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Source: Environmental Health Insights, 18(2)

Published By: SAGE Publishing

URL: https://doi.org/10.1177/11786302241274698

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Environmental Health Insights
Volume 18: 1–11

DOI: 10.1177/11786302241274698
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ABSTRACT: A significant limitation to cattle production is animal trypanosomosis, which threatens household food security and livelihoods. In addition to stalling livestock productivity, the disease has a devastating impact on animal health. Besides, halting livestock productivity, the disease has a devastating effect on health. Thus, the objectives this study was to assess the epidemiology, and financial impacts of bovine trypanosomosis on livestock producers' in Arba Minch and Zuria districts of Gamo zone, Ethiopia, from December 2021 to January 2023. Both repeated survey and cross-sectional study were carried out to assess the economic losses, estimate the prevalence and assess the determinants of bovine trypanosomosis. Direct microscopy was applied using buffy coat method to detect trypanosome parasite. The study included 182 households and 384 bovine species. Bovine trypanosomosis caused substantial economic losses through cattle mortality, drug purchases, and the oxen's loss of draft power. Also, farmers spent a significantly ($P < .05$) higher amount of money treating trypanosomosis than all other diseases combined. The annual losses per household were estimated to be 9528 ± 1754 Ethiopian Birr (ETB) (95% CI: 6065-12 992) (US$ 176.4) which were spent on purchasing trypanocidal drugs per year per household. The overall mortality from bovine trypanosomiasis was 8.8%. Many farmers prioritized draft power losses as the most significant impact of the disease. Analysis of blood samples also showed a 7.8% overall prevalence of bovine trypanosomosis. The disease burden was significantly ($P < .05$) higher in the black body coat animals compared to white ones. This study showed that trypanosomosis is an important animal health problem and a potential threat to health and productivity of cattle in Arba Minch and zuria districts of Gamo, Southern Ethiopia. The common trypanocidal drugs were administered by the farmers themselves. Hence, policymakers and professionals should prevent irrational drug use and regularly monitor local trypanocide usage.

KEYWORDS: Bovine trypanosomosis, economic impacts, epidemiology, Gamo zone, Ethiopia

RECEIVED: January 18, 2024. **ACCEPTED:** July 18, 2024.

TYPE: Original Research

FUNDING: The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research was graduate thesis research project and supported by Arba Minch University, Gamo Ethiopia. However, authors do not have publication fund.

DECLARATION OF CONFLICTING INTERESTS: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Introduction

In Africa, livestock development is impacted by tsetse-transmitted animal trypanosomosis. Approximately 10 million km^2 of sub-Saharan Africa are affected by this disease, which poses a serious threat to the survival and production of domestic livestock.[1] Consequently, it contributes negatively to overall development and to the country's food self-sufficiency efforts in particular by impeding livestock development and agricultural production. Due to its direct and indirect effects on agricultural and livestock production, this disease costs the national economy more than US$200 million every year.[2,3]

In Ethiopia, approximately 65.35 million cattle, 39.89 million sheep, 50.50 million goats, and 12.45 million horses are at risk within the 180 000 to 220 000 km^2 of agriculturally viable land affected by trypanosomosis.[3,4] The animal trypanosomiasis, however, affects some of these populations of animals. There are more than 3 million animal deaths caused by African animal trypanosomiasis (AAT) every year, and 50 million animals are at risk of contracting the disease.[5] AAT renders vast semiarid and lowland areas unsuitable for breeding domestic animals that are a source of dairy and meat products, it is one of the main hindrances to food security. Since livestock rearing is mostly practiced in rural communities, this results in an economic loss of approximately 20% of agricultural productivity as well as a slowdown in rural development.[6,7]

Tsetse-transmitted trypanosomosis affects various mammals, but it is particularly important to cattle from an economic perspective. It is characterized by intermittent fever, parasitemia, anemia, lymphadenopathy, jaundice, progressive emaciation, weakness and reduced productivity.[8] The transmission of this debilitating and fatal disease not only thwarts the rearing of livestock as banking system, but also their use for traction in resource-poor regions like Ethiopia.[9] Along with livestock deaths, the disease results in direct losses through reduced meat and milk production, indirect losses from reduced fertility and drought capacity, and increased livestock production costs.[10] Globally, trypanosomiasis related losses could amount to 4 to 4.5 billion US dollars annually in direct and indirect economic losses.[11]

Host factors, such as physiological status, nutrition, and the environment, determine the severity of the disease as well as pathogenicity. Tsetse fly (*Glossina* species) is the vector that transmit the parasite, *Trypanosoma* species. Animals infected with *Trypanosoma congolense*, *Trypanosoma vivax*, or *Trypanosoma brucei brucei* exhibit varying parasitemia marked by intermissions and paroxysms.[12] As a result, the animal becomes anemic, develops rough hair coats, has abortions, produces less milk, suffers intermittent pyrexia, gets depressed, and eventually dies due to extreme emaciation.[13,14] Moreover, iatrogenic transmission could also occur when using the same needle or surgical instrument on more than one animal, at sufficiently short intervals, that the blood on the needle or instrument does not dry.[1]

