grazing, which indicates the low attention given for the allocation of land for livestock feed production. Therefore, to improve cattle production and productivity in the study areas, great attention should be paid to forage development and grazing land management. The area's main cattle production system was a mixed crop-livestock production system. Households in the area often have common grazing land and practice a free grazing system (Table 2). This is a common practice in the smallholder livestock farming as reported in the literature (Adane et al., 2021; Gillah et al., 2013; Mazimpaka et al., 2017) in Ethiopia and elsewhere in Africa. Common salt (sodium chloride) was the only mineral supplement given to cattle in the study areas, which is similar with other areas (Duguma, 2020; Geleti et al., 2014).

The consumption pattern of milk and dairy products depends on the quantity of milk, access to markets and fasting period in the year. Table 2 shows that 83.3% of the households use the milk produced both for family consumption and as a source of income through the sale of milk and milk products such as butter and yoghurt. Similarly, Tekle (2010) reported that most households use their milk and milk products for both family consumption and as a source of income. The importance of milk in the diet of Ethiopians differs according to the farming system and socio-cultural environment (Bereda et al., 2014).

3.2. Associations of demographic information with management practice and milk utilization

The associations between smallholder farmer demographic characteristics and livestock management systems are presented in Table 3. The

Table 3. The association (*p*-values) between management practices and demographic characteristics of cattle owners in the north western part of Ethiopia.

	Demographic characteristics						
Management practices	Age	Sex	Marital status	Education level	Amount of land	Religion	Grazing land owned
Management system	0.45	0.43	0.24	0.08	0.005	0.001	0.020
Grazing land ownership	0.009	0.34	0.88	0.006	0.000	0.011	0.540
Grazing system	0.30	0.99	0.99	0.000	0.000	0.990	0.150
Number of cattle	0.036	0.90	0.88	0.016	0.000	0.290	0.001
Milk utilization	0.27	0.49	0.047	0.93	0.03	0.090	0.240
Mineral supplementation	0.56	0.68	0.15	0.74	0.81	0.310	0.440

educational level of farmers was related to their livestock management system, pasture landholding, grazing system and the number of cattle. The result shows that farmers with better educational levels use private grazing land, semi-intensive management system and improve productivity by reducing the number of cattle (Malusi et al., 2021). Similarly, the result by Herring et al. (2018) explains that farmers' education is important in the basic philosophy of animal husbandry. Therefore, educated farmers usually keep fewer higher-productive livestock compared to less educated ones (Kabubo-Mariara, 2007; Taruvinga et al., 2022). On the other hand, the same author explained that as education increases, opportunities for alternative income generation also increase. The extent of land ownership of farmers in the study areas also showed a strong relationship with the management system, pasture landholding, grazing systems, number of cattle holding and milk utilization. Accordingly, the education level of livestock keepers plays a great role in smallholder production and productivity improvement. Farmers in the lowland agro-ecologies own relatively larger land and are therefore located separately from farmers in the midland and highland agro-ecologies. Consequently, they practise their livestock rearing activities differently than the croplands prevalent in the midland and highland agro-ecologies depending on resource availability (Table 2). As shared in the focus group discussion, farmers in lowland agro-ecologies have access to a larger area of communal grazing land where they can freely graze their livestock without restrictions.

3.3. Livestock compositions and cattle population trends

Cattle were the largest livestock species (10.6 ± 5.2), followed by sheep (4.3 ± 4.4), goats (3.6 ± 4.9) and equines (1.9 ± 1.4) in the study areas (Table 4). Similar kinds of species compositions have been frequently reported in different parts of Ethiopia (Bekele et al., 2016; Tadesse et al., 2014). Cattle are raised for a variety of purposes including milk production, source of power, cash income generation and socio-cultural significance (Bereda et al., 2014). The mean number of cattle holding per household is higher than that reported by Bekele et al. (2016) with a mean number of 9.67, and Tamrat (2018), but lower than the report of Mekonnen et al. (2012) who reported 12.2 heads of cattle, in different parts of Ethiopia. The mean number of cattle was different between agro-ecologies. With the values of 18.3, 8.1 and 5.4 heads per household in the lowland, midland and highland agro-ecologies, respectively, cattle herd size was significantly higher in the lowland agro-ecological zones. Similar results were reported somewhere else in Ethiopia (Abera et al., 2020; Tadesse et al., 2014). This is because farmers in the lowlands operate an agro-pastoral production system and rely heavily on cattle for their livelihoods (Gwaza et al., 2018).

