

Research Article

Epidemiology of Reported Animal Anthrax in North Shewa Zone, Ethiopia: Retrospective Study of Temporal, Seasonal and Spatial Patterns and Vaccination Coverage, 2020–2024

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Abstract

Anthrax is a highly fatal zoonotic disease caused by *Bacillus anthracis* and remains an important livestock and public health concern in Ethiopia. However, epidemiological information from routine surveillance in North Shewa Zone is limited. This study aimed to characterize the temporal, seasonal, spatial, and species distribution of reported animal anthrax and assess disease burden and vaccination coverage in North Shewa Zone from 2020 to 2024. A retrospective descriptive study was conducted using Disease Outbreak and Vaccination Activity Report (DOVAR) data collected from January 2020 to December 2024. Data from 23 districts and 374 peasant associations were analyzed using descriptive statistics to assess outbreak occurrence, morbidity, mortality, case fatality rate (CFR), temporal and seasonal patterns, species distribution, and vaccination coverage. Cases were based on clinically suspected anthrax reported through routine surveillance. Eleven outbreaks were reported in eight districts, resulting in 89 cases and 48 deaths among 19,130 animals at risk. Overall morbidity, mortality, and CFR were 0.47%, 0.25%, and 53.9%, respectively. Outbreaks occurred in 2020, 2021, and 2024, with the highest occurrence in 2024 (54.5%). No outbreaks were reported in 2022 and 2023. Most cases (78.7%) occurred during the rainy seasons, with August recording the highest monthly occurrence (28.1%). Cattle represented the majority of cases (49.4%) and deaths (58.3%). Moretena-Jeru had the highest number of reported cases, while Menz-Lalo recorded the highest CFR. Outbreak-response vaccination achieved 81.1% coverage, whereas routine prophylactic vaccination covered only 30.15% of the target population. Animal anthrax remains a significant livestock health concern in North Shewa Zone, characterized by seasonal outbreaks and high fatality. Strengthening routine risk-based vaccination, surveillance, laboratory-supported diagnosis, timely reporting, and safe carcass disposal is recommended.

Keywords

Animal Anthrax, Bacillus Anthracis, Case Fatality Rate, North Shewa Zone, Retrospective Surveillance, Vaccination Coverage

1. Introduction

Anthrax is an acute, highly fatal zoonotic disease affecting domestic and wild herbivores as well as humans. It is caused by *Bacillus anthracis*, a Gram-positive, non-motile, spore-forming bacterium whose environmentally resistant spores

can survive in soil for decades, enabling recurrent outbreaks in susceptible animal populations [1]. The name "anthrax" originates from the Greek word "anthrakis" ("coal"), referring

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to the characteristic black eschar observed in cutaneous anthrax in humans. Herbivorous animals are primarily infected by ingesting spores while grazing on contaminated pastures, although inhalation may also occur [2]. Carnivores usually become infected by consumption of contaminated carcasses. In contrast, humans acquire infection mainly through direct contact with infected animals or contaminated animal products, making anthrax an important occupational disease among livestock keepers, farmers, butchers, veterinarians, and workers handling hides, wool, and other animal products [3, 4].

Anthrax remains one of the world's most important yet neglected zoonotic diseases and is recognized as a notifiable disease by the World Organization for Animal Health [5]. The disease is endemic across many regions of Africa, Asia, and South America, where favorable environmental conditions promote the long-term persistence of *Bacillus anthracis* spores and recurrent outbreaks in livestock and wildlife [6]. A global risk assessment estimated that approximately 1.1 billion livestock and 63.8 million poor livestock keepers reside in areas environmentally suitable for anthrax, underscoring its substantial impact on livestock production, food security, rural livelihoods, and public health [3]. In addition to causing high livestock mortality, anthrax results in considerable economic losses through reduced animal productivity, carcass disposal, emergency vaccination campaigns, movement restrictions, and limitations on livestock trade [6–8]. Recurrent outbreaks continue to occur in many African countries, particularly in pastoral and mixed crop–livestock production systems where veterinary service coverage, disease surveillance, and outbreak response remain inadequate [7, 9].

Ethiopia possesses the largest livestock population in Africa and is recognized as an anthrax-endemic country, with recurrent outbreaks reported across diverse agro-ecological settings [2, 6, 10]. Anthrax was ranked as the second highest-priority zoonotic disease after rabies during Ethiopia's National One Health Zoonotic Disease Prioritization (OHZDP) exercise, underscoring its importance to both animal and public health [11]. Previous studies have shown marked spatial and seasonal variation in anthrax occurrence, with outbreaks increasing during and immediately after the rainy season [3, 12]. However, these studies have largely focused on outbreak investigations or localized areas, and comprehensive analyses of routine surveillance data remain scarce. Moreover, because many suspected outbreaks are diagnosed clinically without laboratory confirmation, surveillance records may underestimate the true disease burden and geographic distribution of anthrax, highlighting the need for strengthened laboratory-supported surveillance and systematic analysis of routine surveillance data [2, 13].