Leta et al[15] reported that bovine trypanosomosis is prevalent in Ethiopia at a various proportion ranging from 1.38% to 17.15%. In Ethiopia, there are 5 major trypanosome species that affect livestock: *Trypanosoma congolense, T. vivax* and *T. brucei* in cattle *T. evansi* in camels, and *T. equiperdum* in horses.[15,16] It is estimated that the direct loss due to mortality caused by trypanosomosis in Ethiopia amounts to 1.5 to 2 billion Ethiopian Birr each year.[16] Trypanosomosis is one of the most significant livestock illnesses in the Gamo zone, Arba Minch Zuria district.[17,18] The tsetse fly species, *Glossina pallidipes*, and biting flies (*Stomoxys* and *Tabanus*) have been reported as the vectors of this disease, which limits livestock productivity and threatens lives and livelihoods.[19]

In Gamo zone of southern Ethiopia, veterinarians and farmers regularly use a variety of brands and sources of trypanocidal drugs to control trypanosomosis. The practice of irrational drug use and management, which in turn causes financial loss, has been reported across Ethiopia.[20,21] Understanding the disease's socioeconomic burden and the feasibility of controlling is essential to enhancing farmers' livelihoods and economies affected by trypanosomiasis.[22] With regard to the epidemiological status, the impacts of bovine trypanosomosis, no comprehensive study has been conducted to address the financial losses caused by this disease on livestock producers in the extensive farming system in Gamo zone. However, bovine trypanosomosis is an endemic disease in the study area.[18,19] Therefore, purpose of this study was to provide baseline information on the epidemiological aspects and financial impacts of the disease based on the livestock producers perspectives and observations in an extensive farming system.

Materials and Methods

Description of study area

The present study was conducted in Peasant Associations (PAs) in Arba Minch city and Zuria, Gamo Zone in Southern Ethiopia, which is located about 502 km southwest of Addis Ababa (Figure 1). The study includes 5 PAs from Arba Minch city and Zuria namely: Shara, Wozeqa, Chano Mille, Chano Dorga and Genta Kanchama bordering Kulfo and Harre, rivers which separately enter the Chamo and Abaya lakes respectively. The area has a sub-humid climate with a moderately hot temperature; vegetation is dominantly occupied by wood-grass land especially along the sides of grazing. The climate alternates with long summer rainfall (June-September) and winter dry season (December-March) with mean annual rain fall of 750 to 930 mm. The mean annual temperature is 30°C which is between 10°C and 37°C and the altitude ranges from 1200 to 3125 m above sea level.[19] Marshy areas are commonly found in the lowland areas of the majority of the study PAs in which most of time livestock are grazed. Along with recently expanded cultivated lands, there are different types of vegetation, including savanna grasslands, forests, and riverine areas. These vegetation types are mostly found in areas occupied by cultivated land and pastures. The existence of tsetse fly and tsetse transmitted trypanosomosis was also reported.[17,18,23,24]

Socioeconomic and farming practices in the study area

A mixed farming system is practiced in this area, in which livestock plays a significant role in agricultural production. Livestock provide meat, milk, cash income, and used for transportation purposes. The livestock species reared include cattle, sheep, goats, and equines. Animals are kept in a communal grazing system with herds; locally, called it "Wudde." The herd is owned by 7 to 10 owners or household levels with the average number of animals per herd estimated to be 100 for cattle. The herds are managed in outdoor system by close supervision of one owner.

Study population

In Arba Minch and zuria, the population of cattle found in various agroclimatic conditions in the 5 selected PAs was estimated at 155 617.[4] Generally, animals are managed by extensive production system; utilize communal grazing and watering points. Herds without prior disease exposure and herd owners who chose not to participate voluntarily were excluded from the study. Cattle and/ or households are final sampling units of the study; herd is defined as the collection of different age, sex and body condition groups of cattle owned by 7 to 10 owners or household or family members.

Study design

A cross-sectional study was undertaken to estimate the prevalence and assess determinants of bovine trypanosomosis in selected areas. A repeated questionnaire survey was carried out for a year, that is between December 2021 to January 2023 to assess the economic impacts of the animal diseases at household level in general and bovine trypanosomosis in particular from farmers' perspective using structured questionnaire survey. The study approach was based on the identification of the disease by animal owners that was asked for indigenous knowledge that could describe the clinical symptoms of the disease. The records of the district veterinary clinic was used to scrutinize clinically affected animals as described in Radostits et al,[25] and the financial assessment for herds were assessed based on.[26,27]

