# Mapping livestock systems, bovine and caprine diseases in Mayo-Kebbi Ouest Province, Chad

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Availability of data and materials: all data used or analyzed in this study can be obtained from the corresponding author upon request.

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## Abstract

This study aimed to compile an inventory of the main diseases affecting these species in Mayo-Kebbi Ouest Province in Chad. A survey was conducted between 6 May and 7 August 2024 using a cascade data collection method identifying 310 farmers and 19 veterinarians with an average of 10 to 12 years of experience in advising and supporting livestock practices The data collected included socio-professional characteristics of participants, livestock practices, and geospatial information. These data were managed in Excel and analysed with R. The analysis involved descriptive and inferential statistical techniques including binary logistic regression resulting in maps illustrating disease hotspots and livestock systems. Thematic maps, tables and charts with a 5% significance threshold visualised risk areas and associated livestock practices. The results show a predominance of male farmers (91.9%) from 20 different ethnic groups. The livestock systems identified include data on farming divided into extensive (14.8%), mixed (0.3%) and semi-intensive farming (84.8%). On average, farms have 41 cattle and 25 goats. Animal diseases were found to cause 29.5% reduction in herd productivity. Transhumance ($p$=0.000356) and animal disease incidence ($p$=0.03) were observed as significant risk factors associated with the abandonment of livestock farming. The main diseases recorded in cattle include contagious bovine pleuropneumonia (11.3%), bovine tuberculosis (2.5%), foot-and-mouth disease (45.0%), bluetongue (1.7%) and disease with symptoms reminiscent of rinderpest (2.5%). For goats, notable diseases include brucellosis (3.8%), lumpy skin disease (19.2%), goat plague (7.9%) and Rift Valley fever (6.3%). These findings confirm the importance of a geospatial epidemiological surveillance tool for monitoring animal diseases in this region.

## Introduction

Sub-Saharan transhumant farming systems pose significant challenges to veterinary health due to the unique nature of semi-nomadic livestock-rearing practice. The key problem is infectious diseases with high transmission risk related to movement of livestock mixed herds and shared resources.

Geospatial analysis is an essential tool for studying livestock systems and animal diseases in rural areas where data access and health monitoring are often limited. The use of Geographic Information Systems (GIS) facilitates the identification of high-risk areas, location of epidemic hotspots and mapping of livestock practices, which enables the development of more targeted health control strategies. For example, integrating GIS in the surveillance of 'pest of small ruminants', also called goat plague, and foot-and-mouth disease has facilitated early epidemic detection and resource allocation optimisation was successfully applied in Algeria (Dahmani *et al*., 2022). Similarly, a study in China demonstrated the effectiveness of GIS in epidemic surveillance, increasing responsiveness to health threats (Sun *et al*., 2016). In a study by Palaniyandi *et al*. (2016), remote sensing and GIS were used to map vector breeding habitats and monitor epidemic transmission.

According to research by Belimenko and Gulyukin (2016), GIS enables the creation of interactive and analytical maps, providing valuable tools for estimating epidemiological risks and understanding the spread of diseases such as anthrax and rabies. This spatial and visual approach offers innovative perspectives for developing more effective control and prevention strategies. Evidence from this research demonstrates the effectiveness of these technologies in identifying areas vulnerable to disease transmission and in prioritising control strategies. However, inherent challenges arise when using GIS, including data collection complexity, statistical method limitations and issues related to spatial precision and data interpretation.

Mayo-Kebbi Ouest Province in Chad represents a strategic area for livestock farming, a crucial activity for the national economy. However, it is also a region where transhumance, a traditionnel practice of seasonal livestock migration that increases the risk of pathogen spread. Therefore, this region faces major health challenges due to the high prevalence of diseases primarily affecting cattle and goats. GIS was used to map disease hotspots and livestock systems aiming at the compilation of an inventory of the main veterinary diseases in Mayo-Kebbi Ouest to assist efforts to control them.

## Materials and Methods

### Study area description

The study was carried out in the Mayo-Kebbi West Province of Chad, which shares borders with Cameroon and other Chad provinces and is characterised by geographic diversity, with major rivers supporting agriculture and livestock. The administrative subdivisions of the province are given in Table 1, and the spatial information shown on a map (Figure 1).

The socio-cultural diversity, livestock systems and farming practices in this province lead to health challenges for cattle and goat herders. A survey was carried out from 6 May to 7 August 2024 producing a sample consisting of 310 livestock farmers and 19 veterinarians.