At the regional level, the Amhara Regional State is recognized as an important anthrax-risk area in Ethiopia due to recurrent outbreaks, favorable ecological conditions for *Bacillus anthracis* spore persistence, and a large livestock population [2, 6, 10]. Ecological modeling has identified North Shewa Zone as environmentally suitable for anthrax persistence and

transmission [2]. However, comprehensive information on the epidemiological patterns of animal anthrax in the North Shewa Zone, including temporal, seasonal, and spatial distributions, species-specific distributions, case fatality rates, and vaccination coverage, remains limited. This evidence gap hinders risk-based surveillance, targeted vaccination planning, and effective disease prevention and control. Therefore, this retrospective study analyzed routine anthrax surveillance data from North Shewa Zone, Amhara Regional State, Ethiopia, during 2020–2024 to characterize anthrax occurrence patterns, estimate morbidity, mortality, and case fatality rates, assess vaccination coverage, and provide evidence to strengthen surveillance and guide control strategies.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted in North Shewa Zone, Amhara Region, central Ethiopia, located approximately 130 km northeast of Addis Ababa. The zone lies between 8°38'–10°42' N latitude and 38°40'–40°03' E longitude, covering an area of 16,172.52 km². It is characterized by diverse agroecological conditions, comprising lowland (<1,800 m; 34.2%), mid-altitude (1,800–2,400 m; 28.0%), and highland (>2,400 m; 37.8%) areas, with elevations ranging from 1,290 to 3,000 m above sea level. The area receives bimodal rainfall, with an average annual precipitation of 400–700 mm, and is predominantly characterized by a mixed crop–livestock production system. This production system involves extensive grazing, which may increase livestock exposure to *Bacillus anthracis* spores persisting in contaminated soil and pastures.

According to the North Shewa Livestock Development Department Annual Report (2025), the zone has an established animal health service network comprising 23 district veterinary clinics and 343 veterinary posts, providing 100% district-level coverage and 91.7% geographical coverage at the veterinary-post level. This infrastructure supports routine animal health services, disease surveillance, outbreak investigation, vaccination, case reporting, and implementation of disease prevention and control measures. The zone has a large and diverse livestock population, estimated at 2,403,688 cattle, 1,297,577 sheep, 1,061,654 goats, 455,469 equines, and 21,756 camels.

2.2. Study Design

A retrospective descriptive surveillance study was conducted using secondary data from routine animal anthrax surveillance records collected between 2020 and 2024. Data were obtained from the Disease Outbreak and Vaccination Activity Report (DOVAR) database maintained by the Livestock and Fishery Resource Department of the Amhara Region, Ethiopia. The study aimed to describe the temporal, spatial, and species

of anthrax cases and assess livestock anthrax vaccination activities in North Shewa Zone.

2.3. Source and Study Population

The source population comprised domestic livestock species, including cattle, sheep, goats, and equines, reared in the 23 districts of North Shewa Zone, Amhara Region, Ethiopia, during 2020–2024. Wildlife was excluded because the surveillance system covers only disease events in domestic animals. The study population included all suspected, probable, or tentatively confirmed anthrax outbreak records reported through the DOVAR system. Records containing key epidemiological variables, including district, outbreak date, affected species, number of cases, and deaths, were included in the analysis. Duplicate, incomplete, or unverifiable records were excluded.

2.4. Data Collection and Analysis

Anthrax outbreak and vaccination data were extracted from the DOVAR database using a standardized data extraction format. The extracted variables included district, outbreak date (year and month), affected livestock species, number of outbreaks, suspected anthrax cases, deaths, and number of vaccinated animals. Annual livestock population estimates were obtained from the Livestock and Fishery Resource Department and used to calculate disease occurrence indicators and vaccination coverage.

The data were entered, cleaned, coded, and reviewed for completeness and consistency before analysis using Microsoft Excel 2019. Descriptive epidemiological analyses were conducted using frequencies, proportions, morbidity, mortality, case fatality rate (CFR), outbreak occurrence, and vaccination coverage to assess the temporal, spatial, and species distribution of anthrax. Trends and distribution patterns of anthrax

outbreaks, cases, deaths, and vaccination activities were summarized using tables, graphs, and maps.

2.5. Ethical Considerations

Permission to access the retrospective surveillance data was obtained from the North Shewa Zone Livestock and Fishery Resource Department. The study involved secondary analysis of routinely collected records, with no direct involvement of animals or human participants. All data were handled confidentially, and no personally identifiable information was collected, accessed, or reported.

3. Results

3.1. Temporal Distribution

Across the 23 districts and 374 peasant associations (PAs) included in the study area, a total of 11 anthrax outbreaks were reported during the five-year study period (2020–2024), corresponding to an overall outbreak occurrence of 2.94%. The annual distribution of outbreaks varied considerably across the study period. The highest number of outbreaks was recorded in 2024, with six outbreaks (54.5%) and an outbreak occurrence of 1.60%, followed by 2020, with three outbreaks (27.3%) and an occurrence of 0.80%. In contrast, 2021 recorded the lowest number of outbreaks among the years in which outbreaks were reported, with two outbreaks (18.2%) and an occurrence of 0.53%. No anthrax outbreaks were reported in 2022 or 2023. Overall, the temporal distribution showed an irregular pattern, with a marked increase in the number and occurrence of outbreaks in 2024 compared with the preceding years (Table 1 and Figure 2).

Table 1. Annual distribution of anthrax outbreaks (2020–2024),

Year	Number of Outbreaks	Outbreaks occurrence (%)	Proportion of total Outbreaks (%)
2020	3	0.80	27.3
2021	2	0.53	18.2
2022	0	0	0
2023	0	0	0
2024	6	1.60	54.5
Total	11	2.94	100

