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(RESEARCH ARTICLE)

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Socioeconomic impact of bovine brucellosis in Mandelia Prefecture, Chad.

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Abstract

Bovine brucellosis is a zoonosis that has a direct impact on animal production and farmers' incomes. The objective of this study was to describe the socio-economic characteristics of bovine brucellosis in sedentary herds in the Mandiagho canton, Chari Baguirmi province. Two surveys were conducted in February and March 2023. The first was a household census of herders in order to collect blood, hygroma and milk samples. The second was a cross-sectional survey of 52 households to collect socio-economic data.

The cattle breeders surveyed were at 100% male, Muslim and non-educated person. Married men accounted for 78.84%, with an average age of 36 (42.31%), ranging from 46 to 55 (25%). Arab herders accounted for 78.84% and 11.53% were from Gourane ethnic group. The sedentary breeding system was practiced by 51.92% of farmers, and the sale of dairy produce generated significant income for farmers, amounting to more than 1279141.48 USD during the study period. The cost of losses due to abortions was estimated at 13707.16 USD, and stillbirths due to hygromas were estimated at 64889.12 USD during the same period. Given the very high costs associated with the socio-economic impact, the authorities in charge of livestock farming must organize training and awareness campaigns on biosecurity practices in order to better equip farmers in this area.

Keywords: Socio-economic impact; Bovine brucellosis; Chari Baguirmi; Chad

1. Introduction

In sub-Saharan Africa, the socio-economic and political importance of livestock farming is well known [1-3]. Livestock farming in Chad contributes more than 20% to the national Gross Domestic Product (GDP), provides a livelihood for 40% of the population, and generates more than 8875315.00 USD per year for the public treasury, underscoring the importance of this sector for the country's economic development in terms of sustainability. A cattle farming in particular is an effective source of income for livestock farmers and rural pastoral households. Despite this economic opportunity, the livestock sector in Chad is confronted with climatic phenomena linked to annual rainfall, which is unevenly distributed across the country, periodically leading to a lack of pasture and water, especially in the dry season [1-3]. Resilience in the face of such events is a means of overcoming the constraints faced by these herders. That is why different groups of cattle herders in Chad were met according to local specificities. Sedentary herders, who kept their animals in a permanent location while carrying out their activities on site or not far from their camp, accounted for 67.91% of the total. Transhumant herders, who moved their herds with the seasons, accounted for 21% of the total. 11% of nomads were herders who also moved their herds with the seasons but over long distances; and finally, mobile herders, who raised livestock based on the periodic movement of herds in search of pasture and water, began to settle

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around large urban areas in recent years [4-6]. It should be noted that the number of pastoral households was approximately 74.096 including 66.401 men and 7.695 women in this study. In addition, the cattle population in Chad was estimated at 26 million head during the last national census throughout the country, representing 26.5% of the total population of 94 million. The province of Chari Baguirmi, located in the Sudanese zone, comprises agropastoral systems with sedentary livestock, which totals 1.645.654 head of cattle out of a total of 16.900.896 million head of cattle. Chari is a specific area for sedentary livestock farming, represented by a total of 797.464 head of cattle. Of this figure, our study site is mainly based in the department of Chari (one of the 23 provinces located in Chari Baguirmi), which had more than 149.569 head of cattle [4-6]. Despite this potential in terms of livestock numbers, these animals are affected by various animal diseases, including brucellosis, which is a major zoonosis monitored by the Animal Disease Epidemiological Surveillance Network in Chad (REPIMAT) since 1995 [7,8]. Brucellosis is a contagious infectious disease common to many animal species and humans. It is caused by Gram-negative coccobacilli belonging to the *Brucellacea* family, genus *Brucella*, of which more than a dozen species have been isolated. The most recurrent and pathogenic are *Brucella melitensis, B. abortus, B. suis, B. ovis, B. neotomae, B. canis, B. microti, and B. inopinata* [9-11]. This major zoonosis, present throughout the world, affects 500.000 new cases per year in humans. It is a notifiable disease because it presented a risk to public health. Humans contract brucellosis through direct contact with infected animals via secretions or indirectly by consuming or, handling aborted fetuses or contaminated products, particularly unpasteurized milk and undercooked meat [12]. In Chad, the seroprevalence of brucellosis was estimated at between 12.5% and 18% [13]. In fact, this increase in seroprevalence was not specifically mentioned in any Strategic Document from the Ministry of Public Health. Assessments of bovine brucellosis are poorly understood in terms of socio-economic impact factors. Therefore, the overall objective of this study was to describe the main socio-economic characteristics of sedentary cattle farming and identify the impact of brucellosis on farms in the Mandiagho canton.