Table 4. Major livestock species composition, cattle herd composition and population trend for the last ten years in different agro-ecological zones of north western Ethiopia.

Parameter	Agro-ecological zones Lowland (n = 120) Mean ±SD	Midland (n = 80) Mean ±SD	Highland (n = 120) Mean ±SD	Overall (n = 320) Mean ±SD	Sig.
Livestock species composition					
Cattle	18.3 ± 9.9[a]	8.1 ± 3.2[b]	5.4 ± 2.5[c]	10.6 ± 5.2	$P < 0.001$
Sheep	3.0 ± 5.2[b]	4.3 ± 3.3[ab]	5.5 ± 4.7[a]	4.3 ± 4.4	$P < 0.001$
Goat	10.0 ± 12.1[a]	0.6 ± 1.9[b]	0.2 ± 0.8[b]	3.6 ± 4.9	$P < 0.001$
Equines	2.2 ± 2.2[a]	1.3 ± 0.8[b]	2.3 ± 1.2[a]	1.9 ± 1.4	$P < 0.001$
Herd composition					
Cow	6.0 ± 3.8[a]	2.2 ± 1.0[b]	2.0 ± 1.0[b]	3.4 ± 1.9	$P < 0.001$
Bull	1.2 ± 0.6[a]	1.4 ± 0.7[a]	0.6 ± 0.7[b]	1.1 ± 0.7	$P < 0.001$
Heifer	2.4 ± 2.9[a]	1.1 ± 1.1[b]	1.1 ± 1.0[b]	1.5 ± 1.7	$P < 0.001$
Female calf	2.9 ± 2.1[a]	0.9 ± 0.8[b]	0.5 ± 0.6[b]	1.4 ± 1.2	$P < 0.001$
Male calf	3.2 ± 2.1[a]	1.2 ± 1.0[b]	0.5 ± 0.6[c]	1.6 ± 1.2	$P < 0.001$
Oxen	2.6 ± 1.4[a]	1.3 ± 1.2[b]	0.7 ± 1.4[c]	1.5 ± 1.3	$P < 0.001$
Total	18.3 ± 9.9[a]	8.1 ± 3.2[b]	5.4 ± 2.5[c]	10.6 ± 5.2	$P < 0.001$
Cattle trend		$X^2 = 27.6$***			
Increasing	13.3	1.3	1.7	5.4	
Decreasing	86.7	95.0	98.3	93.3	
Stable	0	3.8	0	1.3	
Sheep trend		$X^2 = 16.3$***			
Increasing	11.7	18.8	4.2	11.6	
Decreasing	77.5	78.8	90	82.1	
Stable	10.8	2.5	5.8	6.4	
Goat trend		$X^2 = 74.1$***			
Increasing	18.3	1.3	0	6.5	
Decreasing	70.8	88.8	57.5	72.4	
Stable	10.8	10.0	42.5	21.1	
Equines trend		$X^2 = 90.2$***			
Increasing	2.5	56.3	18.3	25.7	
Decreasing	79.2	30.0	74.2	61.1	
Stable	18.3	13.8	7.5	13.2	

n = number of animals per household.

Household observations on the trend of livestock species composition and size over the last ten years in the study area are summarized in Table 4. The number of animals per household showed a decreasing trend for cattle (93.1%), sheep (82.5%), goats (70.3%) and equines (64.9%). In a similar case, a gradually decreasing trend in cattle over time was reported by Benti et al. (2021) in western Showa and Mekonnen et al. (2012) for Horro cattle. This is mainly due to the expansion of cropland, which led to a shortage of grazing land and a consequent shortage of forage. Frequent disease outbreaks, inadequate veterinary care and water shortages have also been cited as reasons for the declining trend (Dossa & Vanvanhossou, 2016; Duguma, 2020; Kassahun, 2004). However, the total number of cattle seems to be following an increasing trend as the increase in human population leads to increasing demand for livestock and livestock products, and the number of people involved in livestock production increases (CSA, 2021). To meet the alarmingly increasing demand for livestock products and by-products in Ethiopia and other developing countries, increasing productivity by improving management is an important solution.