**Table 1.** Administrative subdivision of the Mayo-Kebbi Ouest Province, the basis for structuring the study's spatial analyses.

| Department | Canton (District) |
|---|---|
| Lac Léré | Guégo, Biparé, Léré |
| Mayo-Binder | Binder |
| El-Ouaya | Guelo, Lagon, Bissi |
| Mayo-Dallah | Pala, Torrock, Gouin, Gagal, Gouingodom, Lamé |

*Based on the administrative structure effective under the 5th Republic of Chad, as of 4 July 2024.*



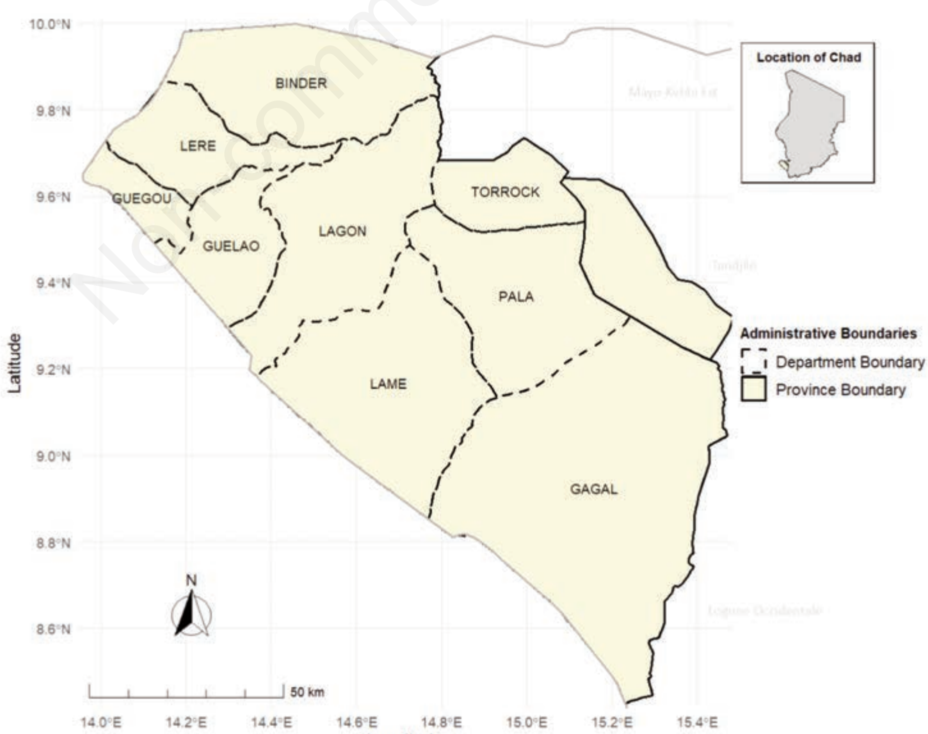


**Figure 1.** Map of Mayo-Kebbi Ouest Province in Chad showing the geographic boundaries and main landmarks of the study area. Map created using a shapefile from 1 January 2017.

## Data collection

Participants were selected using systematic census and snowball sampling (Djagba *et al*., 2020), allowing for a representative sample capturing the socio-cultural diversity and livestock practices in the province. Snowball sampling is a non-probability sampling method, where new units are recruited by other units to form part of the sample. It is a commonly used approach to capture the complexity of pastoral systems in animal health studies (Djagba *et al*., 2020), was employed. Structured interviews were conducted using KoboToolbox (version 2.024.04), covering socio-professional characteristics, farming practices, health perceptions, and geospatial perspectives. Local translators facilitated data collection to enhance reliability. Data were collected through a questionnaire designed using KoboToolbox, ensuring a structured and reliable collection process. The structured interviews addressed various aspects: i) socio-professional characteristics: age, gender, ethnicity and participants' experience, key elements to understanding the diversity of actors in livestock farming. This diversity's influence on livestock practices has been highlighted in a study on goat farming in Togo by Djagba *et al*. (2020); ii) livestock practices: The surveyed practices encompassed a range of systems, including extensive, mixed or semi-intensive farming, as well as average herd size. This classification is crucial for understanding how each system influences animal health and is in line with Missohou *et al*. (2016), who report that livestock systems in West Africa directly impact animal health management and disease spread; iii) health data: identified disease types, prevention, treatment strategies and associated risk factors were collected. Gathering this data was essential for identifying the main pathogens affecting animal populations, following studies, such as that by Ali *et al*. (2013) that is focused on brucellosis health risks in professional settings similar to this study. A description of the socio-professional profile of the region's livestock farmers (Figure 2, Table 2) aid the understanding of livestock practices, while information on the experience and availability of veterinarians in the province (Table 3) is essential for assessing the technical support provided to livestock farmers.

## Data analysis

The inferential statistical tests used in this study included the chi-square and Fisher's exact tests, which were employed to analyse associations between qualitative variables. This methodology is frequently adopted in epidemiological research on animal health (Ali *et al*., 2013). Additionally, binary logistic regression was employed to identify risk factors associated with the abandonment of livestock farming, with a significance level of 5%. This approach facilitates risk assessment by integrating various variables, as demonstrated in research concerning the prevalence of animal diseases and health risks in Africa (Noudeke *et al*., 2017).

A description how the collected information was subjected to binary logistic regression including application of chi-square and Fisher's exact tests need to be given in a paragraph here, with results provided in tables to be placed in the Results section.