2. Materials and methods

2.1. Study areas

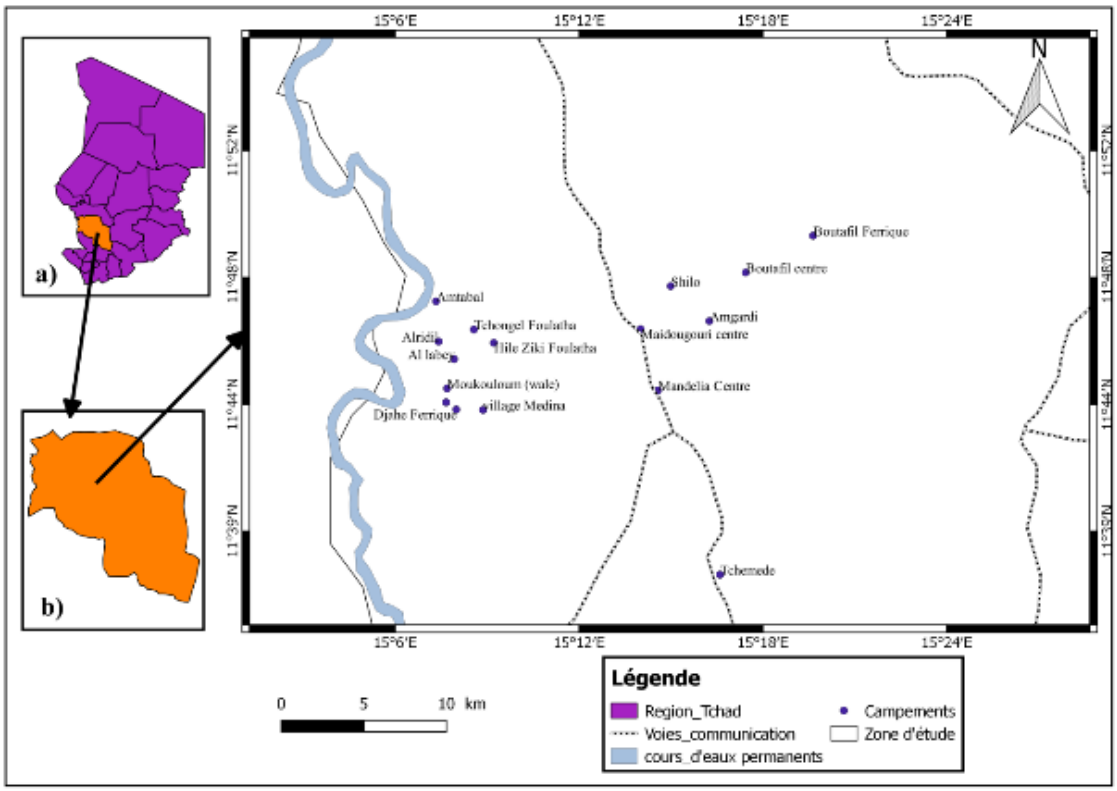

Figure 1 Study area in Mandelia Prefecture

The study was conducted in the province of Chari, specifically in the Mandiagho canton of Mandelia Prefecture, Chad. The Mandiagoh canton is a prefecture located 55.7 km from the capital, N'Djamena. The Mandelia area is located between the Chari and Logone rivers. It is in the west of the country and borders Cameroon, bounded to the far north by Guera, to the south by the province of Moyen Chari, and to the east by the provinces of Hadjer Lamis and Bahr El-

Ghazel. It covers an area of 543.200 ha = 45,432 km^2 with an estimated population of 84.615 inhabitants spread across more than 500 villages, giving a population density of 32 inhabitants/km^2 [17]. The average temperature is 28.7°C, with average rainfall of 726.2 mm. The GPS coordinates of the villages and camps visited were used to draw a map of our study area (Figure 1).

2.2. Sampling and data collection

A cross-sectional, retrospective survey was conducted from February 15 to March 22, 2023, in 52 pastoral households of cattle farmers. Owners of long-established cattle farms and active farmers with experience in the field were interviewed. Pre-established questionnaires were administered in the form of interviews (questions and answers) to all volunteer farmers who agreed to participate in the study.