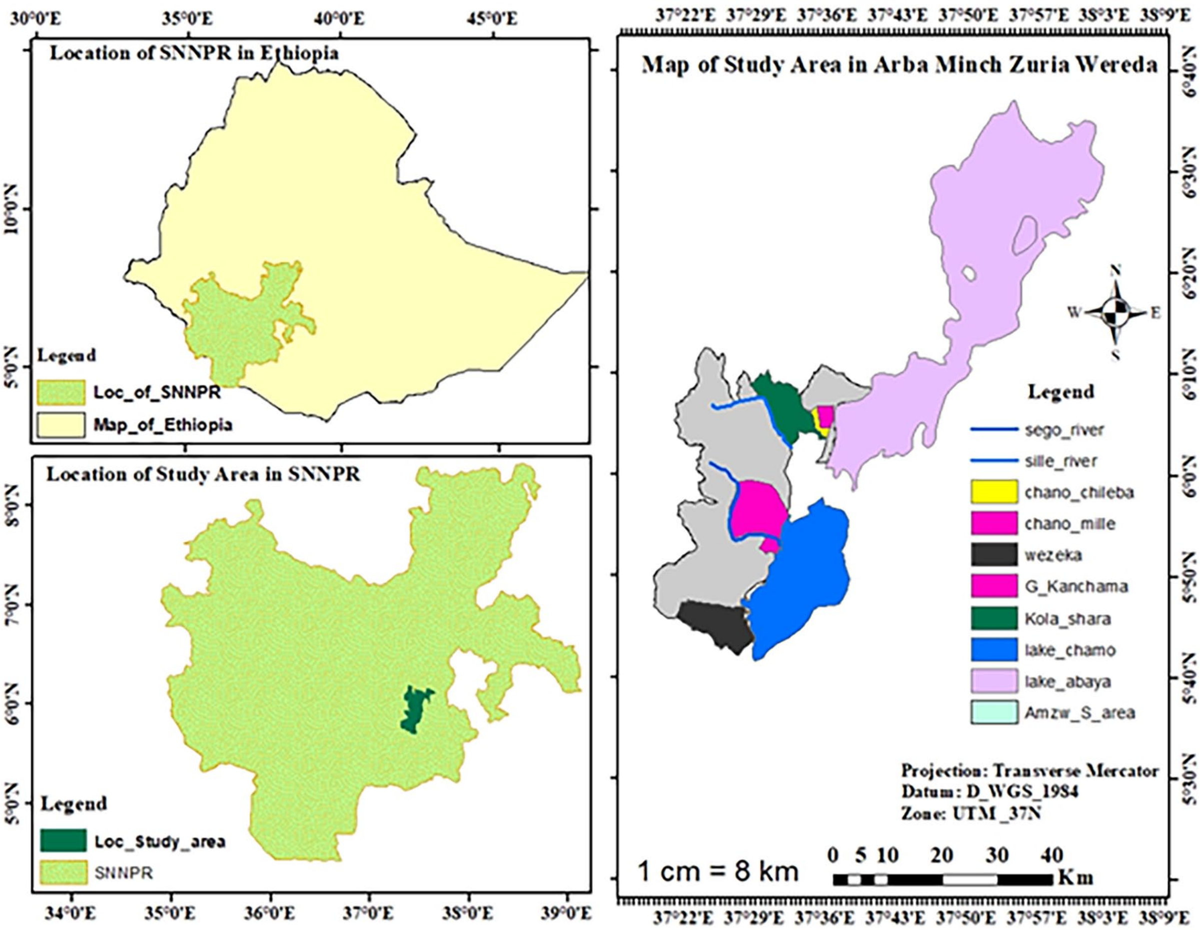

Figure 1. Map showing the location of study areas, Gamo Zone, Southern Ethiopia.

Sampling technique and sample size determination

This study was carried out in 5 selected PAs of Arba Minch and Zuria districts. The districts were purposefully selected based on the livestock population and the endemicity of trypanosomosis, PAs were chosen at random. From selected PAs, households and respective herds were selected by simple random sampling to assess the economic losses and experience of the herd owners for the occurrence of the disease in their herd. According to the PA population size, 182 households were chosen to maintain representative proportion until the total sample size was reached.

A 2-stage cluster sampling technique formulae was used to calculate the actual sample size for individual cattle, having the following parameters predetermined: CI = 95%, desired level of precision 5%, expected prevalence 10%[19] and in between cluster variance 0.0157.[28] An average of 7 cattle were found in each herd. With the formula, the number of animals to be sampled was based on the fixed number of clusters is as follows:

$$\mathrm{Ts} = 1.96^2\,\mathrm{g}\left\{Pexp\left(1-Pexp\right)1-Vc\right\}$$

$$\mathrm{gd}^2 - 1.96^2\,\mathrm{Vc}$$

Where, Ts = number of animals to be sampled; Vc = between cluster variance; d = desired level of precision; pex*P* = expected prevalence; g = number of dusters needed

A total of 396 cattle from the 182 households were picked randomly from the study areas. On average 2 animals per householder was sampled.

Study methodology

Parasitological study. Blood samples from the superficial ear veins of each animal were collected using heparinized capillary tubes, which were then sealed with Cristaseal. These tubes were subsequently placed in a hematocrit centrifuge and spun at 1200 revolutions per minute for 5 minutes. Packed cell volume (PCV) is measured by using hematocrit reader for determination of the level of anemia, and those values less than 25% were regarded as anemic. The capillary tubes were then cut using a diamond pen at about 1 mm below the buffy-coat to include the upper most layers of the red blood cells and 3 mm above to include the plasma. The content of each capillary tube was pressed onto a microscopic slide, and covered with 22 mm × 22 mm cover slip. Each sampled slide was examined under 40X objective lens for the presence of motile trypanosomes.[29,30]

Table 1. Percentage of cattle herd structure.