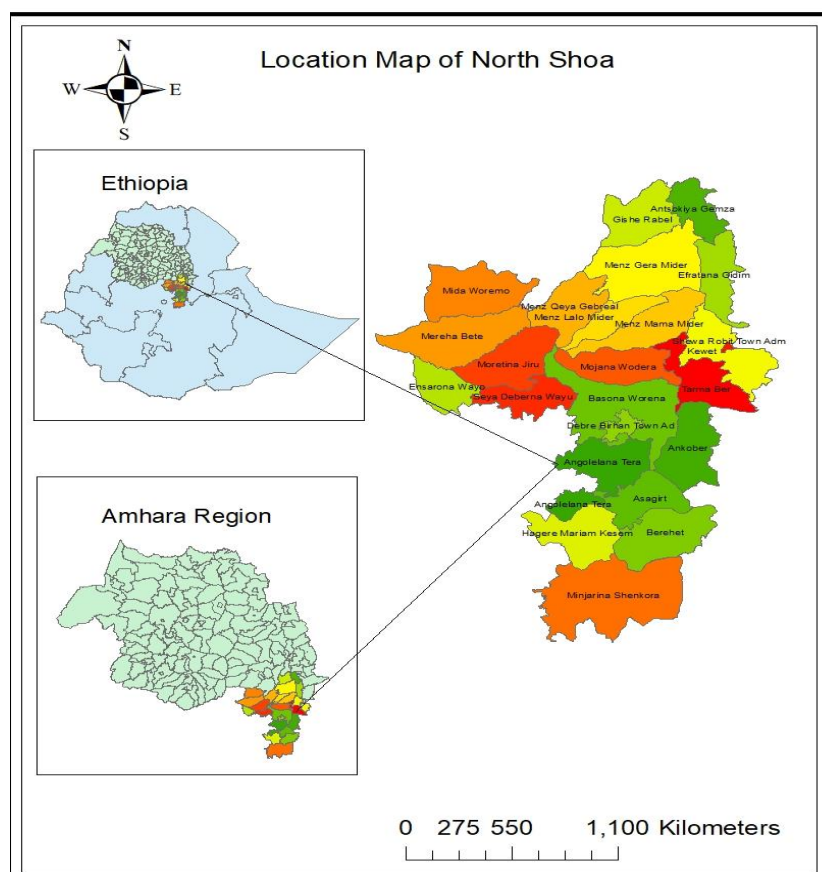


Figure 1. Map of the study area showing districts of North Shewa Zone, Amhara Region, Ethiopia.

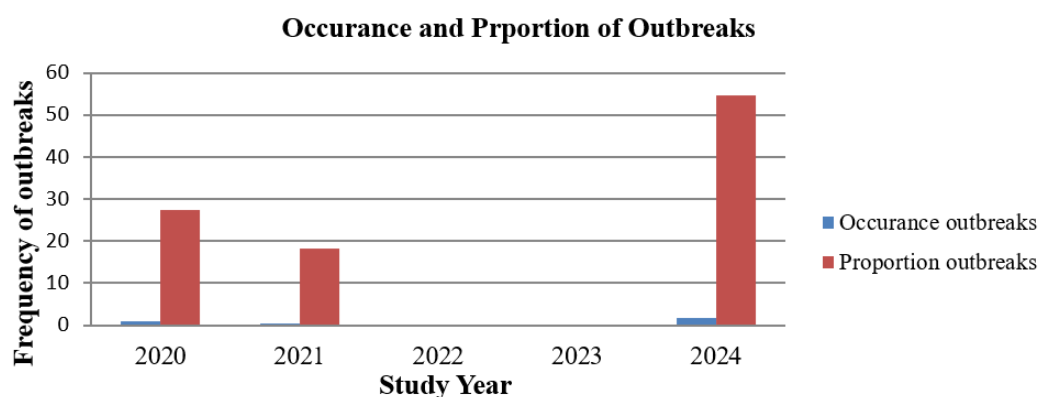


Figure 2. Number of Anthrax disease outbreaks by year in North Shewa Zone, Ethiopia, from 2020 to 2024.

3.2. Epidemiological Measures Anthrax Morbidity, Mortality, and Fatality Rate Across Years

Anthrax outbreaks occurred in 2020, 2021, and 2024, while no cases or deaths were reported in 2022 and 2023. Across the outbreak years, 19,130 animals were at risk, of which 89 developed anthrax and 48 died, resulting in an overall morbidity rate of 0.47%, mortality rate of 0.25%, and case fatality rate (CFR) of 53.9%. The highest disease burden was observed in

2024, with 36 cases and 21 deaths. Although 2024 had the largest population at risk (8,900 animals), its morbidity (0.40%) and mortality (0.24%) rates were lower than those of 2020 and 2021; however, it recorded the highest CFR (58.3%). In contrast, 2021 had the highest morbidity (0.57%) and mortality (0.33%) rates, with 21 cases and 12 deaths among 3,680 animals at risk, corresponding to a CFR of 57.1%. In 2020, 32 cases and 15 deaths were recorded among 6,550 susceptible animals, yielding a morbidity rate of 0.49%, mortality rate of 0.23%, and the lowest annual CFR (46.9%). Overall, anthrax

affected a small proportion of the susceptible livestock population (<1%) but was associated with a high fatality rate, with more than half of infected animals dying during the study period (Table 2).

Table 2. Anthrax morbidity, mortality, and fatality rate across years in the North Shewa zone, Ethiopia, from 2020 to 2024.

Year	Population at risk	Number of case	Number of Death	Morbidity rate (%)	Mortality rate (%)	Case Fatality rate (%)
2020	6550	32	15	0.49	0.23	46.9
2021	3680	21	12	0.57	0.33	57.1
2022	0	0	0	0.0	0.0	0.0
2023	0	0	0	0.0	0.0	0.0
2024	8900	36	21	0.40	0.24	58.3
Total	19,130	89	48	0.47	0.25	53.9

3.3. Temporal and Seasonal Distribution of Animal Anthrax Cases, Deaths, and CFR

The monthly distribution of anthrax cases, deaths, and case fatality rate (CFR) showed considerable temporal variation during 2020–2024 (Table 3). The highest number of cases was reported in August (n = 25; 28.1%), followed by May (n = 15; 16.9%), while no cases were reported in January, February, March, or September. The highest numbers of deaths occurred in May (n = 11) and August (n = 10). The CFR was highest in July (77.8%), followed by May (73.3%), November (70.0%), and October (66.7%), whereas the lowest CFR was recorded in December (16.7%). Despite having the highest number of cases, August had a comparatively lower CFR of 40.0%. Overall, anthrax occurrence was concentrated in specific months, whereas CFR varied considerably across months, particularly in months with relatively few reported cases.