Farmers' questionnaires were structured into seven groups of topics.

- Information on the participant's profile, including gender, age, ethnicity, religion, marital status, level of education, and occupation.
- Livestock farming activities and interaction with animals, including the farming system, feeding/watering locations, type of bovine brucellosis treatment, purchase/sale locations, herd size, and the sale of animal products such as milk and manure.
- Information on the reproduction system, including reproduction methods, cases of infertility, management of males/females, abortion, stillbirths, calving, and calving locations.
- Information on knowledge of bovine brucellosis, including the name of brucellosis in the local language, symptoms of brucellosis, milk consumption, cattle quarantine, treatments, and vaccination.
- Economic gains from livestock farming. Based on literature and field investigations, questions relating to herd size, number of cows in the herd, quantity of milk produced per herd, and milk selling price were used to estimate financial income during this study.
- The economic losses caused by brucellosis were assessed during the study period based on the main indicators, which are cases of abortion, hygromas, and stillbirths during the past two years and during the study period. A price was assigned to each case situation according to the animal. This process made it possible to collect socio-economic and technical data from livestock-raising households, as well as information on their level of knowledge, attitudes, and practices relating to brucellosis, and to identify the risk factors influencing the disease in Mandiagho Canton.

$$Prevalence\ among\ households\ surveyed = \frac{Numbers\ of\ farmer's\ responding}{Total\ numbers\ of\ respondents} \times 100$$

3. Results

3.1. Demographic characteristics of sedentary livestock farmers in Mandelia

A total of 52 livestock farmers (cattle owners) out of 250 agreed to be surveyed (Table 1). This was a group composed exclusively of men, with a sex ratio of 1:0. Nearly eighty percent (78.84%) were married, of whom 21.15% were polygamous. The average age of the herders was 36, ranging from 46 to 55.

In terms of the ethnic groups of the herders, Arabs accounted for 78.84%, 11.53% were from the Gourane ethnic group, 5.78% were Foulatha, and 3.84% were from Chari Baguirmi. The study revealed that 100% of livestock farmers were uneducated and Muslim. In terms of occupation, 90.38% of respondents were livestock farmers and 9.62% were both farmers and livestock farmers (Table 1).

Table 1 Demographic characteristics of sedentary livestock farmers in Mandelia.

Characteristics	Modality	Frequency	Percentage (%)
Gender	Men	52	100
	Women	0	0
Age group	[25-35]	3	5.77
	[36-45]	22	42.31
	[46-55]	13	25
	[56-65]	9	17.31
	[66-76]	5	9.62
Ethnic Group	Arabe	41	78.84
	Gourane	6	11.53
	Foulatha	3	5.78
	Baguirmi	2	3.84
Religion	Muslim	52	100
	Christian Animist	0 0	0 0
Marital status	Single	0	0
	Married	41	78.84
	Polygamous	11	21.15
	Divorced	0	0
Level of education	Primary	0	0
	Secondary	0	0
	Higher	0	0
	Uneducation	52	100
Profession	Breeder (animal holder)	47	90.38
	Farmer (plant) and breeders	5	9.62
	Trader	0	0

3.2. Characteristics of cattle breeding and reproduction.

The technical characteristics of the cattle breeding system are shown in Table 2 below, which highlights that the sedentary breeding system accounted for 51.92% of the province's cattle population, while 34.46% of breeders practiced transhumance and 9.61% belonged to nomadic groups.

With regard to feeding, 100% of farmers used natural pasture and 90.38% watered their cattle at the Chari and Logone rivers, while 9.61% obtained water from pastoral wells.

Livestock is bought and sold at weekly markets in Mandelia Prefecture. Herd owners with more than 100 head of Arabian zebu per household are more common 92.30% than those with fewer than 100 head 7.69%. Animal products such as milk and manure are sold weekly to the public, providing an additional source of income for households.

When their animals were sick, 86.53% of livestock owners did not contact veterinary services and confirmed that they used antibiotics sold by non-professional pharmacists themselves. The reproductive characteristics of cattle shown in Table 3 indicate that 100% of the farmers surveyed practiced free mating (natural or uncontrolled), and 21.15% of

farmers complained of male infertility. However, 19.23% of the farmers surveyed used borrowed breeding bulls for mating within their herds.