The collected data were subjected to analysis using descriptive statistics, including means and standard deviations, to characterise livestock practices and the populations studied. Data were systematically organised and cleaned using Excel 2013, while statistical analyses were conducted with the R software (version 4.3.3). This

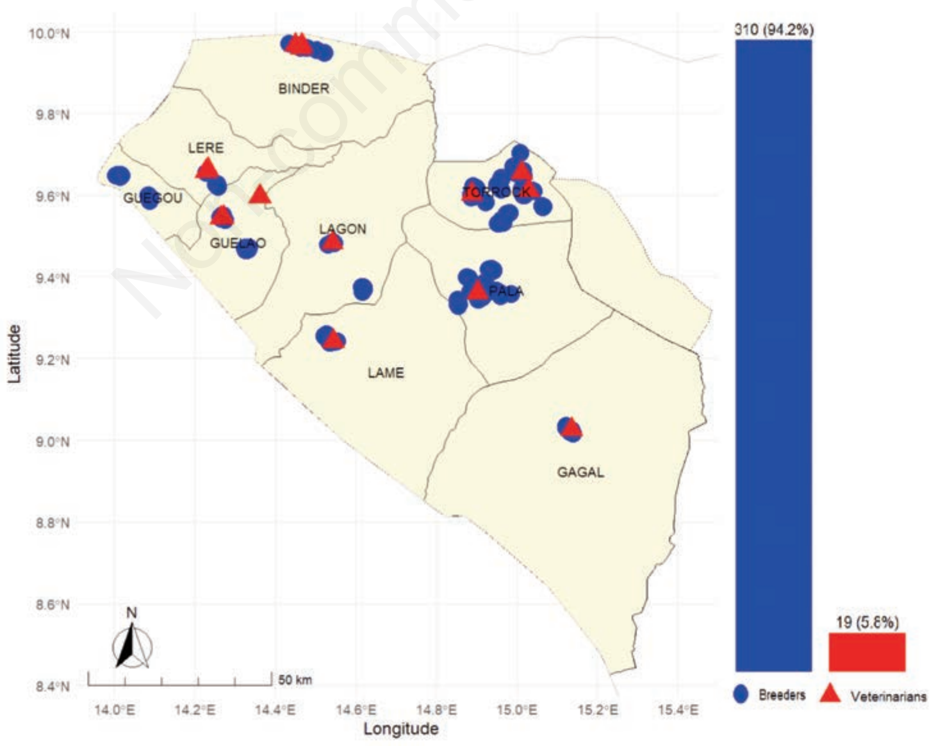


**Figure 2.** Map of survey data collection points among farmers and veterinarians in the province illustrating the geographic coverage of the study.

approach aligns with methodological recommendations for data analysis in animal health contexts, where statistical rigor is essential to obtain reliable results (Mazzucato *et al*., 2023).

## Spatial analysis tools

Geospatial data were analysed using the R programming language along with Excel for data management, with the objective of mapping the distribution of livestock systems and epidemic hotspots. This combination of tools allows for a detailed and accurate visualisation of high-risk areas, as demonstrated in various studies employing similar approaches for rural health surveillance (Dahmani *et al*., 2022). Thematic maps were designed to visually illustrate high-risk areas and factors contributing to the abandonment of livestock farming. The effectiveness of GIS in identifying and managing epidemic-prone zones has been well documented in comparable contexts, notably in China, where similar geospatial systems have improved responsiveness to animal disease outbreaks (Sun *et al*., 2016). Please describe briefly how your data were calculated in the GIS environment here.

# Results

The results of this study highlight several key characteristics of livestock systems and health challenges in the Mayo-Kebbi Ouest province as illustrated in Figures 3 and 4. In addition, Table 4 provides an overview of the disease types that are common in cattle and goats, which assists the identification of species-specific diseases and their biosecurity implications.

## Characteristics of farmers and livestock systems

The majority of farmers, accounting for 91.9%, are men from 20 different ethnic groups. Veterinarians participating in the survey reported an average of 10 to 12 years of professional experience, which is considered crucial for managing rural health risks. In this province, livestock systems are primarily characterised by a semi-intensive approach, and were found to amount to 84.8% of the observed practices, while extensive farming constituted 14.8% and the mixed system accounts only 0.3%. The farms in the study area were calculated to hold an average of 41 cattle and 25 goats, although these figures varied depending on the farming system and local constraints.

## Impact of diseases on productivity

Veterinary diseases have a significant impact on herd productivity, and we noted an average reduction of 29.5% in production (Figure 5). Transhumance ($p$=0.000356) and the incidence of animal diseases ($p$=0.03) were found to be the major risk factors linked to the abandonment of livestock farming (Figure 6).

## Diseases observed

The diseases recorded among cattle and goats in this study include brucellosis, lumpy skin disease and goat plague. Among cows the main diseases include contagious bovine pleuropneumonia (11.3%), bovine tuberculosis (2.5%), foot-and-mouth disease (45%), bluetongue (1.7%). The most frequently observed diseases in goats include brucellosis (3.8%), lumpy skin disease (19.2%), goat plague (PPR) (7.9%), and Rift Valley fever (6.3%). This sum-