CATTLE CATEGORY	NUMBER	PERCENTAGE (%)
Lactating cow	303	18.1
Dry cow	230	13.6
Heifers	283	16.8
Calves	333	19.8
Oxen	534	31.7
Total	1683	100

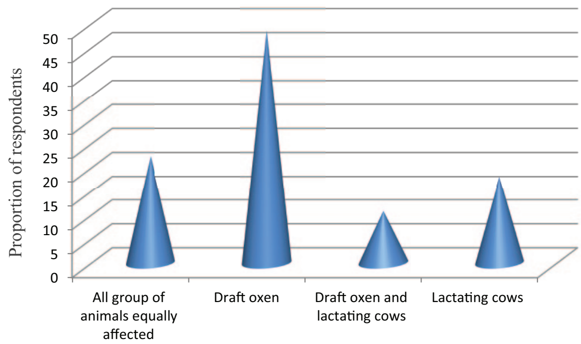

Figure 2. Group of cattle were severely affected by trypanosomosis as perceived by owners.

Questionnaire survey. A repeated cross-sectional questionnaire survey was conducted face-to-face with the herd owners. The data obtained from the survey of the households was supported by secondary data from the respective PAs of the study areas, and local markets. These data were compared with the base line production parameters of the normal herd and with the herds that would be affected by bovine trypanosome. The questionnaire designed was based on literature.[9,26,31] The first section encompassed herd size and composition within the selected PAs and households. The second section focused on physical and financial losses in the affected herds, specifically addressing the number of deceased animals. The third section included questions on market prices of various livestock and their products, as well as treatment and feed costs. Lastly, herd owners were queried about the frequency of veterinary clinic visits for sick animals, and their use of prophylactics or curative measures before and after disease occurrence.

Estimation of economic losses due to bovine trypanosomosis. This study was used to estimate quantitatively the direct economic losses due to cattle mortality, and drug purchase. Moreover, farmers were asked to rank the effects of trypanosomosis based on parameters like milk yield, draft power losses, cost of trypanocides, and mortalities. The economic impact of trypanosomosis were determined by an estimation of the direct (visible) production losses such as mortality, draft power and indirect impacts like control costs using the framework for economic impact assessment of livestock disease.[9,22,27,32,33]

Data analysis

The repeated survey and parasitological data were recorded in a Microsoft Excel spread sheet. STATA version 14.2 computer software was applied for statistical analysis at a 95% confidence interval. Trypanosomosis prevalence is computed by dividing the number of infected cattle by the total number of sampled animals and multiplying the result by 100. Cattle deaths caused by trypanosomosis in households during a year were added to estimate the mortality rate due to trypanosomosis-induced death of cattle. Those variables with a P-value $< .05$ in univariable logistic analysis was considered statistically significant risk factors. Linear regression was used to compare the cost of trypanocidal drug purchase among the 5 peasant associations, the cost of treating trypanosomosis, and the cost of treating all other animal diseases. In all cases, 95% of confidence intervals were used and P-value $< .05$ were considered as significant.

Result

Socioeconomic status and herd structures

All respondents' livelihoods depend on mixed-crop livestock production systems. Animals play an essential role in agriculture, providing food, income, and transport. The total number of animals observed during this time series cross sectional study (repeated survey) for a year was 1683 cattle. The percentage of age- and production-specific herd structures was shown (Table 1).

Household awareness on bovine trypanosomosis

Household awareness. Most of the participants (98%, 95% CI: 94.3-99.3) believed that trypanosomosis, locally called "Gendi" in Amharic and "Wuxale" in Gamogna, was the major livestock disease. Moreover, 65.5% [95% CI: 57.6-71.4] of the study participants reported that the disease is at its peak during the wet and prolonged rainy seasons.

Fifty-one of the livestock producers claimed that draft oxen are more susceptible to bovine trypanosomosis than other cattle groups (Figure 2). Moreover, 10.8% and 18.2% of the farmers who responded stated that greater issues with trypanosomosis is common encounter in draft oxen and lactating cows, respectively, and in lactating cows alone. However, 22.4% of respondents claimed that the disease affected every animal group equally.

Farmers' perception of signs of bovine trypanosomosis. Herders' knowledge on diagnosis of bovine trypanosomosis were shown in Table 2. According to the claims made by the respondents, the most commonly reported symptoms of trypanosomosis were, in decreasing order, rough hair coat, diarrhea, lacrimation of the eyes, constipation, anorexia, emaciation, and coughing. Among the 182 responders, 78.4% disclosed diarrhea, eye lacrimation,

Table 2. According to respondents' perceptions, the most frequently observed clinical signs of trypanosomosis.