More than half of the farmers 55.77% reported cases of abortion in their herds. In cases of abortion, farmers handled the calves or aborted fetuses without protecting their hands with gloves, and 94.23% of them reported discarding the aborted fetuses in the wild. Only 5.77% of farmers incinerated or buried the aborted fetuses.

During calving, 9.61% of farmers recorded cases of stillborn calves. However, 100% of farmers did not disinfect the premises after calving. In addition, 100% of respondents collected fresh cattle dung with their hands and spread it for sale to the public (farmers, gardeners, brick makers, etc.).

Table 2 Technical characteristics of cattle farmers

Characteristics	**Modality**	**Percentage N=52**
Livestock farming system	Sedentary Transhumance Nomadic	27 (51.92%) 20 (34.46%) 5 (9.61%)
Feeding ground gazing	Grazing Farm	52 (100%) 0 (0%)
watering point	River (Chari/Logone) Pastoral wells Water trough/Fountain	47 (90.38%) 5 (9.61%) 0 (0%)
Types of treatment in case of illness	Modern medicine Traditional methods	45 (86.53%) 7 (13.46%)
Place of sale of animals	Market Nearby farm Other farm	52 (100%) 0 (0%) 0 (0%)
Place of purchase of animals	Marcket Nearby farm Other farm	52 (100%) 0 (0%) 0 (0%)
Herd size per household	Arab cattle (>100) Peulh cattle (<100) Bororo cattle (<100)	48 (92.30%) 4 (7.69%) 0 (0%)
Sale of animal products	Dairy products Manure	52 (100%) 52 (100%)

The reproductive characteristics of the cattle presented in table 3 showed that 100% of the farmers surveyed practiced free mating (natural or non-controlled), 21.15% of breeders complained about male infertility. However, 19.23% of breeders surveyed used male sires on loan for mating within their herds.

More than half of farmers 55.77% reported cases of abortion in their herds. In the event of abortion, breeders handled the runt without protecting themselves hands by using gloves, and then 94.23% of them said they threw the runt back into the wild. Only 5.77% of breeders incinerated or buried the runts.

Table 3 Characteristics of cattle reproduction

Characteristics	**Modality**	**Percentage N=52**
Mode of reproduction	Free Insemination	52 (100%) 0 (0%)
Infertility of sire	Yes No	11 (21.15%) 41 (78.84%)
Granular testes	Yes No	24 (46.15%) 28 (53.84%)
Male Management	Lend No lend	10 (19.23%) 42 (80.77%)
Abortions	Yes No	29 (55.77%) 23 (44.23%)
Management of Abortions	Incinerated Thrown in the wild	3 (5.77%) 49 (94.23%)
Paturition	Stillbirths Born viable Born non-viable	5 (9.61%) 47 (90.38%) 0 (0%)
Disinfection of the area after calving	Yes No	0 (0%) 52 (100%)

3.3. Livestock farmers' knowledge of brucellosis

According to interviews with livestock farmers, 25% of them had knowledge of brucellosis infection, 85% had knowledge of hygroma and 100% had consumed milk. Farmers who were familiar with brucellosis referred to it as "*Bakkalé*" in the Fulani language, or "*Droup or Amdroum*" in Arabic, a term that actually refers to hygroma (Figure 2).

The results of the field survey showed that 100% of livestock farmers did not quarantine or isolate sick animals. Nor did they vaccinate against brucellosis and specific treatment against brucellosis. In addition, 85% of livestock farmers perceived hygromas (Figure 2). When a case of hygroma was observed in an animal, the farmer would heat iron on a fire and, once it was hot, apply it to the site of the inflammation to reduce the pus and relieve the animal.