**Table 2.** Socio-professional characteristics of livestock farmers (n = 310).

| Parameter | Department | | | | Mean±SD |
|---|---|---|---|---|---|
| | El-Ouaya (%) | Lac Léré (%) | Mayo-Binder (%) | Mayo-Dallah (%) | |
| Gender | | | | | |
| Female | 2 | | | 10 | 8.06 |
| Male | 98 | 100 | 100 | 90 | 91.94 |
| Ethnicity | | | | | |
| Arabe | 2 | | | 1 | 0.97 |
| Bororo | 2 | | | 6 | 5.16 |
| Caro | | | | 1 | 0.65 |
| Foulbé | 2 | | 100 | 4 | 5.48 |
| Haoussa | 8 | 33 | | 6 | 8.06 |
| Kera | | | | 0.5 | 0.32 |
| Lame | | | | 5 | 3.87 |
| Lélé | | | | 1.0 | 0.65 |
| Mbaïnawa | | 11 | | | 0.65 |
| Mbaye moisala | | | | 0.5 | 0.32 |
| Mboum | | | | 0.5 | 0.32 |
| Moundang | 82 | 28 | | 52 | 54.52 |
| Nabouzi | | 6 | | | 0.32 |
| Ngambaye | 2 | | | 9 | 7.10 |
| Niellim de Sarah | | | | 0.5 | 0.32 |
| Peuhl | | 17 | | | 0.97 |
| Sime PV | | | | 1 | 0.97 |
| Tikalga | | 6 | | | 0.32 |
| Toupouri | | | | 3 | 2.58 |
| Zimé | 2 | | | 8 | 6.45 |
| Experience in farming (years) | 20.72±9.23* | 26.83±17.35* | 35.14±16.69* | 23.26±16.90* | 23.32±16* |

*SD, standard deviation; mean± SD.*

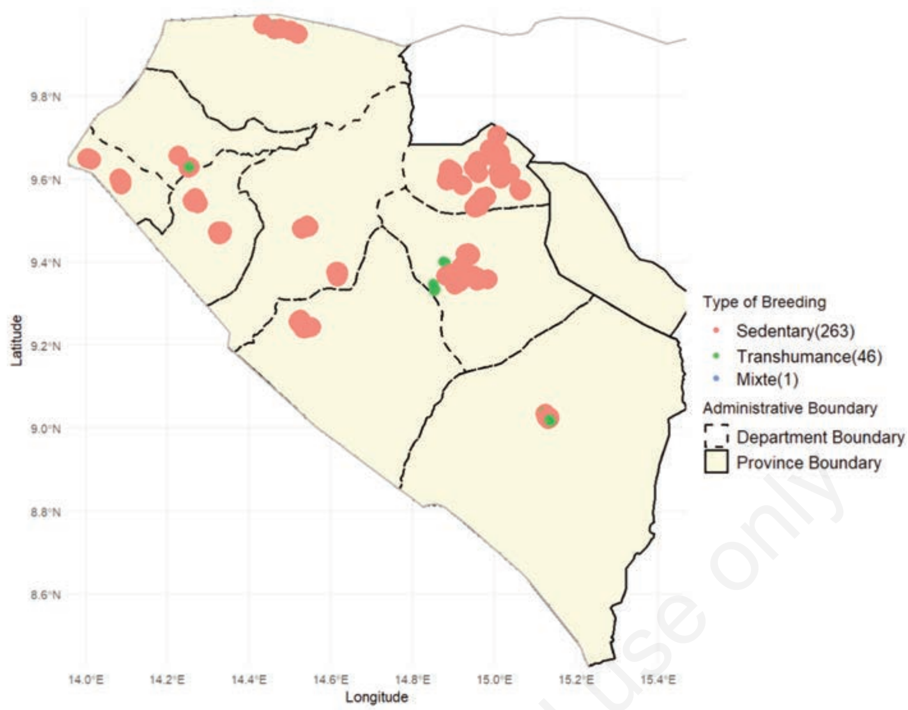


**Figure 3.** Map showing the spatial distribution of livestock systems in Mayo-Kebbi Ouest Province enabling a geographical view of livestock practices.