3.4. Major feed resource

The main feed sources for cattle in the study areas were ranked by season and agro-ecological zone (Table 5). Overall, the most important feed resources for cattle in all seasons and agro-ecologies were natural pasture (0.31), crop residues (0.18), stubble grazing (0.18), private grazing land (0.14) and conserved forage (0.12). In general, the major cattle feed resources in this study were similar to previous studies (Bereda et al., 2014; Tamrat, 2018; Tsadkan, 2012). However, the availability and contribution of feed sources varied by season and agro-ecological zones (Benti et al., 2021). Farmers combined different feed resources based on availability (Bereda et al., 2014).

The overall result of the study is similar with the reports by DMG Njarui et al. (2011), Mutua et al. (2012) and L. M. Mburu (2015) in smallholder cattle farming systems studies that were conducted in eastern African countries. Consistent with this result, Benti et al. (2021) and Teklay (2008) also reported that natural pasture was predominant in the lowland agro-ecology, but crop residues were more dominant in the midland agro-ecology than in the lowland. One possible reason for this statement was that in the midlands, pasture was declining due to conversion to cropland, so a crop-dominated production system was practised in this area. However, the main problem for farmers' dependence on natural pasture, especially in lowland agro-ecology, was seasonal dependence on quality and quantity, leading to low productivity and increased susceptibility to disease (Okello & Sabiiti, 2006). The seasons also showed variations in the availability and use of feed resources; in the rainy season, natural pasture and private grazing land were the most important forage resources, while in the dry season, crop residues and stubble grazing were most important (Table 5). Our results are consistent with other reports (M. Alemayehu, 2004; Ma'alin et al., 2021; Teshome et al., 2010) that natural pasture is the main source of feed for livestock in the rainy season. On the other hand, crop residues were the main feed source in the dry season, as reported by Duguma (2020) and Mekonnen et al. (2012). In terms of feed value and digestibility, crop residues are of poorer quality compared to other feeds (Scarpa et al., 2003). Similar to our result, poor-quality major feed resources are a common problem in studies in Kenya and Uganda (Möller, 2018). To ensure consistent availability and quality of feed throughout the year, using low-cost alternatives like crop residue treatment and forage development using irrigation systems could be a better solution for the problem.

Table 5. Ranking of major feed resources of cattle of study areas in different seasons of the year and agro-ecological zones of Ethiopia.

		Agro-ecological zones												
		Lowland				Midland				Highland				
		Rank				Rank				Rank				
Season of the year	Feed resources	1st	2nd	3rd	Index	1st	2nd	3rd	Index	1st	2nd	3rd	Index	Overall index
Dry season	Natural pasture	83	13	15	0.42	11	1	17	0.11	46	21	8	0.26	0.26
	Stubble grazing	0	22	15	0.09	0	10	0	0.04	11	18	17	0.11	0.08
	Private grazing land	2	35	3	0.12	1	1	39	0.09	4	39	22	0.15	0.12
	Crop residue	15	25	21	0.17	38	9	21	0.32	23	29	9	0.19	0.23
	Conserved feed	7	9	55	0.13	21	46	3	0.33	22	8	41	0.17	0.21
	Concentrate	12	3	10	0.07	9	13	0	0.11	17	4	24	0.12	0.1
Wet season	Natural pasture	93	18	4	0.49	23	37	0	0.29	79	30	2	0.43	0.4
	Stubble grazing	0	0	18	0.03	0	9	22	0.08	10	19	10	0.11	0.07
	Private grazing land	11	45	8	0.2	57	12	9	0.42	2	35	22	0.14	0.26
	Crop residue	3	10	14	0.07	0	20	27	0.13	17	23	16	0.16	0.12
	Conserved feed	4	6	26	0.08	0	0	20	0.08	3	12	45	0.11	0.09
	Concentrate	8	29	4	0.13	0	2	1	0.01	1	3	24	0.05	0.06
Year round	Natural pasture	79	18	10	0.41	12	27	14	0.22	49	27	11	0.30	0.31
	Stubble grazing	3	27	15	0.11	14	10	7	0.14	22	20	8	0.16	0.14
	Private grazing land	11	33	10	0.16	29	4	17	0.23	10	25	28	0.15	0.18
	Crop residue	14	18	26	0.15	18	19	27	0.24	17	20	17	0.15	0.18
	Conserved feed	6	9	29	0.09	5	14	13	0.13	13	18	31	0.15	0.12
	Concentrate	7	12	12	0.08	2	6	3	0.05	9	10	22	0.10	0.08