Figure 2 Livestock farmers' knowledge of brucellosis

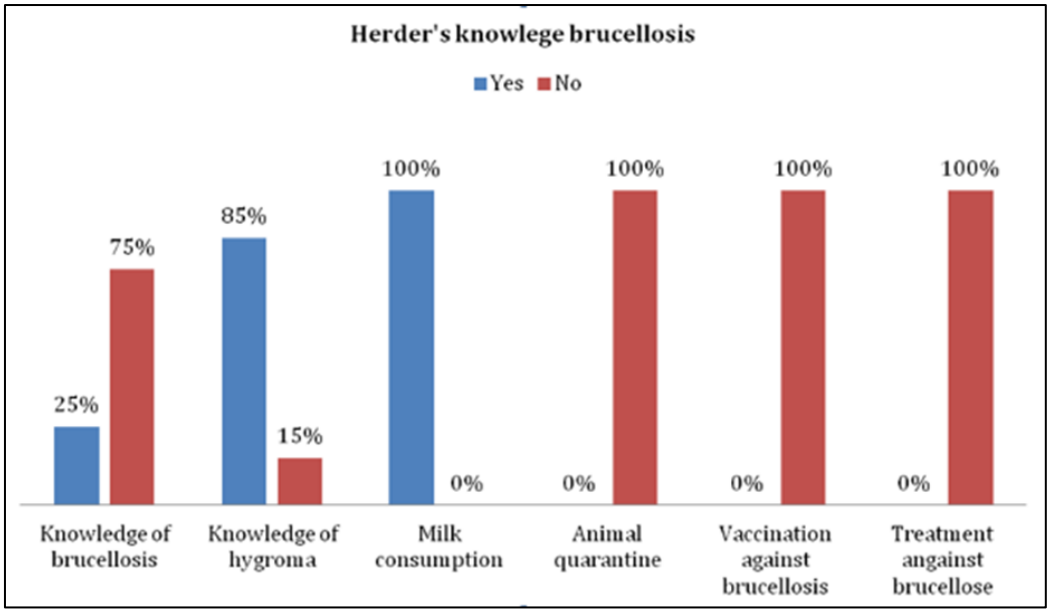

Figure 2 Knowledge, skills, and practices related to brucellosis

3.4. Estimates of economic gains from cattle farming in Chari Baguirmi

Sales and income from animals received as dowries for daughters, but above all the sale of livestock products, particularly milk and cattle manure provide daily income for farmers to cover their costs.

The selling price of a liter of fresh or curdled cow's milk in Chad varies according to the season and the place of sale. In the dry season, fresh milk was sold for between 2.68 USD and 2.95 USD in N'Djamena, while in the rainy season, the price can fall to as low as 1.79 USD per liter.

The herds studied consisted of 6705 animals, including 4587 females, or about 68% of the total (Table 4). Daily milk production was 156 liters, generating a daily income of 278.52 USD at 1.79 USD per liter.

The average production per female is 3 liters per day. The most numerous age group was animals aged [75-120[days, with 2000 animals, including 1300 females. This group also recorded the highest milk production, with 63 liters per day, representing a total income of 146222.95 USD (Table 4). The second largest category in terms of numbers is that of [120-165[days, with 1970 animals and 1.390 females, producing 42 liters of milk per day for a cumulative income of 104230.72 USD. The older age categories, such as [165-210[, [210-255[, and [300-345[, had smaller numbers and daily production ranging from 3 to 12 liters, with total income varying between 1178.35 USD and 714140.24 USD. The total income obtained from sales was 264593.91 USD.

Table 4 Estimates of the economic gains from cow's milk sold by farmers

Category	Herd size	Females	Milk yield/day (liters)	Unit price/day (USD)	Total price (USD)
[30-75[	465	307	24	42.85	13154.71
[75-120[	2000	1300	63	112.48	146222.95
[120-165[	1970	1390	42	74.99	104230.72
[165-210[	380	240	6	10.71	2570.95
[210-255[	930	660	12	21.42	14140.24
[255-300[	310	220	3	5.36	1178.35
[300-345[	650	470	6	10.71	5034.78
Total	6705	4587	156	278.52	**1277570.80**

In Chad, the purchase price of cattle varied according to zootechnical parameters. The maximum price reached 758.79 USD for a bull and the minimum 535.62 USD for a cow. However, there were price fluctuations between markets and within the same market, due to the heterogeneity of the cattle available. For cattle intended for export, the distance between the place of sale and any destination, such as Mandelia to N'Djamena, for example, meant that the selling price was high. On average, the price of a bull was 446.35 USD, a young bull 239.24 USD, a cow 264.24 USD, a heifer 219.60 USD, a calf 126.76 USD, and a young cow 135.69 USD.

Considering the price of calf at 126.76 USD as the loss price due to abortion and stillbirths, Table 5 shows that over the period from 2020 to 2022, economic losses related to three types of pathologies, namely abortions, hygromas, and stillbirths, were assessed based on the number of cases, the average per unit, and the unit cost of the loss.