CLINICAL SIGNS	KANCHAMA (N = 47)		QOLA SHARA (N = 35)		WOZEQA (N = 33)		CHANO MILLE (N = 17)		CHANO DORGA (N = 50)		TOTAL (N = 182)	
	N	%	N	%	N	%	N	%	N	%	N	%
Ruffled hair	34	72.3	29	82.8	26	78.8	15	88.2	45	90.1	149	81.8
Progressive emaciation	32	68.1	33	92.3	28	84.8	13	86.7	48	96.0	154	84.6
Physical weakness	29	61.7	20	57.2	18	54.5	9	52.9	42	84.0	118	64.8
Reduce production	33	70.2	21	60.0	26	78.7	16	94.1	38	76.0	134	73.6
Depression	27	57.4	26	74.3	23	69.7	8	47.0	34	68.0	118	64.8
Loss of apptence	28	59.6	15	42.8	19	57.6	12	70.5	25	50.0	99	54.4
Lacrimation	23	48.9	21	60.0	18	54.5	10	58.8	28	56.0	100	54.9
Constipation	12	25.5	8	22.8	13	39.4	7	41.2	17	34.0	57	31.3
Swelling of lymph nodes	21	44.7	12	34.3	7	21.2	5	29.4	25	50.0	70	38.4
Salivation	9	19.2	13	37.1	10	33.3	11	64.7	13	26.0	56	30.7
Diarrhea	11	23.4	18	51.4	14	42.4	7	41.2	16	32.0		

Table 3. Average yearly treatment costs per household (in ETB) for bovine trypanosomosis and other diseases.

STUDY SITES	TREATMENT COST OF TRYPANOSOMOSIS (ETB) (MEAN ± SE)	TREATMENT COST OF OTHER DISEASES (ETB)	ALL TREATMENT COST DUE TO DISEASES (ETB)	*F* VALUE (*P* VALUE)
Ganta Kanchama	4173 ± 232	3357 ± 121	7,430 ± 1144	
Chano Mille	6,823 ± 872	3,077 ± 530	9,900 ± 1402	4.13
Channo Dorga	2,560 ± 886	1,240 ± 217	3,800 ± 1103	(0.0032)
Shara	19,040 ± 2216	10,090 ± 2216	29 130 ± 4216	
Wozeka	18,245 ± 7123	10,118 ± 6174	28,363 ± 13 297	
Gross mean	9,528 ± 1754	5276 ± 1852	14, 624 ± 1693	

and a rough hair coat as common signs of trypanosomosis. Even though trypanosomosis lacks pathognomonic signs, the majority of farmers in the study locations could recognize the typical clinical signs of the disease listed in veterinary literature.

Costs of purchasing drugs to control bovine trypanosomosis

The average amount of money spent per household for the treatment of all livestock diseases was 14 624 ± 1693 Ethiopian birr (ETB) (95% CI: 9309-19 940) (US$ 270) per year, of which 9528 ± 1754 ETB (95% CI: 6065-12 992) (US$ 176.4) was spent on purchasing trypanocidal drugs per year over household (Table 3). About 85.2 ETB (US$ 1.6) was for one animal (in this case cattle) on trypanosomosis treatment per month. Most farmers treat their animals on a 15-day basis. For each animal, more than 15 doses could be purchased annually based on the average market price of 110 ETB (US$ 2) during the study period.

Table 3 shows that the mean expenditures for treating all diseases in Wozeka were substantially greater than in other PAs (Chano Dorga and Ganta Kanchama). In contrast, Shara Kebele spent more than Wozeka on treating trypanosomosis. Trypanosomosis treatment expenses were substantially ($P < .05$) more than the other illness treatment expenses in the districts (Table 3).

Trypanocidal drug utilization practices

During the interview, participants disclosed that the primary method utilized to manage trypanosomosis in their herds was the use of trypanocides in combination with antibiotics and insecticide. Trypanocides was used widely by cattle keepers as both curative and prophylactic measures. Diaminazine and isometamidium were the most often used trypanocides, while tetracycline and pen-strep were frequently used antibiotics. In addition, tsetse flies control was effected by chemicals like Delthametrin 1% spraying. (Table 4).

Most respondents reported that they relied primarily on Isometamidium chloride (ISM) and Diminazene aceturate were the trypanocides used as preventive and curative for treating trypanosomosis. Compared to ISM (31%), diminazene aceturate (DA) was the medication of choice (69%). This was because diminazene was more affordable and could be found in single dose or sachet form across all suppliers. However, 59% of the farmers said they treat their animals 15 or more times a year with trypanocidal medications, either directly or through family members (Table 4). According to 58% of the farmers surveyed, medications obtained from approved private suppliers and government veterinary clinics had a higher chance of being effective than those obtained from unauthorized open marketplaces.

Of those who responded, 89.1% treated their animals because they believed the animals had trypanosomosis; however, only 42.6% used ISM for prevention, and 34.7% used it for treating sick animals. A total of 95.4% (95% CI: 91.4-97.8) of farmers used varying doses of DA based on the age groups; for ISM, 34.5% claimed the same dose to all age category was given. Calves never received treatment, while oxen are treated nearly 20 times/year, with cows and bulls falling in between. Farmers are caring for their livestock alone in 66% of the cases. The percentage of farmers that administer DA and ISM on their own is 59% and 57%, respectively (Table 4). Participants also revealed besides common trypanocides, Tetracycline and Pen-strep were the most common used antibiotics. They also disclosed tsetse flies were controlled through spraying using insecticides like Delthametrin 1%.