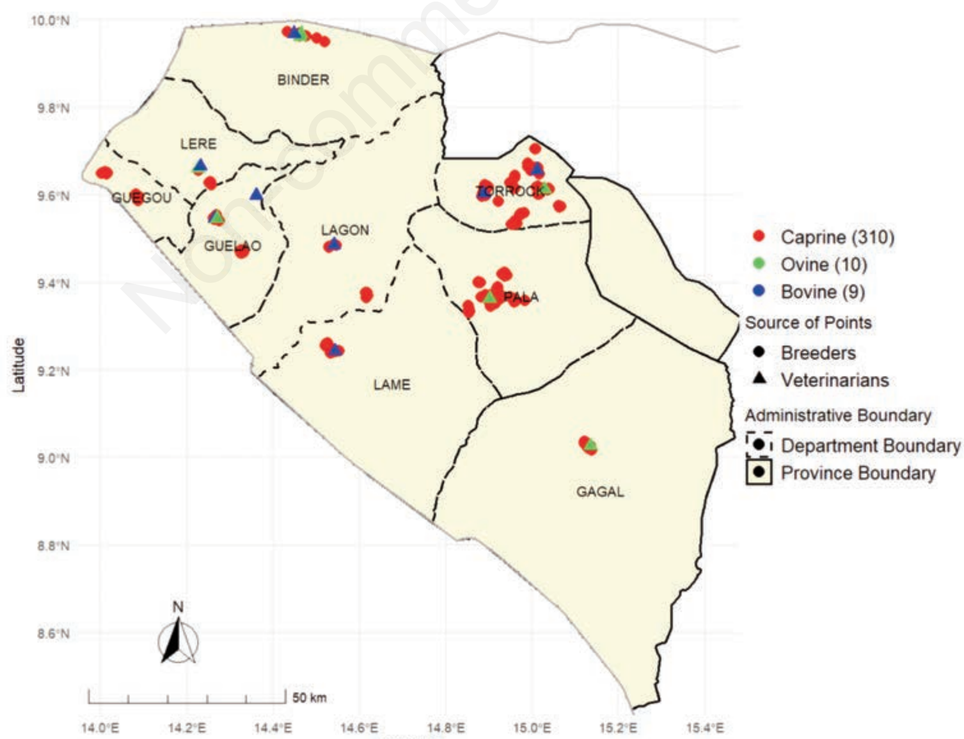


**Figure 4.** Map of the geographic distribution of cattle and goats in Mayo-Kebbi Ouest Province identifying areas of high concentration for each species.

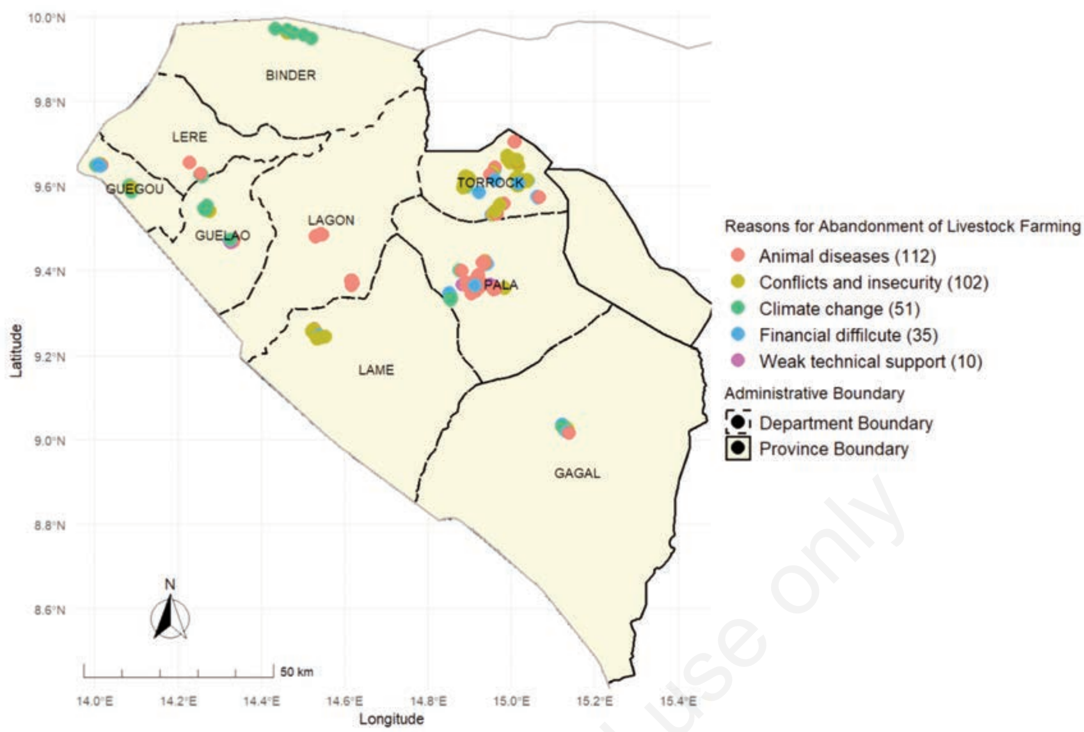


**Figure 5.** Map of geographical areas where herders have ceased livestock activities allowing for an analysis of causes linked to health and economic risks.



**Table 3.** Veterinarian characteristics.

| Parameter | Departement | | | | Mean |
|---|---|---|---|---|---|
| | El-Ouaya (%) | Lac Léré (%) | Mayo-Binder (%) | Mayo-Dallah (%) | |
| Gender | | | | | |
| Female | 25 | 33 | | | 12.50 |
| Male | 75 | 67 | 100 | 100 | 87.50 |
| Ethnicity | | | | | |
| Foulbé | | | 50 | | 6.25 |
| Gourane | | | | 14 | 6.25 |
| Moundang | 75 | 100 | 100 | 57 | 68.75 |
| Zimé | 25 | | | 29 | 18.75 |
| Experience in support of livestock farmers (2024) | 10.25±9* | 12±10* | 11±0* | 9±8.93* | 10.12±7.92* |
| Availability of veterinary clinics (%) | | | | | |
| Yes | 100 | 67 | 100 | 100 | 94 |
| No | | 33 | | | 6 |

*Table based on 19 veterinarians; SD= standard deviation; *mean± SD.*

**Table 4.** Types of bovine and caprine diseases.

| Type of disease | Cattle disease | Goat disease |
|---|---|---|
| Bacterial | Contagious bovine pleuropneumonia (11.3%)<br>Bovine tuberculosis (2.5%) | Brucellosis (3.8%) |
| Viral | Foot-and-mouth disease (45.0%)<br>Bluetongue (1.7%)<br>Suspected rinderpest (2.5%)* | Lumpy skin disease (19.2%)<br>Goat plague (7.9%)<br>Rift Valley fever (6.3%) |

**Although rinderpest has been eradicated worldwide, respondents reported clinical signs consistent with the disease. Due to logistical constraints, laboratory confirmation was not conducted.*

mary of transmission modes and symptoms for each animal disease is summarized in Table 5, which should aid identifying health risks. Figure 7 highlights high-risk areas for health interventions and the epidemic risk map (Figure 8) illustrates areas of high disease prevalence in Mayo-Kebbi Ouest province, derived from geospatial data. This map highlights epidemic hotspots particularly concentrated in the Pala and Torrock areas, where risk densities reach peak levels.