In Table 5, the number of abortion cases was 39 in 2020, 26 in 2021, and 43 in 2022. Taking into account a unit loss set at 126.76 USD, the total losses recorded were 4943.73 USD in 2020, 3295.82 USD in 2021, and 35450.78 USD in 2022, for a total financial loss of 13632.00 USD.

Animals showing signs of hygroma leading to death or sale were recorded during the three years. There were 42 cases in 2020, 28 in 2021, and 51 in 2022. Considering the price of a unit loss of 535.62 USD, total losses amounted to 22495.84 USD in 2020, 14997.23 USD in 2021, and 27316.38 USD in 2022, for a total of 64533.33. Finally, there were 25 stillbirths in 2020, 15 in 2021, and 18 in 2022, representing a unit loss of 126.76 USD. The corresponding economic losses are 3169.06 USD in 2020, 1901.43 USD in 2021, and 2281.72 USD in 2022, representing a financial loss of 7320.89 USD over three years. The overall economic losses from abortions, cases of hygroma, and stillbirths amounted to 85851.98 USD.

Table 5 Financial losses from abortions, stillbirths, and hygromas

Category		Number	Average	Loss per unit (USD)	Total loss (USD)
Arbortions	2020	39	0.75	126.76	4943.73
	2021	26	0.5	126.76	3295.82
	2022	43	0.83	126.76	5450.78
Hygroma	2020	42	0.81	535.63	22495.84
	2021	28	0.54	535.63	14997.23
	2022	51	0.98	535.63	27316.38
Stillbirths	2020	25	0.48	126.76	3169.06
	2021	15	0.29	126.76	1901.43
	2022	18	0.35	126.76	2281.72

4. Discussion

4.1. Descriptions of the socioeconomic characteristics of sedentary herders

This study in the Chari department, mainly in the Mandiagho canton, showed a frequency of 100% among men, and 78.84% were married, of whom 21.15% were polygamous. These results differ from those obtained by [14], who reported that men accounted for 100% of pastoral households and that livestock farmers aged 15 to 64 accounted for 49.2%. Our results could be justified by several reasons: The fact that a cattle farming requires energy, experience, and a significant amount of time means that women cannot take on this role entirely, as they marry at a young age and are responsible for housework and caring for their children. Nevertheless, they milked cows and collected cattle dung to sell in order to earn money.

Livestock farmers are 100% married, with a sex ratio of 1:0 women, and are also polygamous. This high proportion of married men is positively correlated with Muslim culture, where men marry very early and can take as many wives as they can afford, depending on their financial means. In this study, the livestock farmers surveyed were 100% Muslim and uneducated. This result is consistent with studies by [15], which reported that 95% of livestock farmers in Cameroon were Muslim, 81% of whom were illiterate. However, the opposite is observed among Beninese livestock farmers, 21% of whom had primary education and 7.33% secondary education. In Tanzania, 34.4% of livestock farmers

had primary education, 28.1% secondary education, and 34.4% college education [16]. The fact that these livestock farmers are uneducated could be due to ignorance, parental neglect, and even a refusal to send their children to school despite the government's efforts to provide education for all. Considering the sociodemographic characteristics of livestock farmers, such as gender, age group in the exercise of their livestock farming activities, ethnic groups, religion, marital status, and level of education in relation to indirect ELISA laboratory test analyses, there is no significant difference (p-value>0.05) in brucellosis infection reported by [17]. Awareness-raising and inclusive, if not formal, education of the livestock farming community on the basics of livestock farming would be necessary to understand the issues and challenges relating to their activities in terms of animal health and production.

Arab ethnic groups were more represented (78.84%) than other ethnic groups. The Arab Zebu accounted for 92.30%. These results confirm the publication of the Pastoral Livestock System Support Project [18-20] that the Arab pastoralist population extended across the central part of Chad, leaving the peripheral region of Lake Chad to Salamat in the southeast and to the north of Adamaoua in Cameroon. The fact that Arab Zebu was the majority breed in this study corroborates the findings of research conducted by [20] on the main domestic animal breeds in Chad, where Arab Zebu accounted for more than 85%. There are several possible explanations for our results: given that the Arab Zebu is the majority breed in our study area and that this breed is a good milk producer (an average of 3 to 4 liters per day) and has a high carcass yield, but is also docile and very well suited for work, the high percentage of Arab Zebus and the preference for this breed would be linked to these zootechnical parameters.

