Prevalence and Impact of Anthrax on Cattle Production in the Municipality of Boukoumbé in Northern Benin.

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Abstract- Anthrax-causing Bacillus anthracis comes from the Greek word for coal because it generates black, coal-like eschars. It is a 1–1.5' 3–10 mm Gram-positive, aerobic, spore-bearing bacillus and the sole obligate pathogen in the genus Bacillus. The aimed of this study is to highlight the impact of the prevalence of anthrax on bovine production in the administration unit (municipality) of Boukoumbé in northern Benin and determine the exact reason for the persistence of this disease in this community despite the several actions taken by the Anthrax Control Project (PLCB). The current study was conducted in Boukombé, Atacora, and North-West Benin. Tanguiéta, Cobly, Natitingou, Toucountouna, and Togo border it from the north to the west. The longitudinal and retrospective surveys were the two types of survey data used in this study. Prevalence and the incidence of the diseases was calculated and then, this rate was compared using a curve showing how it changed over time. The Number of dead animals (ANIMOR) on farms is the phenomenon to be modeled. To achieve this, a linear regression was performed by including certain characteristics specific to each farm. Obtained data were subjected to linear regression using R software (version 3.6.3) to show the relationship between the risk factors associated with anthrax, the number of animals infected, and the bovine mortality rate. The results showed that the evolution of anthrax occurred in three phases from 2004 to 2016: a significant phase of expansion or growth (2004-2012), a phase of regression or decline (2012-2014) then a tiny phase of growth (2014-2016). Moreover, the maximum number of anthrax outbreaks was recorded in 2015. The livestock owner (breeders) training, knowledge of the mechanism of contamination, residence in the district of "Manta," and vaccination of animals are the significant factors responsible for the dissemination of disease and death of animals within farms.

Index Terms- Anthrax, prevalence, bovine, factors, Municipality, Boukoumbé.

I. INTRODUCTION

Anthrax-causing Bacillus anthracis comes from the Greek word for coal because it generates black, coal-like eschars. It is a 1–1.5' 3–10 mm Gram-positive, aerobic, spore-bearing bacillus and the sole obligate pathogen in the genus Bacillus (Baillie and Read, 2001). By phenotype, B anthracis fits together with B cereus, B thuringiensis, and B mycoides (Turnbull, 1999). Even if it is impossible to differentiate between species using 16S rRNA sequencing, multiple-locus variable number tandem repeat analysis and amplified fragment length polymorphism provide compelling evidence that B anthracis can be distinguishable from other B cereus groups in a reliable manner (Keim et al., 1997, Keim et al., 2000). Bacillus anthracis is the only species of the genus Bacillus that may cause pandemic disease in humans and other mammals Bacillus anthracis is the only species of the genus Bacillus that may cause pandemic disease in humans and other mammals. In addition, B anthracis is one of the most molecularly monomorphic bacteria known. However, all known strains have been grouped into five categories based on tandem repeats in the VrrA gene (Jackson et al., 1998). PXO1 and PXO2.24 25 are two virulence plasmids that B anthracis uses to encode its primary virulence components. The tri-toxin carrying plasmid pXO1 has a size of 184.5 kilobase pairs (kbp), and it contains the genetic code for three toxins that cause haemorrhaging, oedema, and necrosis, respectively (Leppla, 1991). They are the 83 kDa fatal factor, 89 kDa edoema factor (calmodulin-dependent adenylate cyclase), and the 85 kDa protective antigen, which contains the 20 kDa host cell receptor (Leppla, 1982, O'Brien et al., 1985). Before a vaccine for domestic animals became available, anthrax was a serious disease among farm animals in many parts of the world (Larson, 2004, Maxson et al., 2022).

Although effective veterinary vaccination and antibiotic therapy have reduced animal and human anthrax infections, the disease remains prevalent in in various regions of the world such as West Africa and several islands including Haiti and parts of the Philippines and Indonesia (Swartz, 2001). It is thought that between 20,000 and 100,000 cases of anthrax happen worldwide every year. Most of these things happen in rural areas that have not been developed much, where they damage the animals that make this area wealthy (Swartz, 2001). In west Africa, especially in Benin, this disease is mainly known in the North-West region in the municipalities of Boukoumbé, Cobly and Matéri, Tanguiéta, Toucountouna, Natitingou, some of which border Togo (PLCB, 2019).