Table 4. Different practices and trypanocidal drug utilization used by farmer in the districts.

DRUG USE PRACTICES	DA—% OF FARMERS	ISM—% OF FARMERS
Use of the trypanocide		
Yes	69.2	30.8
Use of the trypanocide		
Treat trypanosomosis	54.4	34.7
Prevent trypanosomosis	25.6	42.6
Use depends availability	20.0	23.7
Dilute and keep left over		
Yes	25.8	56.3
No	74.2	43.7
Treatment season		
Wet	7.9	18.9
Dry	8.5	32.2
Both	83.6	48.9
Drug dilution medium		
Boiled water	1.5	1.5
Well water	98.5	98.5
Drug administration		
Farmer	59.0	57.2
Veterinary assistant	41.2	42.8
Drug use frequency		
Once per month	20.1	10.1
Two times per month	78.2	85.1
Two times per year	2.1	5.2
Dosing a drug		
Same dose to all age category	4.6	34.5
Dose young and adult based on size of animal	95.4	65.5
Use of other chemicals (like Deltamethrin 1%)		
Yes	95.5	95.5
No	4.5	4.5

Costs associated with cattle mortality from trypanosomosis

The annual mean mortality loss was estimated to be 9817 ETB (USD 181.8) per household. It is based on current market estimation and the cost was determined if animal death was observed.

Mortality rate due to trypanosomosis

According to the respondents, cattle deaths were 64.2% (117/182) of the total annual deaths in the last 12 months (2021/2022) (95% CI: 57.1-70.9), and the mortality rate of cattle was 8.8% (Table 5).

Prevalence of bovine trypanosomosis

Trypanosome infection was found in 31 of the animals examined using the buffy coat method, yielding an overall study area prevalence of 7.8% (Table 6).

Analysis of trypanosomosis prevalence with animal factors

The following variables were taken into account in the univariate logistic regression analysis of trypanosomosis presence: sex, age, coat color, and body condition score (BCS). A statistically significant association was seen for BCS, and coat color

Table 5. Mortality rate of cattle due to trypanosomosis in 5 kebeles in the 12 months study.

STUDY SITES	NO. OF DEATHS IN 1Y	CATTLE DISEASED BY TRYPANOSOME IN 1Y	MORTALITY (%)
Ganta Kanchama	16	199	8.1
Chano Mille	4	54	7.4
Channo Dorga	8	96	8.3
Shara	26	294	8.8
Wozeka	29	299	9.7
Total	83	942	8.8

Table 6. Prevalence of trypanosomosis in Arba Minch and zuria district.

VARIABLE	CATEGORY	NUMBER OF ANIMALS EXAMINED	NUMBER OF INFECTED ANIMAL (%)	95% CONFIDENCE INTERVAL
Study district	Ganta Kanchama	112	10 (8.9)	4.75-15.83
	Chano Mille	46	3 (6.52)	1.56-18.15
	Channo Dorga	46	5 (10.8)	4.28-23.58
	Shara	59	4 (6.78)	2.21-16.64
	Wozeka	135	9 (6.67)	3.36-12.25
Total		398	31 (7.8%)	5.52-10.87

Table 7. Univariable logistic regression for risk factors associated with prevalence of bovine trypanosomosis.

VARIABLE	CATEGORY	ANIMALS EXAMINED	NO. OF INFECTED ANIMAL (%)	OR	95% CI	*P*-VALUE
Sex	Male	180	14 (7.78)	-	-	Ref
	Female	216	17 (7.41)	1.07	0.62-1.85	.782
Age	Adult	237	18 (7.59)	-	-	Ref
	Young	159	13 (8.17)	1.205	0.71-2.04	.489
Color	White	118	5 (4.24)	-	-	Ref
	Red	102	6 (5.88)	1.33	0.50 - 3.56	.559
	Black	176	20 (11.4)	8.32	3.37-20.52	.001
BCS	Good	111	5 (4.51)	-	-	Ref
	Medium	137	8 (5.84)	1.19	0.51-2.76	.674
	Poor	148	18 (12.2)	3.37	1.62-6.99	.001

($P < .05$), but not sex and age of the study districts ($P > .05$) (Table 7). Moreover, in poor body conditioned animals, the odds of bovine trypanosomosis occurrence was 3.4 times higher compared with normally body conditioned animals (OR = 3.37, $P < .05$).

Compared with white animals, black-colored animals had a significantly higher incidence of trypanosomosis (OR = 8.32, $P < .05$). Trypanosomosis was more prevalent in black-coated animals than in those of the other colors in the study area.

Discussion

Most of the farmers mentioned that bovine trypanosomosis was the major livestock disease in the area. This is consistent with results reported elsewhere in Africa and in the country where tsetse transmitted trypanosomosis is prevalent.[15,34-36] In Baro-Akobo and Gojeb river basins, south-western Ethiopia, all farmers interviewed stated trypanosomosis was the most serious disease they encountered.[3] Similarly, in a survey conducted in Nigeria's Tsetse and Trypanosomosis Control Project areas, farmers were very familiar with the disease and gave it top priority due to its catastrophic effects on their farming operations.[6,37] It is also in agreement with Fesseha et al[38] and Seyoum et al[19] have ranked trypanosomosis as the top obstacle to cattle productivity that study district was tsetse-infested and that the disease results in observable losses in production. The studies conducted by Afewerk et al[39] and Tewelde et al[40] confirmed that farmers strongly recognized trypanosomosis as the primary problem for livestock productivity and agricultural development in the northwestern and western parts of Ethiopia, respectively. This is related to its profound morbidity and mortality effects.