Index = sum of [(3 * number for rank 1) + (2 * number for rank 2) +(1 * number for rank 3)] given for an individual reason divided by the sum of [(3 * number for rank 1) + (2 * number for rank 2) + (1 * number for rank 3)] for overall reason.

Table 6. Reproductive performances of indigenous cattle in different agro-ecological zones of north western Ethiopia.

	Agro-ecological zones				
Reproductive parameters	Lowland LSM±SD	Midland LSM ±SD	Highland LSM ±SD	Overall LSM ±SD	*P*-value
Age at first service of bull (month)	45.1 ± 5.1^{b}	49.1 ± 11.3^{a}	37.8 ± 5.3^{c}	43.4 ± 8.6	<0.001
Age at first service of heifer (month)	41.2 ± 5.9^{b}	44.6 ± 9.1^{a}	37.1 ± 3.7^{c}	40.5 ± 6.9	<0.001
Age at first calving (month)	52.3 ± 5.9^{b}	55.8 ± 8.9^{a}	50.6 ± 5.0^{b}	52.5 ± 6.8	<0.001
Calving interval (month)	16.7 ± 6.0^{c}	24.8 ± 4.9^{a}	21.2 ± 4.6^{b}	20.4 ± 6.1	<0.001

[abc]Means in a row with different superscripts are significantly different at P<0.001

3.5. Reproduction performance of indigenous cattle

The reproductive performance traits such as age at first mating of bulls (AFS), age at first service of heifers (AFS), age at first calving (AFC) and calving interval (CI) for indigenous cattle are presented in Table 6.

3.5.1. Age at first service (AFS) of a bull

Age at first service is the age at which the breeding bull or heifer mates for the first time. The effectiveness of animal rearing can be evaluated if puberty comes as early as possible (Belay, 2016). The overall mean age of bulls at first service in the study area was 43.4 ± 8.6 months, with values of 45.1 ± 5.1, 49.1 ± 11.3 and 37.8 ± 5.3 months for the lowland, midland and highland agro-ecologies, respectively (Table 6). The overall result of the present study on AFS of bulls was comparable to the reported values of 43.20 months for Mursi cattle (Terefe et al., 2015) and less than 46.80 months for Malle cattle (Masama et al., 2003), and 55.20 months for Boran cattle (Takele, 2014). On the other hand, the values are longer than 36 months for Gamo Gofa cattle (H. Kebede et al., 2017) and 40.2 months for Arsi cattle, as previously reported. These differences in indigenous cattle in Ethiopia could be due to breed and management differences (Getaneh et al., 2019; Hidosa et al., 2017). The AFS for bulls in this study was lower for the highland agro-ecology than for the midland and lowland agro-ecologies, which contradicts the report of Adane et al. (2021) who recorded a lower value for the lowland agro-ecology.

3.5.2. Age at first service (AFS) of heifers

The mean age at first service of indigenous heifers in this study was 40.5 ± 6.9 months, with 41.2 ± 5.9, 44.6 ± 9.1 and 37.1 ± 3.7 months in the lowland, midland and highland agro-ecologies, respectively (Table 6). The overall mean AFS of heifers in this study was earlier than previous results of indigenous heifers reported by Benti et al. (2021) at 44.45 ± 0.167 months, Ftiwi and Tamir (2015) at 45.3 ± 0.5 months, Benti et al. (2021) at 43.7 ± 0.47 months, Kebamo et al. (2019) at 42.52 months and Hundie et al. (2013) at 48.9 months for Horro. However, the current study's result (40.5 ± 6.9 months) was longer than the results of Altaye et al. (2014) at 37.03 ± 6.5 months, Tadele & Nibret

(2014) at 30.8 ± 5.6 months, and W. Ayalew and Feyisa (2017) at 33.51 ± 0.70 months. The variation in AFS value in different studies on indigenous Ethiopian heifers was due to breed or management differences (Terefe et al., 2015); therefore, management factors, especially nutrition, determine pre-pubertal growth and reproductive development of the heifer (Masama et al., 2003).