Marked seasonal variation was also observed (Table 4; Figure 3). The highest proportion of cases occurred during the long rainy season (June–August), accounting for 45 cases

(50.6%) and 22 deaths, with a CFR of 48.9%. The short rainy season (March–May) accounted for 25 cases (28.1%) and 16 deaths, with a higher CFR of 64.0%. The post-rainy season (September–November) recorded 13 cases (14.6%) and 9 deaths, and the highest seasonal CFR (69.2%). In contrast, the dry/hot season (December–February) recorded the fewest cases (n = 6; 6.7%) and deaths (n = 1), with the lowest CFR (16.7%).

Overall, 70 of the 89 reported cases (78.7%) occurred during the two rainy seasons, demonstrating a strong seasonal concentration of anthrax occurrence during periods of rainfall. Although the long rainy season accounted for the greatest number of cases and deaths, its CFR was lower than those observed during the short rainy and post-rainy seasons. The relatively high CFR during the post-rainy season, despite the smaller number of cases, indicates a greater proportion of fatal outcomes among cases reported during this period. However, seasonal CFR estimates should be interpreted cautiously because they are based on relatively small numbers of cases. Overall, the findings demonstrate substantial seasonal variation in anthrax occurrence and fatal outcomes, with most cases occurring during rainy periods (Table 4; Figure 3).

Table 3. Monthly distribution of reported animal anthrax cases, deaths, and case fatality rate (CFR) in North Shewa Zone, Amhara Region, Ethiopia, 2020–2024.

Monthly distribution	No. of Case	No.of Death	CFR (%)
January	0 (0.0)	0	0.0
February	0 (0.0)	0	0.0
March	0 (0.0)	0	0.0
April	10 (11.2%)	5	50.0
May	15(16.9%)	11	73.3

Monthly distribution	No. of Case	No.of Death	CFR (%)
June	11(12.4%)	5	45.5
July	9(10.1%)	7	77.8
August	25(28.1%)	10	40.0
September	0 (0.0)	0	0.0
October	3(3.4%)	2	66.7
November	10(11.2%)	7	70.0
December	6 (6.7%)	1	16.7
Total	89 (100)	48	53.9

Table 4. Seasonal Distribution of Animal Anthrax Cases, Deaths, and Case Fatality Rate (CFR) in North Shewa Zone (2020–2024).

Season	Period	Cases, n (%)	Deaths, n	CFR (%)
Long rainy	June–August	45 (50.6)	22	48.9
Short rainy	March–May	25 (28.1)	16	64.0
Post-rainy	September–November	13 (14.6)	9	69.2
Dry/hot	December–February	6 (6.7)	1	16.7
Total		89 (100.0)	48	53.9

Seasonal distribution of Anthrax case in North Shewa (2020-2024)

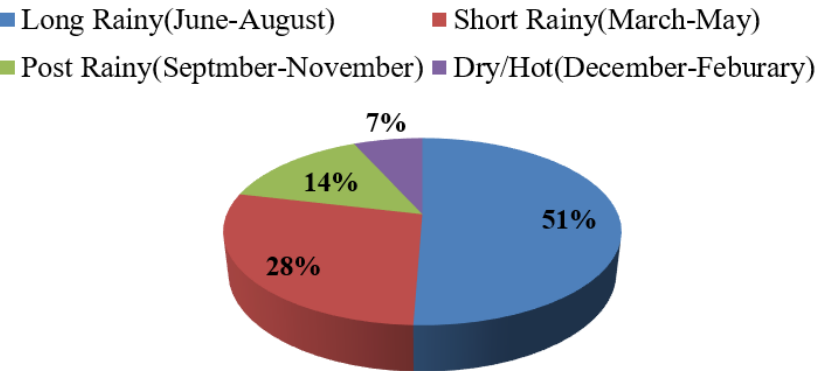


Figure 3. Seasonal Distribution of Animal Anthrax Cases, in North Shewa Zone (2020–2024).

3.4. Distribution of Animal Anthrax Cases, Deaths, and CFR by Species

Among the 89 reported anthrax cases, cattle accounted for the largest proportion (n = 44; 49.4%), followed by equines (n = 29; 32.6%), sheep (n = 12; 13.5%), and goats (n = 4; 4.5%). Of the 48 reported deaths, most occurred in cattle (n = 28; 58.3%), followed by equines (n = 16; 33.3%), sheep (n = 3; 6.3%), and goats (n = 1; 2.1%). The overall CFR was 53.9%.

Species-specific CFRs were highest in cattle (63.6%), followed by equines (55.2%), whereas sheep and goats each had a CFR of 25.0% (Table 5). Overall, cattle and equines accounted for the majority of reported cases and deaths and also showed relatively high CFRs. However, these findings describe the distribution and fatality of reported cases rather than species-specific disease risk. Differences in disease risk among species cannot be determined because reliable species-specific population denominators were unavailable. In addition, the relatively small numbers of cases among sheep and goats may result in less stable CFR

estimates (Table 5).

Table 5. Reported anthrax cases, deaths, and case fatality rate by livestock species in North Shewa Zone, Ethiopia, 2020–2024.