## Discussion

These findings align with observations in comparable regions of West Africa, where transhumance practices, combined with a lack of biosecurity measures, heighten the health risks faced by herds (Missohou *et al*., 2016; Meybeck *et al*., 2017). Integrating GIS and appropriate biosecurity measures could significantly enhance the management of animal diseases and reduce associated economic losses. For example, similar initiatives implemented in Algeria have shown that GIS can facilitate a more efficient alloca-

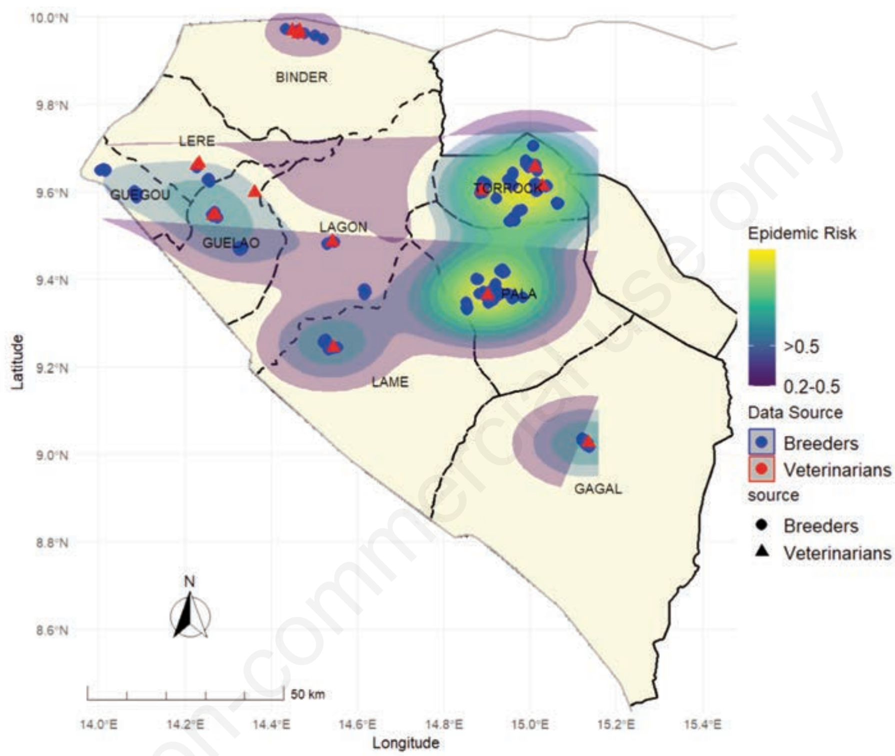




**Figure 6.** Epidemic risk map indicating high-density disease areas in the region.

**Table 5.** Modes of transmission and symptoms of recorded animal diseases.

| Veterinary disease | Transmission mode | Symptom |
|---|---|---|
| Brucellosis | Contaminated water or feed ingestion, animal cohabitation, uncontrolled animal movement | Abortions, genital infections, joint problems |
| Lumpy Skin disease | High prevalence of vector arthropods (flies and ticks), high animal population density | Skin nodules, ulcers, respiratory issues |
| Foot-and-Mouth disease | Transmission between infected and healthy animals via saliva, milk, or blood; lack of biosecurity measures | Vesicular lesions in mouth and on feet, lameness, reduced production |
| Rift Valley fever | Favourable climatic conditions for mosquitoes, movements of infected animals | Fever, abortions, neonatal infections |
| Bluetongue | Presence of competent vectors (Culicoides midges) | Mouth ulcers, swelling, respiratory issues |
| Contagious bovine pleuropneumonia | Inhalation of respiratory droplets from infected animals | Fever, laboured breathing, cough, nasal discharge |
| Goat plague (PPR) | Contact with contaminated objects like feeders or waterers | Respiratory issues, gastrointestinal disorders, mouth ulcers |
| Bovine tuberculosis | Transmission through respiratory and oral routes | Lung infections, potential transmission to humans |

tion of resources in epidemic management (Dahmani *et al*., 2022). Moreover, the use of GIS for real-time epidemic hotspot mapping in China has increased responsiveness to health crises, illustrating its potential to enhance the resilience of livestock systems in analogous contexts (Sun *et al*., 2016). This underscores the importance of reinforcing biosecurity practices, especially in high-risk areas. Comparable research has shown that proximity and lack of biosecurity measures increase disease transmission risks within intensive and semi-intensive livestock systems (Missohou *et al*., 2016).