3.5.3. Age at first calving (AFC)

In the current study, the overall mean AFC of indigenous heifers was 52.5 ± 6.8 months. The values for the lowland (52.3 ± 5.9 months), midland (55.8 ± 8.9 months) and highland (50.6 ± 5.0 months) agro-ecologies were significantly ($p < 0.001$) different (Table 6). The overall mean AFC of indigenous heifers obtained was earlier than previous studies on indigenous heifers in Ethiopia reported by Terefe et al. (2015) at 55.20 months; Getaneh et al. (2019) at 58.78 months; Adane et al. (2021) at 54.5 ± 0.2 months; and Yifat et al. (2012) at 1729.9 ± 58.2 days. However, the AFC value of our result was higher than previous reports by W. Ayalew and Feyisa (2017) at 42.85 ± 0.70 months; Ma'alin et al. (2021) at 4 years; Tadele and Nibret (2014) at 39.8 ± 5.6 months; M. Ayalew and Asefa (2013) at 47.16 ± 8.7 months; and Altaye et al. (2014) at 46.06 ± 13.99 months. The variation in the AFC of heifers across different studies may be due to breed and agro-ecological differences.

3.5.4. Calving interval (CI)

CI is the time interval between two consecutive calvings and is very important in terms of the cow's lifetime productivity. This is because a cow with a longer CI has fewer lactations and calves in her lifetime than a cow with a shorter calving interval (Ayeneshet et al., 2018). The overall mean CI of the indigenous cows in this study was 20.4 ± 6.12 months, which was significantly affected by agro-ecology (Table 6). The overall CI of the current study was comparable to the report of 20.9 ± 0.2 months by A. Kebede (2009), 21.36 ± 3.84 months by Duguma et al. (2012) and 622.6 ± 15.3 days in Boran cows by Yifat et al. (2012). However, the CI obtained is longer than 16.8 months reported by Takele (2014), 431.08 ± 78.03 days by Kumar et al. (2014) and 15.96 months by Tegegne et al. (2013) for indigenous cows in Ethiopia. On the other hand, our result was lower than the reported CI of 26.64 ± 0.6 months (Ayeneshet et al., 2018) and 24.9 months (M. Ayalew & Asefa, 2013). These differences between time intervals in the study could be explained mainly by differences in management, as diet can either positively or negatively affect concentrations of hormones and metabolites in cows (Benti et al., 2021).

3.5.5. Reproductive performance of cattle in different agro-ecologies

Reproductive performance of cow/heifer is the term used to describe an individual's production of offspring per breeding event or lifetime, and it can be evaluated using AFS, AFC, CI and life-time calf production. The reproductive performance of indigenous cattle in the current study showed a significant difference ($p < 0.001$) between agro-ecological zones. A better performance was found in the highland agro-ecological zone, but a lower performance was found in the midland agro-ecological zone than in the lowland and highland agro-ecological zones. Focus group discussion revealed that the reason for better reproductive performance in the highland agro-ecological zone of our study was that farmers bred their cattle for milk production and cash income from fattening and therefore conducted drought activities with their horses. Consequently, farmers applied better management to their cattle. The main reason for the relatively poor reproductive performance of indigenous cattle in the midland agro-ecology, as revealed by the group discussion, is that farmers in this area raise their cattle to support their crop production for the purpose of drought power rather than for the production of cattle products and by-products (Duguma & Janssens, 2016). As a result, during a severe forage shortage, farmers used special management to raise bulls or oxen rather than heifers or cows. Gakige et al. (2020) reported that the food-feed production dilemma affected the improvement of mixed crop-livestock production performance in east Africa. Therefore, strong extension work is required so that the farmers understand the benefit of livestock feed production. On the other hand, the reason for the relatively better reproductive performance of cattle in the lowlands compared to the midlands could be due to the better availability of pasture and the higher ambient temperature. In support of the result of this study, Hussein (2018) reported that cows reared in lowland agro-ecology reach first calving earlier than cows reared in midland and highland agro-ecology. According to Ayeneshet et al. (2018), it was explained that poor management practices greatly affect the reproductive performance of cows. In general, the reproductive performance of indigenous cattle was mediocre. To satisfy the alarming increase in the need for animal products and by-products, the performance of indigenous cattle still needs improvement. Therefore, improving management and applying controlled crossbreeding with high-performing breeds are important measures that should be taken by all stakeholders to improve the overall productivity of smallholder cattle production and the livelihood of the farmer in sub-Saharan Africa countries and east African regions that mostly practise this production system.