Species	Number of Cases %	Number of deaths (%)	Case fatality rate (CFR)
Cattle	44 (49.4)	28(58.3)	63.6
Sheep	12 (13.5)	3(8.3)	25.0
Goat	4(4.5)	1(2.1)	25.0
Equine	29 (32.6)	16(33.4)	55.2
Total	89	48	53.9

3.5. Spatial Distribution of Reported Anthrax Outbreaks

A total of 11 anthrax outbreaks were reported from eight of the 23 districts in North Shewa Zone during the study period, while the remaining 15 districts had no reported anthrax outbreaks. These outbreaks resulted in 89 reported cases and 48 deaths, corresponding to an overall case fatality rate (CFR) of 53.9% (Table 6). Moretena Jeru recorded the highest number of reported cases (n = 18; 20.2%), followed by Menz Lalo (n = 13; 14.6%). Ensaro, Merhebet, and Mojana Wodera each reported 12 cases (13.5%). The highest number of deaths was recorded in Menz Lalo (n = 9; 18.8%), followed by Merhebet (n = 8; 16.7%), while Moretena Jeru and Mojana Wodera each recorded seven deaths (14.6%).

District-specific CFRs varied from 38.9% to 69.2%. The highest CFR was recorded in Menz Lalo (69.2%), followed by Merhebet (66.7%), Ankober and Midda (60.0% each), Mojana Wodera (58.3%), Menz Qeya (42.9%), Ensaro (41.7%), and Moretena Jeru (38.9%). Although Moretena Jeru had the highest number of reported cases, it had the lowest CFR among the affected districts. Conversely, Menz Lalo recorded fewer cases than Moretena Jeru but had the highest number of deaths and the highest CFR. Overall, the findings demonstrate considerable spatial variability in reported anthrax cases, deaths, and case fatality rates across affected districts. However, these variations should be interpreted as differences in reported disease occurrence rather than true variations in district-level disease risk, as reliable livestock population denominators at the district level were not available (Table 6).

Table 6. Spatial distribution of reported anthrax outbreaks, cases, deaths, and case fatality rate among affected districts of North Shewa Zone, Amhara Region, Ethiopia, 2020–2024.

District	No. of outbreaks	Cases, n (%)	Deaths, n (%)	CFR (%)
Ankober	1	5 (5.6)	3 (6.3)	60.0
Ensaro	1	12 (13.5)	5 (10.4)	41.7
Menz-Lalo	2	13 (14.6)	9 (18.8)	69.2
Menz-Qeya	1	7 (7.9)	3 (6.3)	42.9
Merhebet	2	12 (13.5)	8 (16.7)	66.7
Midda	1	10 (11.2)	6 (12.5)	60.0
Mojana-Wodera	1	12 (13.5)	7 (14.6)	58.3
Moretena-Jeru	2	18 (20.2)	7 (14.6)	38.9
Total	11	89 (100.0)	48 (100.0)	53.9

3.6. Annual Anthrax Outbreaks, Outbreak Response, and Prophylactic Vaccination Coverage

During the five-year study period (2020–2024), a total of 11 anthrax outbreaks were reported in eight districts, placing 19,130 animals at risk. Emergency (ring) vaccination was implemented in response to all reported outbreaks, with 15,600 animals vaccinated, corresponding to an overall outbreak-response vaccination coverage of 81.1%. The annual distribution of outbreaks varied considerably, with the highest outbreak burden recorded in 2024, when six outbreaks occurred in three districts and 8,900 animals were at risk. Of these, 7,350 animals were vaccinated, resulting in the highest annual outbreak-response vaccination coverage (82.6%). In 2020 and 2021, three and two outbreaks were reported, respectively, with corresponding vaccination coverage of 80.9% and 80.2%. No outbreaks or outbreak-response vaccination activities were reported in 2022 or 2023 (Table 7).

Routine prophylactic vaccination was conducted throughout the study period. A total of 1,579,646 livestock were vaccinated, representing 30.15% of the cumulative target population of 5,240,144 animal-years. The number of animals vaccinated annually increased from 201,843 in 2020 to 309,552 in 2021, 336,788 in 2022, and 367,052 in 2023, before slightly declining to 364,411 in 2024. Despite this overall increase in the number of animals vaccinated, routine prophylactic vaccination coverage remained substantially lower than outbreak-response vaccination coverage. In contrast, emergency vaccination consistently achieved high coverage (80.2–82.6%) among animal at risk during outbreaks. The absence of reported outbreaks in 2022 and 2023 coincided with continued routine prophylactic vaccination; however, the available surveillance data do not allow a causal relationship between vaccination coverage and the absence of reported outbreaks to be established. Overall, the findings demonstrate strong implementation of emergency vaccination during outbreaks but comparatively lower cumulative coverage of routine prophylactic vaccination during the study period (Table 7; Figure 4).

Table 7. Annual distribution of anthrax outbreaks and vaccination activities in North Shewa Zone, Amhara Region, Ethiopia, 2020–2024.

Year	No. of Outbreaks	Affected Districts, n	Animal at risk, n	Animals Vaccinated During Outbreak Response (n)	Outbreak Response Vaccination Coverage (%)	Animal Vaccinated for Routine prophylaxis, n (%)
2020	3	3	6550	5300	80.9	201843 (3.85%)
2021	2	2	3680	2950	80.2	309552 (5.92%)
2022	0	0	0	0	0.0	336788 (6.43%)
2023	0	0	0	0	0.0	367052 (7.0%)
2024	6	3	8900	7350	82.6	364411 (6.95%)
Total	11	8	19130	15600	81.1	1,579,646 (30.15%)

Table Footnote
Abbreviations: n, number of animals. Outbreak response vaccination coverage was calculated as the number of animals vaccinated during outbreak response divided by the livestock population at risk × 100. Percentages in the routine prophylaxis vaccination column represent the proportion of the cumulative target livestock population (5,240,144 animals) vaccinated during each year and across the study period.