The enzootic cycle of anthrax in natural settings is characterized by long-term spore persistence in soil and an obligate-lethal transmission mechanism, with herbivorous mammals serving as the primary hosts (Carlson et al., 2018, Hugh-Jones and Blackburn, 2009).

During grazing, both wild herbivores and livestock are exposed to B. anthracis spores from the soil, become ill, and often return spores to the soil as they decompose. This may contribute to the disease's spread (Turner et al., 2014). Wildlife epizootics can result in downstream infections in livestock and humans due to the fact that domesticated and wild herbivores commonly share grazing sites. In some areas, anthrax is extremely common, and cases tend to occur in cycles that are consistent with the seasons; in other areas, the disease re-emerges in big epidemics after going for years or even decades without a single reported instance (Hugh-Jones and Blackburn, 2009). B. anthracis spores can remain in the soil for long periods under optimum conditions (decades). Soils that are alkaline and full of calcium may allow sporulation and cause patterns of persistence at the landscape level, which could spread B. anthracis to the continents. The epidemic hit the Municipality of Boukoumbé in 2005, 2007, 2012, 2013, 2015, and 2018. As a result, 52 people died from eating anthrax-tainted meat (PLCB, 2018).

The occurrence of anthrax outbreaks has led to the impoverishment of farmers affected by the loss of animals, the weakening of their financial capacities, with a negative impact on family nutrition, health care, children's education, and security, a destabilization of the rural social fabric, and an exodus of ruined farmers who are forced to seek other occupations in urban areas. To the losses related to the death of animals, one must add the loss of use of spore-infected fields as pasture and as "cursed field" farmland (PLCB; 2016). In the Benin Republic, Order No. 080/MDR/DCAB/SGM/DA/CP from February 6, 2001, made it clear that this zoonosis, rabies, and brucellosis were all critical.

Even though there is much information about the spread of anthrax, its symptoms, and how to isolate, identify, and prevent B. anthracis, the disease still happens, especially in developing countries.

As part of the fight against this disease in the border countries, WAEMU (West African Economic and Monetary Union), WHO (World Health Organization), and FAO (Food and Agriculture Organization), in partnership with the governments of Togo and Benin, have put in place a joint Togo-Benin anthrax strategy. The main goal of this program was to create a joint multi-year plan for Togo and Benin to fight this disease. The goal was to reduce the yearly anthrax cases reported in these countries significantly. It was also to secure two regions hosting about 40 resurgent cursed fields, particularly in the Savannah region, where anthrax cases with human mortality have been recorded almost every year in both countries. The main levers in which the program invested were the establishment of revolving funds for vaccines to support vaccination campaigns against animal diseases and assistance to states in the training of anthrax experts (WHO, 2012).

The current research aimed to highlight the impact of the prevalence of anthrax on bovine production in the administration unit (municipality) of Boukoumbé in northern Benin and determine the exact reason for the persistence of this disease in this community despite the several actions taken by the Anthrax Control Project (PLCB):

II. MATERIALS AND METHODS

1. **Study environment**

The current study was conducted in Boukombé, Atacora, and North-West Benin. Tanguiéta, Cobly, Natitingou, Toucountouna, and Togo border it from the north to the west. According to the revised territorial division (Municipal Development Plan; 3rd generation of Boukombé 2018-2022), Boukombé has 7 districts and 93 settlements on an area of 1,036 km2. The town has a Sudano-Guinean climate, with rainy seasons from April to October and November to March. March (36°C) is the hottest month, and August (24°C) is the coolest. Annual precipitation is 1,100 mm. The harmattan, a dry and scorching wind, blows from November to February. From March to June, the monsoon ocean brings rain.The investigation was carried out in all seven districts of Boukoumbé (because of the numerous cases reported and the persistence of the disease in this region). In addition, Boukoumbé shares a border with the Republic of Togo and Burkina Faso. Due to the vastness of the vegetation, rich in various forage species, animals from these neighboring countries come to graze during the dry season. This makes the town a privileged checkpoint for transhumance. The study area is shown in Figure 1.