As shown in Figure 2, 50.9% of livestock keepers stated that bovine trypanosomosis is severe in draft oxen than in other groups of cattle. In contrast, 22.4% said that the disease was equally severe in all groups of animals. On the other hand, 10.8% and 18.2% of the respondent farmers noted that more trypanosomosis problem has been encountered in draft oxen and lactating cows, and lactating cows alone, respectively. For 50.9% of farmers, the most significant effects of trypanosomosis came from draft loss caused by oxen sickness. Similar finding was reported by Seyoum et al[3] that showed 49.5% of animals' affected was working oxen. The farmers noted that due to bovine trypanosomosis, oxen worked inefficiently and draught cattle could not be introduced into tsetse-infested areas for crop farming.

Even though trypanosomosis lacks pathognomonic signs, the majority of farmers in the study locations were able to identify the typical clinical signs of the disease, which are listed in the veterinary literature.[8,14,23] Similarly, according to a study carried out in tsetse-infested regions of 3 West African countries, the majority of farmers who were interviewed were able to list the typical trypanosomosis clinical signs.[41] However, the level of precision depends on the experience of the livestock keepers. Farmers were aware of several bovine trypanosomosis clinical signs, but many were unaware of the more subtle and less obvious signs such as anemia, fever, and swollen lymph nodes. Nonetheless, farmer diagnosis was evaluated in the endemic area, and farmer practical competence to diagnose the disease was higher than indicated by their understanding of signs.[38,41,42] This shows that farmers use their knowledge of the signs of the disease to treat their animals, and it was a comparable understanding of the problem as reported in other African countries.[41-43]

The average annual expenditure per household in the study area for treating all animal diseases was estimated to be 14 624 ± 1693 Ethiopian birr (ETB) (95% CI: 9309-19 940) (US$ 270) in this repeated survey. Of this, 9528 ± 1754 ETB (95% CI: 6065-12 992) (US$ 176.4) was spent annually per household on trypanocidal drugs. A study conducted by Chanie et al[46] in Ethiopia showed that estimated annual expenditure on preventive drugs was about 480 ETB per household (US$28.23), which is almost 20 times higher due to increased rate of US$ and current drug price. The cost in the current study is relatively 4 times higher in US$ as compared to the study conducted by Cattand et al[44] that reported average costs for animals treated using insecticides. The cost amounts to US$ 43.3/house hold per year and expend US$ 34.12 per household for curative drugs to treat the sick animals. The cost in this study is 1/6th of the national per capita,[45] thus it affects highly the livelihoods of livestock producers in the area. Costs of trypanocidal drugs have been increasing from time to time.[3,31,46]

In this study, 59% of farmers administered trypanocidal drugs by themselves or through family members, and 85% of them indicated that they treat their animals 15 or more times per year. The same results were reported by Tewelde et al[40] and Chanie et al[46] that 57% and 43% of the drugs were applied by farmers themselves and other uncertified people, respectively. In line with in a survey in West Africa,[47] trypanocidal medications were prescribed in more than 90% of instances without a precise diagnosis of the disease entity. Treatment is given on 15 days to 1 month without assessing clinical signs supposedly the animals is clinical cases. This is in agreement to studies that showed 85% of the treatment was given for clinical cases in the areas of Zambia[48] and upper Didessa valleys of Ethiopia.[40,49] This might be due to farmers suggestion that most cases are asymptomatic and characterized by progressively reduce production and loss of body weight; this is so farmers can treat them in advance before such parameters occur assuming they think the animals have trypanosomosis.[50] This can help them reduce their losses and protect their livestock from the effects of the infection.

The most widely used method of treating trypanosomosis was the use of both curative and prophylactic trypanocides. During the survey year, Diminazene was used by 95.5% of farmers compared to 48.1% for Isomethamedium. This is similar to a study reported by Tekle et al.[49] The difference in usage between the 2drugs could be attributed to trypanocides venders, including pharmacies, offering Diminazene in single doses or sachets at a lower price. Farmers who use curative trypanocides to treat trypanosomosis aggravate the risk of abuse and irrational use of this drug, especially if they administer the medication themselves. In accordance with Tesfaye et al,[21] 70% of farmers use DA to treat their animals. 95.4% of farmers used different doses of DA based on the differences in age category. Oxen are treated frequently (nearly 20 times per year), calves almost never, and cows and bulls are treated in between.