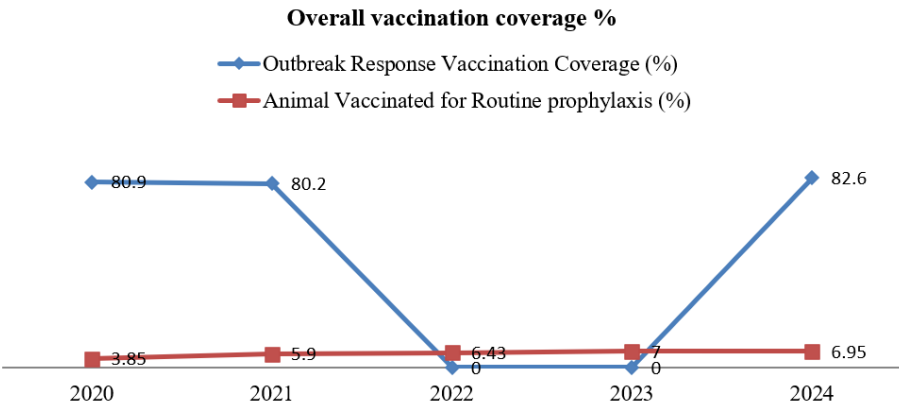


Figure 4. Annual anthrax outbreaks response and prophylactic vaccination coverage in livestock, North Shewa Zone, Ethiopia, 2020–2024.

4. Discussion

4.1. Temporal Distribution of Anthrax Outbreaks

This retrospective analysis demonstrated marked temporal, seasonal, species-specific, and geographical variation in reported animal anthrax cases in North Shewa Zone during 2020–2024. The finding of this analysis an irregular temporal distribution of anthrax outbreaks in North Shewa Zone during 2020–2024, with only 11 outbreaks recorded over the five-year period. More than half (54.5%) occurred in 2024, whereas no outbreaks were reported in 2022 and 2023, indicating a sporadic rather than continuous pattern of disease occurrence. This pattern is consistent with the ecology of *Bacillus anthracis*, whose resistant spores can persist in soil for prolonged periods and initiate outbreaks when favorable environmental conditions coincide with susceptible livestock populations [14, 15]. The low overall outbreak occurrence (2.94%) agrees with previous Ethiopian studies describing anthrax as an endemic disease characterized by intermittent outbreaks rather than sustained annual transmission [15]. Similar temporal variations reported elsewhere in Ethiopia have been associated with differences in rainfall patterns, environmental contamination, livestock movement, and vaccination coverage [16] highlighting the importance of environmental reservoirs and ecological factors in anthrax epidemiology.

The sharp increase in outbreaks observed in 2024 contrasts with reports of stable or declining anthrax occurrence following improvements in vaccination and surveillance activities in some Ethiopian settings [17, 18]. This variation may be related to localized ecological conditions, including rainfall-driven exposure of dormant spores through soil erosion, flooding, and runoff, combined with incomplete vaccination coverage, communal grazing practices, livestock movement, and improved outbreak detection. The absence of reported outbreaks in 2022 and 2023 should be interpreted cautiously, as passive surveillance may be affected by underreporting, delayed notification, and limited diagnostic capacity, particularly in remote areas [19]. Therefore, continued surveillance, routine prophylactic vaccination, rapid outbreak investigation, and improved laboratory confirmation remain essential to reduce the risk of future anthrax outbreaks in North Shewa Zone, as environmental reservoirs of *B. anthracis* remain capable of triggering disease emergence when favorable conditions occur.

Anthrax outbreaks in North Shewa Zone exhibited a characteristic pattern of low morbidity and mortality but high case fatality during the outbreak years (2020, 2021, and 2024). Among 19,130 animals at risk, 89 cases and 48 deaths were recorded, resulting in overall morbidity, mortality, and case fatality rates of 0.47%, 0.25%, and 53.9%, respectively. The low morbidity indicates that only a small proportion of the susceptible livestock population became clinically affected

during outbreaks, whereas the high case fatality rate reflects the rapid and frequently fatal progression of anthrax once clinical disease develops. Similar epidemiological patterns have been reported in Ethiopia, where anthrax remains endemic with relatively limited outbreak occurrence but substantial mortality among affected animals, particularly when disease recognition and control measures are delayed [15, 17].

The observed annual variation in morbidity, mortality, and CFR likely reflects differences in environmental exposure, outbreak intensity, livestock susceptibility, and the timing of control measures. The highest CFR in 2024 (58.3%) despite relatively lower morbidity and mortality may indicate delayed outbreak detection or increased exposure to contaminated environments before intervention. In contrast, the higher morbidity and mortality recorded in 2021 may be associated with localized exposure to *Bacillus anthracis* spores in endemic grazing areas. Similar Ethiopian studies have emphasized the role of environmental contamination, delayed reporting, and response capacity in determining the severity of anthrax outbreaks [20].

The absence of reported outbreaks in 2022 and 2023 should be interpreted cautiously, as passive surveillance systems are prone to underreporting, delayed case detection, and incomplete laboratory confirmation, which may underestimate the true burden of anthrax. Similar challenges have been documented in Ethiopia, where limitations in disease reporting and diagnostic capacity affect the timely detection and confirmation of outbreaks [2]. Overall, the findings highlight that anthrax remains a significant livestock health concern in North Shewa Zone due to its high fatality despite affecting a small proportion of animals at risk. Continuous surveillance, routine prophylactic vaccination, prompt case reporting, and rapid outbreak response are therefore essential for reducing mortality and preventing future outbreaks, consistent with international recommendations for anthrax prevention and control [6].