The results regarding farmer and veterinarian profiling show that both have long professional experience, which is crucial for the successful management of rural health risks. It emphasises the crucial role of knowledge transfer in livestock practices and animal health. Integrating educational and training programmes could improve the implementation of health practices and risk management, as recommended in other livestock contexts in West Africa

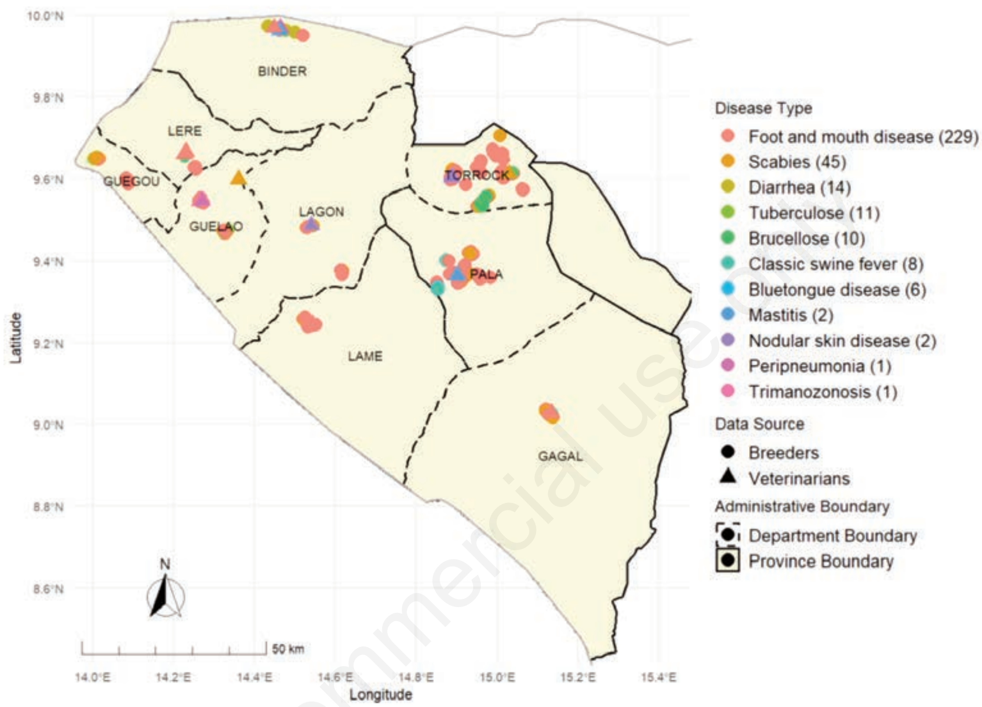


**Figure 7.** Geographic distribution of veterinary diseases identified in Mayo-Kebbi Ouest Province.

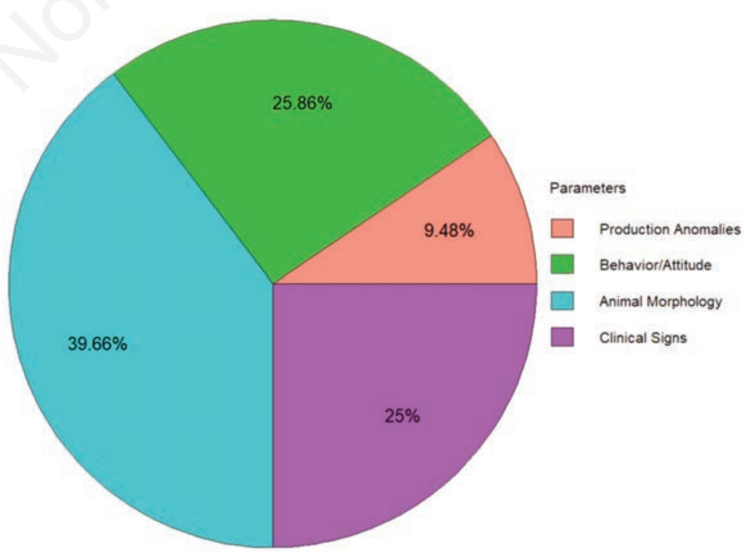


**Figure 8.** Parameter distribution of diagnostic criteria.

(Djagba *et al*., 2020). With regard to the livestock systems, found to be primarily characterised by a semi-intensive approach is representative of many sub-Saharan African regions, where herders choose this model to balance productivity with sustainable resource management (Missohou *et al*., 2016). Although an average of the farms held around 65 animals, there was a great variation as it is in other Sahel regions, due to socio-economic and environmental factors, as noted in the study by Gnanda *et al*. (2016) in Burkina Faso. With respect to the impact of diseases on productivity, our observation of 29.5% reduction in production reflects figures widely documented in livestock farming contexts in West Africa, where diseases limit animal growth and productivity, directly affecting farmers' incomes (Missohou *et al*., 2016). In addition, our finding that transhumance and the incidence of veterinary diseases as the main risk factors correspond to other African reports as observed in similar studies on pastoral practices in the Sahel (Meybeck *et al*., 2017). These factors increase losses and discourage herders, contributing to a reduction in the sustainability of livestock farming (Noudeke *et al*., 2017). The disease panorama observed in this study shares notable similarities with observations in other West African countries, where high prevalence rates of brucellosis in cattle are well-documented (Noudeke *et al*., 2017). Furthermore, the high PPR rates observed here align with those reported in the semi-intensive livestock systems of the region (Ali *et al*., 2013). It is of interest that the same diseases observed in this study have also been reported in other regional studies, particularly in extensive farming contexts where health control is limited (Hunter *et al*., 2006). Of great importance is the fact that experienced veterinarians have reported symptoms reminiscent of rinderpest in 2.5% of the cases. When this disease was erradicated in 2011, it was the first time for a veterinary disease. Rinderpest, also known as cattle plague, was a highly contagious viral disease affecting cattle with devastating impacts on livestock and agricultural economies. For this reason, this finding will be reported and the cases further investigated. The high prevalence rates of goat plague and brucellosis in goats correspond to regional trends in sub-Saharan Africa, where these diseases are a significant obstacle to goat productivity (Missohou *et al*., 2016).