Table 7. Ranking of the major constraints of indigenous cattle production in the north western parts of Ethiopia. Index = sum of [(3 * number for rank 1) + (2 * number for rank 2) + (1 * number for rank 3)] given for an individual reason divided by the sum of [(3 * number for rank 1) + (2 * number for rank 2) + (1 * number for rank 3)] for overall reason.

	Agro-ecological zones												
	Lowland				Midland				Highland				
	Rank				Rank				Rank				
Production constraints	1st	2nd	3rd	Index	1st	2nd	3rd	Index	1st	2nd	3rd	Index	Overall index
Feed shortage	58	39	12	0.37	51	12	9	0.39	64	37	3	0.46	0.40
Genotype	11	23	35	0.16	9	30	10	0.2	29	10	44	0.21	0.19
Diseases	43	49	19	0.34	7	27	18	0.21	26	42	17	0.25	0.25
Drought	0	9	23	0.06	0	3	6	0.03	0	22	21	0.09	0.06
Water shortage	5	0	23	0.05	8	7	1	0.08	2	6	16	0.05	0.05
Market problem	3	0	8	0.02	2	4	34	0.1	0	5	17	0.03	0.05

3.6. Constraints of cattle production

Prioritization of constraints is the most important action for any livestock improvement and productivity programme (Bekele et al., 2016). Based on the respondents' rankings, the most important livestock production constraints were indexed (Table 7). Accordingly, overall, feed shortage (index = 0.40), disease prevalence (index = 0.25) and less efficient genotypes of indigenous cattle (index = 0.19) were the first three most important constraints to cattle production in the study areas (Table 7). As previous studies reported, feed shortages, diseases and the poor genetic endowment of indigenous animals were responsible for lower productivity (Chala & Ulfina, 2013). Bekele et al. (2016) reported that feed shortage, disease prevalence, lack of improved breeds, lack of market access and lack of water during the dry season were among the challenges in cattle production. According to Terefe et al. (2015), seasonal feed shortages, diseases and drought are the major problems of cattle production in southwest Ethiopia. Duguma (2013) also found that feed shortage due to lack of pasture and a high population are the major limiting factors for cattle production in eastern Ethiopia. This is similar to our study results, which revealed that feed shortage in the dry season is a major challenge for smallholder dairy production systems in different parts of Kenya (Kashongwe et al., 2017b; Nyokabi et al., 2022) and in South Africa (C. Mapiye et al., 2009; O. Mapiye et al., 2018). Several factors may contribute to the feed shortage; according to the report of Mutibvu et al. (2012), rain-fed natural pasture is used as the main source of smallholder cattle production, and both the quality and quantity of available pasture decrease when rainfall decreases, as findings from Masikati (2011) and Svotwa et al. (2007) show in different parts of Zimbabwe. The use of grazing lands for crop cultivation due to population growth and an increase in livestock are other reasons

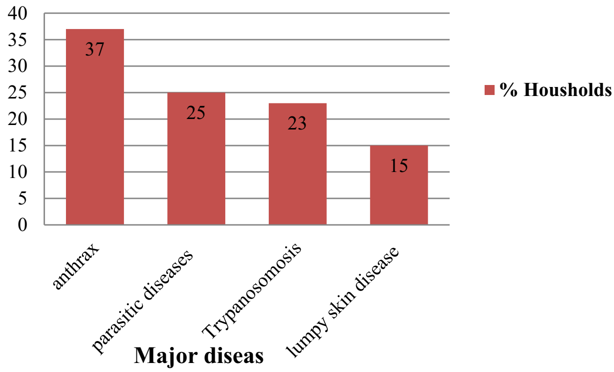

Figure 2. List of the most important cattle diseases in different agro-ecological zones of Ethiopia.