2. **Study design**

The longitudinal and retrospective surveys were the two types of survey data used in this study. First, an observation period of 04 months (January to May 2018) and then a survey period (June to August 2018) was done. During the survey period of this research, no cases of Bacillus anthracis were reported; therefore, no samples could be collected for serological analyses. On the other hand, the second type of retrospective survey asked farm owners who had been affected by diseases in the past to report those events. In deploying this survey, data were collected based on people's past experiences and beliefs. These data were then compared to the PLCB records and used for future analysis.

3. **Data collection method**

The data (the list of farmers who have been affected by this disease, the number of animals affected, the place of death, the vaccination program respected, the grazing area, Etc.) were obtained from the officials of the Project for the Control of Bacterial Anthrax, and an update was made from the responses of this survey. The survey began in January 2018 with meetings with officials of the Project to Control Bacterial Anthrax (PLCB) to gather information related to the epidemiology of anthrax in the commune of Boukoumbé.Thus, after this meeting, a period of observation was made on the field, and the new cursed fields were recorded with the help of the GPS. From June to August 2018, the commune's seven districts were used to gather data.

4.Sampling

In this study, the people who own the farms where the diseases were found are used as a sampling frame. Since the data on the target population was already available, the convenience sampling method was used as a sampling method. A questionnaire with a series of questions was prepared using the kobocollect tools. Due to the small size of the sampling frame, all farms where diseases were found were interviewed, so 70 people were taken into account in this study (Table 2).

5. Data analysis

The data generated from the study were arranged, coded, and entered into an Excel spreadsheet (Microsoft® excel 2007). Furthermore, the rate of anthrax occurrence for each year (from

2008 to 2018) was determined. It was determined using the following formula:

Prevalence = Number of cases existing during the period/number of susceptible species

The following formula determined the annual incidence:

Incidence = Number of new cases during the period/number of susceptible species.

Then, this rate was compared using a curve showing how it changed over time. Also, the proportions linked to the factors explaining the spread of this disease were calculated and compared.For this, several characteristics specific to farmers was postulate and their activities relevant to the appearance or control of this disease. The Number of dead animals (ANIMOR) on farms is the phenomenon to be modeled. To achieve this, a linear regression was performed by including certain characteristics specific to each farm. These variables include the breeder's training, knowledge about anthrax and itscontamination mechanism, locality of residence, and participation or vaccination policy.Statistic vs 8.1 software was used for analysis of the rate in each district on the municipality; including Z test. The Probability value (P-value) of a test less than 0.01 indicated statistically significant differences.

III. RESULTS

A. Prevalence and incidence of anthrax in cattle in the municipality of Boukoumbé from 2005 to 2016

Based on the figure2 analysis, the rate of diseases was almost 0% in 2005, and since then, the municipality has seen a gradual rise in the number of diseases. The number then rose significantly from 2009 to 2012, hitting a peak of 50%. After this year, the prevalence rate drops until 2014, reaching its lowest point. From 2015 to 2016, it experienced a slight increase of approximately 5%.

From the analysis of table 1, it appears that the prevalence of the diseases in district VI was higher, though not significantly(P<0.01) different from district I and II. Similarly, there was a significant difference(P<0.01) between the prevalence of the diseases in district II and district III, V, and VII. Also, they were statistically significant differences in the percentage of the diseases in district I and district III, IV, V, and VII. However, the prevalence of the diseases was significantly lower in district VII than in the rest of the district.

B. Bovine production during the year 2005-2015 in the municipality of Boukoumbé.

In the current study, ANOVA reveals highly significant (P< 0.01) differences among different districts of the municipality of boukoumbé regarding the average yields of bovine production. The district of Tabota produced the highest mean yield, while the lowest production was observed in the district of Natta, though not significantly different from Korontière district (Figure 3).

Regarding the average cattle production in Boukoumbé, ANOVA reveals highly significant (P< 0.01) differences among the different years. Overall, it appears that cattle production in the current municipality experienced a gradual increase until 2008, hitting this high point of 5189 head. Furthermore, the district with the highest mean production was observed in 2008, though it was not significantly different from the years 2007,2006 and 2010. However, from this year, a decrease was observed until 2012, where the production reached its lowest point before rose to almost 3617 animals (Figure 4).