Field observation and interviews with farmers conducted throughout the year revealed that 8.8% of cattle died from trypanosomosis. In accordance with Iwaka et al [51] reported that trypanosomosis increases calves' mortality rates by 6% to 20%, reduces their calving rates by 6% to 19%. Likewise, it has been stated that mortality due to bovine trypanosomosis is common in areas where tsetse fly infestations are present, and deaths could be outnumbered by 20%.[52] In this study, trypanosomosis-triggered mortalities cost households approximately 9817 ETB (US$ 181.8) per year based on estimates of market prices for animal that died of the disease. It is based on current market estimates, and the cost was calculated if individual animal deaths were observed in each household. In this case, mortality was measured in terms of death and culling of animals due to poor body condition. According to Iwaka et al[51] the existence of trypanosomosis in a given area may reduce calving rates, and hinder the improvement of genetics and intensification of livestock production.

A blanket treatment of 15 trypanocide doses per bovine per year was observed for the control intervention. Seyoum et al[3] stated a comparatively similar report that annual treatment ranges between 1 and 12 injections/animal per year, where farmers gave injections on their own, without consulting a veterinarian. This is also in line with the observations of Van den Bossche and De Deken[53] in Eastern Zambia. This shows the use of prophylactic treatment is not effective for 3 months in the tsetse challenged area and it may be due to drug resistance. Trypanocides in combination with antibiotics and insecticide was used to control trypanosomosis within their herds. The antibiotics like Tetracycline and Pen-strep were the most common used in Ethiopia as documented by studies.[3,40]

In total, 384 cattle were tested using the buffy coat technique, 31 were positive for trypanosome infection, with an overall prevalence of 7.8%. This result was higher than the findings of Teka et al,[54] Girma et al,[55] and Anjulo et al[56] who reported overall prevalence of 4.1%, 1.56%, and 1.75%, respectively. In contrast, Zecharias and Zeryehun[57] reported high prevalence of disease (27.5%). Higher prevalence values were also reported by Degneh et al[16] from different parts of Ethiopia. These variations may be caused by differences in the study season, management system, vector infection, fly control operations, animal susceptibility, and use of trypanocidal drugs, increased tsetse challenges, and level of awareness of the disease among animal owners in a given region.

In logistic regression analysis, black-colored animals were significantly more likely to develop trypanosomosis ($OR = 8.32$, $P < .05$). This is due to fact that *Glossina* species are more drawn to huge, dark colors, such as cow skins.[53,58] Moreover, animals with poor body condition were more affected by trypanosomosis when compared with those in good or medium body conditions. Bovine trypanosomosis is a wasting disease that causes a progressive loss of body condition, although it is also possible for other conditions, such as concurrent dietary deficiencies and parasite disorders, to cause poor body condition.[59]

This finding suggested that the mixed agricultural community in the study districts were facing bovine trypanosomosis burden. The bovine trypanosomosis burden and costs associated with the disease indicated significant financial losses to the livelihoods of cattle farmers in Arba Minch and Zuria. However, limitations researcher encountered during study was that herd owners in the study districts did not maintain records of the production and health parameters. To address this, researcher chose areas where bovine trypanosomosis is endemic and spoke with farmers one-on-one about how the disease had impacted their herds in the previous year. Responses were cross-checked and several sources of information were taken into consideration in order to increase the validity of the information provided by the respondents and to offset the potential recollection bias inherent to any questionnaire survey. Another main study limitation was inability to evaluate the production costs of each farming method led us to estimate cow sales rather than the system's benefits. Furthermore, with home slaughter, gifts, and herd transfers, cash is not the main source of livestock output in large systems.

Conclusions

In this study, majority of participants thought that trypanosomosis was the main issue affecting animal health and that it could pose a threat to the productivity of cattle in Arba Minch and zuria, Gamo, southern Ethiopia. This also shows trypanosomosis was found to cause substantial losses to the local farmers through cattle mortality, trypanocide drug costs, and draft power loss of oxen and debilitation of lactating cows. The overall mortality rate due to bovine trypanosomosis in the area was 9.3%. A parasitological prevalence was 7.8%, with Chano Dorga having the greatest proportion at 10.8%. Veterinary clinics and farmers in these tsetse-infested areas commonly use Diminazene and Isomethamedium for trypanosomosis control, as well as chemicals like Deltamethrin 1% to control *tsetse* flies. As long as future integrated control programs involve the active participation of communities, farmers' knowledge of trypanosomosis can play a crucial role in controlling both tsetse and trypanosomosis. Thus, policy makers and professional body concerned should regularly check the type of trypanocides that circulate in the area. It is essential to conduct further research in this area to determine the extent of trypanocidal drug resistance, as well as farmers' views on the efficacy of the current available trypanocides. Using partial benefit analysis, cost benefit analyses should also be conducted.

Acknowledgements

The authors would like to acknowledge Arba Minch University for the financial support to conduct this investigation. We also thank owners of the animals and cooperation during sample collection from the field.

Author Contributions

DD drafted the proposal and the manuscript, collected, analyzed and interpreted the data. ET facilitated and supervised the data collection and edited the manuscript. All authors edited, reviewed and approved the final manuscript.

Ethics Approval and Consent to Participate

The research was in accordance with ethical values. Animal owners were informed by verbal consent to take part in the study. Participation in the study was voluntary. The sampling sites were disinfected just both before and after collecting blood samples, and animals were handled humanely.

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