contributing to the feed shortage in Ethiopia (Bekele et al., 2016; Benti et al., 2021). On the other hand, in Uganda, Kiggundu et al. (2014) reported that the extreme dependence of farmers on grazing land with limited strategies for fodder conservation and supplementation is a factor in feed shortages. Even though feed shortages are a major issue throughout the year, they became particularly severe from March to May in all agro-ecological zones. Therefore, intensive advice on forage development, forage conservation and the reduction of herd size is an important solution to this problem in smallholder cattle production in different parts of the world that have similar agro-ecologies.

Diseases and parasites were the second most common limitation of cattle production, and the most frequently reported diseases were anthrax (37%), internal and external parasites (25%), trypanosomosis (23%) and lumpy skin disease (LSD, 15%) (Figure 2). Similar to our results, because trypanosomosis was more common in lowland agro-ecology than in midland and highland agro-ecologies, the problem was severe in lowland agro-ecology (Bereda et al., 2014). The overall result is consistent with previous studies on cattle diseases reported (Asmare et al., 2017; Tedla et al., 2018; Welay et al., 2018) in different parts of Ethiopia. Although the reported frequency of occurrence varies, diseases and parasites are the main challenges of smallholder production (O. Mapiye et al., 2018) and are responsible for increased morbidity and mortality of cattle (Agholor, 2013; Chaudhary et al., 2013) in different parts of the world. This is due to factors such as changing climatic conditions (Estrada-Peña & Salman, 2013), a poor management system (Chaudhary et al., 2013) and farmers' level of education or understanding. According to the finding of O. Mapiye et al. (2018), less educated farmers tend to have low income and might face a lack of money to purchase veterinary drugs for their animals.

Indigenous cattle breeds have been naturally selected for adaptive traits, and their genetic makeup is adapted to feed and water scarcity, disease and harsh climates (Ahmed et al., 2003; Effa et al., 2011). They are suitable for keeping multipurpose animals on a small scale. However, they are characterized by low production and reproductive performance (Tegegne et al., 2013). Accordingly, farmers in the studied areas reported that they were limited in improving cattle production and reproduction. Controlled crossbreeding with high-performing exotic breeds can improve the production performance and their adaptability to the local environment in smallholder cattle production.

Frequent droughts, marketing problems and water scarcity were also cited as constraints in improving cattle production in the study areas with lower index scores. These constraints were also reported by Onono et al. (2013) in Kenya and by Misganaw et al. (2017) in Ethiopia.

In general, the above constraints were interrelated that lack of forage combined with the increase in cultivated land and changing rainfall patterns contributed to disease outbreaks (Zoma-Traoré et al., 2020). Increasing population growth also reduced the land available for pasture development (Koutou et al., 2016; Zoma-Traoré et al., 2020).

4. Conclusions

This research contributes to the literature and data on smallholder cattle production constraints and the performance level of livestock. The study demonstrated that feed shortages in the dry season and diseases and parasites were major challenges that affected the performance of smallholder cattle production. Feed resource availability and quality are dependent on season, which could lead to low productivity and increased susceptibility to disease during feed scarcity. The reproductive performance of indigenous cattle in this study was mediocre compared to other indigenous breeds in Ethiopia. Agro-ecology is a determinant factor for a number of livestock management activities and performances. Even if dry season feed scarcity is a common challenge for the smallholder livestock production, specific local context solutions are required. Improving the education status of smallholder cattle keepers could bring a significant impact on the production performance and advancement of the sector.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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ORCID

Andualem Tenagne http://orcid.org/0000-0002-6246-7576
Mengistie Taye http://orcid.org/0000-0001-6795-9943
Bekalu Muluneh http://orcid.org/0000-0002-0338-7445
Damitie Kebede http://orcid.org/0000-0001-5494-9906
Getinet Mekuriaw Tarekegn http://orcid.org/0000-0001-7221-2473

Statement of ethics

The research project was presented to the Department of Animal Production and Technology (AnPt), College of Agriculture and Environmental Science, Bahir Dar University, and accepted and approved with a support letter (Ref. 1/1199/1-1-3 dated 24 February 2020).

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