4.2. Epidemiological Measures Anthrax Morbidity, Mortality, and Fatality Rate Across Years

Anthrax outbreaks in North Shewa Zone during 2020–2024 were characterized by low morbidity (0.47%) and mortality (0.25%) but high case fatality (53.9%), indicating limited occurrence but severe outcomes among clinically affected animals. This finding agrees with Ethiopian studies reporting anthrax as a sporadic but highly fatal disease associated with environmental persistence of *Bacillus anthracis* spores and rapid disease progression [2]. The annual variation in disease indicators may reflect differences in environmental exposure, outbreak intensity, livestock susceptibility, and surveillance effectiveness. The higher morbidity and mortality in 2021 may be related to increased exposure in contaminated grazing areas, while the highest CFR in 2024 (58.3%) may suggest delayed

detection or response. Similar effects of ecological conditions and surveillance capacity on anthrax occurrence have been documented in Ethiopia [15, 17].

The interruption in reported anthrax outbreaks during 2022 and 2023 is likely attributable to a combination of enhanced routine prophylactic vaccination, improved outbreak prevention measures, and the inherent limitations of passive surveillance systems. However, in endemic settings, the absence of reported outbreaks should not be interpreted as evidence of disease elimination, as *Bacillus anthracis* spores remain viable in the environment for prolonged periods and sporadic transmission may go undetected because of underreporting, limited diagnostic confirmation, or variations in surveillance performance. These findings underscore the importance of maintaining continuous epidemiological surveillance, strengthening laboratory diagnostic capacity, sustaining routine prophylactic vaccination programs, and ensuring timely outbreak detection and response to prevent disease re-emergence and reduce livestock losses [6, 19, 21].

4.3. Monthly and Seasonal Distribution of Animal Anthrax Cases

Animal anthrax occurrence in North Shewa Zone showed clear temporal variation, with the highest proportion of cases reported in August (28.1%) and May (16.9%), while no cases were recorded from January to March or in September. Most cases (78.7%) occurred during the rainy seasons, including the long rainy season (50.6%) and short rainy season (28.1%). This seasonal pattern agrees with previous reports from Ethiopia and other East African countries, where anthrax outbreaks are frequently associated with periods of increased rainfall and favorable environmental conditions for *Bacillus anthracis* spore exposure [2, 3, 22].

The predominance of cases during rainy seasons may be explained by the combined influence of rainfall, soil characteristics, vegetation dynamics, and livestock grazing behavior on spore persistence, redistribution, and animal exposure. Rainfall can facilitate soil disturbance and movement of contaminated materials, while reduced pasture availability during preceding dry periods may force animals to graze closer to the soil surface, increasing the risk of ingesting *B. anthracis* spores. Previous environmental suitability studies in Ethiopia have also demonstrated that anthrax occurrence is determined by the interaction of climatic, ecological, and landscape factors rather than rainfall alone [2, 17].

The seasonal pattern observed in North Shewa is comparable with findings from Halaba Zone, where anthrax cases were predominantly reported during rainy seasons [17]. However, differences among Ethiopian regions, such as the higher occurrence during the hot-dry season reported in Awi Zone, indicate that local agroecological characteristics, including altitude, soil properties, vegetation availability, and livestock-management practices, influence the timing and distribution of outbreaks [15]. The higher CFR observed during the post-

rainy season (69.2%) should be interpreted cautiously due to the limited number of cases during this period. Variations in CFR between studies may be related to differences in surveillance sensitivity, reporting practices, access to veterinary services, and timing of case detection rather than differences in pathogen virulence.

The absence of reported cases during some months does not necessarily indicate the absence of environmental contamination, as *B. anthracis* spores can persist in soil for prolonged periods. Similar observations have emphasized the importance of considering environmental persistence when interpreting temporal variations in anthrax occurrence [15]. Therefore, the concentration of cases during rainy periods highlights the need for timely preventive vaccination, enhanced outbreak preparedness, and strengthened surveillance before and throughout high-risk seasons. Overall, rainfall is an important contributor to anthrax occurrence in North Shewa Zone; however, its effect is mediated by local ecological conditions and livestock-management practices.

4.4. Anthrax Cases, Deaths, and Case Fatality Rate by Livestock Species

Although anthrax is a multi-species disease, cattle accounted for the highest proportion of reported cases (49.4%) and deaths (58.3%), followed by equines (32.6%), whereas goats had the lowest proportion of cases (4.5%) and deaths (2.1%). Similar species distribution has been reported in Ethiopia, where cattle consistently account for most anthrax cases [17]. This pattern may be partly explained by ecological and management factors. As grazers, cattle are more likely to ingest *Bacillus anthracis* spores from contaminated soil while feeding on communal pastures, whereas goats, being primarily browsers, have reduced exposure because they feed above ground level [23, 24]. The relatively high proportion of equine cases may also be associated with communal grazing and frequent movement during transport and agricultural activities, increasing contact with contaminated environments [25]. However, these findings should be interpreted cautiously because cattle constitute the largest livestock population in North Shewa Zone and Ethiopia, and therefore the higher number of reported cattle cases may partly reflect the larger population at risk rather than inherently greater susceptibility. Furthermore, species-specific incidence rates could not be estimated because population denominators by species were unavailable. Consequently, the present findings describe the distribution of reported cases rather than comparative species-specific risk. Variations in livestock management, grazing practices, and veterinary service utilization may also have contributed to the observed differences among animal species. Future studies incorporating species-specific population data are needed to estimate incidence and determine the true relative risk of anthrax across livestock species [15].