The main activity of those surveyed was livestock farming, accounting for 90.38% of respondents, compared to 9.62% who combined agriculture and livestock farming. These results are significantly higher than the 11.3% obtained by [21, 22], who reported that in both rural and urban areas, the main activity of pastoral households was livestock farming. However, the geo-climatic conditions of our study area are very favorable for agriculture and livestock farming, but the livestock farmers who participated in this study prioritized livestock farming over agriculture. This observation can be explained by the fact that land is mostly occupied by professional farmers for their agricultural work, so these livestock farmers focused solely on their livestock activities, the objective of which was to sell the animals. The sedentary farming system accounted for 51.92% of the department, compared to 34.46% for the transhumance system. These results are lower than the 67.91% published by the Ministry of Livestock and Animal Production [5, 6]. There are several reasons why herders might choose the sedentary system. First, large herds have easy access to pasture and water available all year round at the yarés (permanent watercourses) and along the Chari and Logone rivers.

Secondly, very often during the rainy seasons, herders would undertake short transhumance movements to move their herds away from crops, rather than undertaking full transhumance. The fact that these animals undertook short transhumance movements allowed them to conserve the energy necessary to maintain their bodies and to start the lean season, or dry season, in good condition.

Field investigations among cattle farmers showed that breeding animals mated freely, i.e., without supervision. In addition, 21.15% of farmers reported cases of male infertility. The cases of infertility observed and reported could be explained by the fact that brucellosis is a reproductive disease. At sexual maturity, Brucellae could attack the epididymal ducts, causing orchitis and atrophy of the organ in question. In this study, 19.23% of breeders resorted to borrowing breeding males for mating. These practices could promote the transmission of brucellosis, as Brucella sp bacteria generally enter the body through the oral mucosa, nasopharynx, conjunctiva, genitals, and sometimes through skin lesions [23-25]. Abortion cases were reported in this study at a rate of 55.77% in the herds surveyed, compared to 44.23% in those that did not record them. These results are significantly higher than the 2 to 10% obtained by the authors [25-27]. The high proportion of farmers reporting abortions may reflect the 11% brucellosis seroprevalence obtained by the indirect ELISA test recently published by [17] in the study area. When an animal aborted, 94.23% of farmers confirmed that they disposed of the aborted fetuses in the wild, compared to 5.77% who incinerated or buried them. These results can be explained by the fact that farmers lack knowledge about biosecurity. In practice, farmers tend to handle aborted fetuses without wearing gloves and then dispose of them in pastures. According to several authors in Ethiopia, Kenya, and Niger, this practice could constitute a serious risk factor for the spread and transmission of bovine brucellosis [28-30]. Regarding knowledge of bovine brucellosis, 25% said they were familiar with brucellosis, compared to 75% of farmers who had no idea what brucellosis was. Indeed, the 75% lack of knowledge about brucellosis confirms the statements in [31-35], which mentioned that the disease is little known and neglected by at-risk populations. It should be noted that knowledge of the disease and its symptoms, such as the perception of hygroma by farmers, was common and empirical but not scientifically proven.

5. Conclusion

Bovine brucellosis is a major zoonotic disease circulating in the province of Chari Baguirmi. This study revealed that livestock farmers have not received formal education and have no knowledge of bovine brucellosis. They abandon stillborn calves not far from pastures, which is a very serious risk factor for brucellosis infection in herds, the environment, and the public. The consumption of unpasteurized milk by livestock farmers and the public, who are unaware of the risk of brucellosis infection, is a problem that needs to be addressed. However, the estimated cost of losses due to abortions, stillbirths, and hygromas was very significant in this study. Given the very high costs associated with the socio-economic impact and the risk factors identified, livestock authorities need to organize training and awareness campaigns on biosecurity practices to better equip farmers in this area to effectively combat brucellosis.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare that they have no conflicts of interest related to this study.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

Author Contribution Statèrent

BZ conceived the article project and wrote the first draft of the manuscript. BBA, NBNR, NKA, AG and DS contributed to the critical revision of the document. RLG and DF performed statistical analyses. The authors proofread, corrected, and validated the manuscript.

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