### Factors influencing abandonment of livestock farming

Transhumance practices in the region are identified as a major risk factor for animal disease transmission due to frequent contacts between herds from different geographical areas. This phenomenon has been observed in other West African regions, where cross-border herd movements play a significant role in pathogen spread (Meybeck *et al*., 2017). Additionally, the lack of biosecurity measures in transhumance zones exacerbates these risks, underscoring the need for targeted interventions to enhance biosecurity. Studies indicate that biosecurity strategies are essential to limit disease transmission in high-transhumance contexts (Missohou *et al*., 2016). While essential for managing natural resources, transhumance exposes animals to infected areas, increasing the risk of cross-infections. Our results indicate that herders practising transhumance are more likely to abandon livestock farming due to the economic losses associated with epidemics. To address this issue, integrating mobile surveillance strategies appears crucial for limiting pathogen spread in transhumance areas. Similar surveillance systems have proven effective in enhancing responsiveness and preventing epidemics in rural areas of China, as demonstrated by Sun *et al*. (2016)

### The importance of a geospatial surveillance system

Implementing a Geographic Information System (GIS) for animal disease monitoring could provide an effective response to the health challenges identified in this study. Mapping epidemic hotspots and livestock systems facilitates a more strategic allocation of resources and interventions, enabling the identification of priority areas. Comparative research shows that integrating GIS in livestock practices significantly improves resilience to health crises and promotes the sustainability of livestock systems (Dahmani *et al*., 2022). For instance, in Algeria, GIS use has facilitated more rigorous monitoring of diseases such as foot-and-mouth disease and Peste des Petits Ruminants (PPR), thereby reducing epidemic spread in rural areas (Dahmani *et al*., 2022). Similarly, in China, real-time mapping of epidemic hotspots using GIS has enhanced responsiveness to health crises, illustrating its potential to strengthen livestock system resilience in similar contexts (Sun *et al*., 2016).

### Analysis and interpretation of epidemic risk results

The epidemic risk map highlights a significant concentration of animal diseases around the areas of Pala and Torrock. This high density is attributed to the proximity of semi-intensive farming systems and transhumance movements, which facilitate disease transmission between herds. Implementing a geospatial monitoring system would therefore be essential to enhance the responsiveness of health authorities to epidemics in these high-risk areas. Similar studies have shown that integrating geospatial monitoring systems improves epidemic response in regions where extensive farming and transhumance are common, thereby reducing economic and health losses (Missohou *et al.,* 2016). These findings indicate priority areas for health interventions and the application of enhanced biosecurity measures. Integrating GIS and molecular diagnostics is critical for enhancing disease monitoring and biosecurity in high-risk areas

## Conclusion

This research has shed light on the structural and health challenges faced by the livestock sector in Mayo-Kebbi Ouest province, Chad. The analyses reveal that transhumance practices, the concentration of semi-intensive livestock systems, and the absence of appropriate epidemiological surveillance contribute to the increased vulnerability of livestock systems in this region. To address the identified challenges, it is recommended to strengthen farmers' biosecurity skills and promote sustainable livestock practices through training and awareness programmes. Cooperation between health authorities and farmers is essential to establish an effective epidemiological surveillance system, which could have a significant impact on the sustainability of the livestock sector in the province.

### Recommandations

Biosecurity training for farmers should be intensified and promote the adoption of sustainable livestock practices in line with strategies implemented in comparable contexts in sub-Saharan Africa, where training initiatives have proven effective in reducing animal epidemics (Missohou *et al*., 2016; Djagba *et al*., 2020; Dahmani *et al*., 2022).

The results of this study highlight the fundamental importance of GIS in managing animal diseases, particularly in rural areas. Comparative research, especially in China, demonstrates that GIS optimises epidemic response and strengthens disease surveillance capacity (Sun *et al*., 2016). Implementing a geospatial monitoring system in the region would contribute to optimising resource allocation and improving animal health interventions, as exemplified by Algeria's approach to diseases like PPR and foot-and-mouth disease (Dahmani *et al*., 2022).

Implement prevention and mobile surveillance measures for transhumant herds to limit disease spread. Herd mobility exposes animals to cross-infection risks; therefore, it is essential to integrate suitable biosecurity strategies in transhumance zones, in line with recommendations from studies on rural areas in sub-Saharan Africa (Meybeck *et al*., 2017).

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*Online supplementary materials:*

*Résumé*