4.5. Spatial Distribution of Reported Anthrax Outbreaks

Animal anthrax cases were reported from eight districts, with the highest proportion occurring in Moretena Jeru District (20.2%), followed by Menz Lalo District (14.6%). The highest case fatality rates (CFRs) were recorded in Menz Lalo (69.2%), Merehebet (66.7%), and Ankober and Midda districts (60.0%). However, these district-level differences should be interpreted cautiously because they are based on reported case counts rather than incidence rates. The observed spatial variation may reflect a combination of ecological and operational factors. Although environmental variables were not assessed in the present study, previous evidence suggests that soil characteristics, climatic conditions, flooding, and inadequate carcass disposal can promote the long-term environmental persistence of *Bacillus anthracis* spores [3, 26]. In addition, differences in livestock population density, grazing and animal movement patterns, surveillance and reporting efficiency, diagnostic capacity, veterinary service accessibility, and farmers' awareness may have influenced the distribution of reported cases across districts. Therefore, the findings describe the spatial distribution of reported anthrax cases rather than true differences in district-level disease risk. Future studies incorporating livestock population denominators, environmental variables, and surveillance performance indicators are needed to estimate district-specific incidence and better explain the spatial epidemiology of anthrax in North Shewa Zone.

4.6. Annual Anthrax Outbreaks, Outbreak Response and Prophylactic Vaccination Coverage

The observed annual variation in anthrax outbreaks and vaccination activities likely reflects differences in environmental exposure, surveillance performance, and the effectiveness of disease control interventions. The concentration of outbreaks in 2024 despite the highest emergency vaccination coverage (82.6%) indicates that reactive vaccination was implemented effectively following outbreak detection but could not prevent the initial occurrence of disease because livestock had likely been exposed to *Bacillus anthracis* spores before vaccination. This finding is consistent with the epidemiology of anthrax, in which emergency (ring) vaccination is primarily intended to limit further spread rather than prevent the index cases of an outbreak [27].

Routine prophylactic vaccination increased steadily over the study period, demonstrating strengthened implementation of preventive control measures. However, the overall vaccination coverage of 30.15% remained substantially below the level generally recommended for effective control of anthrax in endemic areas. Insufficient routine vaccination leaves a large proportion of susceptible animals unprotected, allowing environmental spores to sustain periodic outbreaks

when ecological conditions become favorable [3]. The relatively high emergency vaccination coverage (80.2–82.6%) compared with routine prophylactic coverage suggests that outbreak response activities were prioritized once cases were detected, whereas achieving broad preventive vaccination before outbreaks remained challenging. This disparity may reflect constraints in vaccine availability, financial and logistical resources, accessibility of remote communities, and limited capacity to implement annual mass vaccination campaigns.

The absence of reported outbreaks in 2022 and 2023 should be interpreted cautiously. It may indicate improved preventive vaccination and disease control, reduced environmental exposure, or natural year-to-year variation in anthrax occurrence. However, because the study relied on passive surveillance data, underreporting or incomplete detection of outbreaks cannot be excluded. Strengthening risk-based annual prophylactic vaccination, particularly in historically affected districts, together with sustained surveillance, timely outbreak investigation, and rapid emergency response, will be essential for reducing the burden of anthrax in North Shewa Zone.

Limitation: First, diagnostic uncertainty limited the study due to the absence of laboratory confirmation. All cases were identified based on clinical and epidemiological criteria because of limited diagnostic infrastructure at the district level. This retrospective study was based on suspected anthrax cases. However, it had a few limitations of upgrading case definitions to presumptive and confirmed level. Another limitation was the study was focused specifically on livestock or animal cases, human cases were not included.

5. Conclusion

The retrospective analysis shows that animal anthrax remains an important livestock health and surveillance concern in North Shewa Zone. During 2020–2024, 11 outbreaks were reported in eight of 23 districts, resulting in 89 cases and 48 deaths among 19,130 animals at risk. Although reported morbidity (0.47%) and mortality (0.25%) were low, the case fatality rate was high (53.9%). Disease occurrence varied by year, season, species, and location, with the highest number of outbreaks reported in 2024 and most cases occurring during the rainy seasons, particularly the long rainy season. Cattle accounted for most cases, while Moretena-Jeru and Menz-Lalo were among the most affected districts. Emergency outbreak vaccination coverage was relatively high (81.1%), but routine prophylactic vaccination coverage was low (30.15%), highlighting the need for stronger preventive vaccination, particularly in historically affected areas. The absence of reported outbreaks in 2022 and 2023 should not be considered evidence of disease elimination because underreporting and limitations of passive surveillance may have occurred. Therefore, strengthening active surveillance, laboratory confirmation, timely reporting, and risk-based vaccination before the rainy

season is recommended, together with safe carcass disposal, improved biosecurity, community awareness, and prevention of unsafe slaughter and carcass handling. An integrated One Health approach combining vaccination, surveillance, environmental management, laboratory diagnosis, and community participation should be implemented to reduce anthrax transmission and its impact on livestock and public health in North Shewa Zone.

Abbreviations

CDC	Centers for Disease Control and Prevention
CFR	Case Fatality Rate
DOVAR	Disease Outbreak and Vaccination Report
EPHI	Ethiopian Public Health Institute
FAO	Food and Agriculture Organization
MoA	Ministry of Agriculture
MoH	Ministry of Health
OHZDP	National One Health Zoonotic Disease Prioritization
PAR	Population at Risk
STATA	Statistical Software for Data Analysis
WHO	World Health Organization
WOAH/OIE	World Organization for Animal Health/Office International Des Epizooties

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Author Contributions

Zelalem Yitayew: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing

Data Availability Statement

The data used in this article can be found upon request to the corresponding author on reasonable request.

Conflicts of Interest

The author declares no conflicts of interest.

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Biography



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