C. Factors associated with the evolution of anthrax in farm animals in the municipality of boukoumbé

1.Knowledge of the disease by breeders

The result of this study showed that 78.85% of the people interviewed supposed knew or had at least heard of anthrax, while 21.15% affirmed the opposite (Figure 5). The majority of breeders have superficial knowledge about the disease. Table 3 shows the most common names for the disease in the languages spoken in the department of Atacora.

2. Training of farmers on the disease

Regarding the training of breeders on the disease, it was observed that almost (96.15%) of the total breeders have yet to receive training on the practices to follow in the event of suspicion of anthrax in their herd. On the other hand, a negligible percentage (3.85%) of the farmers reported that they try to contact the veterinarian incharge of the district for assistance. If the latter does not respond or is not in the zone, the solution is to call the owner to come and collect the corpse in case of death (Figure 6).

3. Infection source for animals

These results revealed that more than half of the breeders (55.77%) need to learn how the animals become contaminated, compared to nearly 26.92% who affirmed that the contamination is done on pasture and 13.46% reported that the contamination is made with drinking water. It is emerged from the given study that 3.85% of those surveyed revealed that other means of contamination exist (the entry of transhumant herds into the town, Etc.) and is, moreover, according to them, the primary source of contamination (Figure 7).Moreover, the vast majority of those concerned (78.69%) need to know the location of the cursed fields (Figure 8).

4. Spatio-temporal distribution of dead animals from bacterial anthrax

An analysis of the distribution of dead animals from anthrax shows that, with a number oscillating between 0 and 100 deaths, the district of Manta is the most affected following by, while in other districts such as Boukoumbé centre, Natta and Tabota the highest number of dead subjects is below 10 except for a single breeder who recorded more than 80 cases in the district of Tabota (figure 9). On the other hand, in certain districts such as Dipoli, Korontière, and Kossocoungou, the number of recorded cases is almost nil among all the breeders of these localities except for only one in each district in which more than ten subjects had died of the disease.However, from the average point of view, it appears that in the district of Manta, each stock breeder recorded 35 cases of dead animals of bacterial anthrax against approximately 12 for the localities of Tabota (figure 10). In the other districts, the average number of dead animals is almost equivalent and is below 5 cases (figure 10).

Regarding the month that the disease occurs, based on the compilation of available data received from the Anthrax Project authorities, for the period from 1994 to 2016 and on the nineteen outbreaks for which details regarding the month of onset are available, 75% of the outbreaks were recorded during the first four months of the year (January, February, March, April) while the remaining 25% of outbreaks were recorded in the month of March. (Figure 11).

5. Vaccination rate

According to the data received from the Anthrax Project authorities and an update from the current study, the number of animals vaccinated against anthrax, even if it experienced a significant increase (multiplied by 14.3) between 2013 and 2014 under the impetus of the activities of the Fight Against Bacteridian Anthrax (PLCB) project, finally regressed between 2014 and 2015 (Figure 14) before an increase was observed between 2015 and 2016 (Multiply by 2.5) where it reached its peak. After 2016 there was a decrease of 15%. Based on the number of cattle reported by the Directorate of Animal Production, the number of cattle in Boukoumbé vaccinated against anthrax was 56.46% (Figure 15).

Moreover, in the group of breeders met, the majority of Manta breeders, i.e., 91%, claim to vaccinate their animals against anthrax. In addition to the breeders of this locality, those of Koussocoungou are positioned in the second position with a rate of 80%. More than half of the breeders in the district of Natta and Dipoli also specify their participation in vaccinating their animals against this disease. On the other hand, the stockbreeders of Boukoumbé centre, Tabota, and Korontière participate as little as possible in this vaccination operation (figure 15).

D. Factors influencing the number of animals that died of anthrax on the farmers' farms met.

Table 4 below presents the results of the estimates from the linear regression model, particularly on the variations in the number of animals that died following anthrax.

Initially, the analysis of the table indicates that only the coefficients of certain variables, including "training of breeders on what to do in the face of anthrax,"; "knowledge of the mechanism of contamination," residence in the district of "Manta," "livestock composition" and "vaccination of animals against anthrax" are significant at the 5% level (p-value < 0.05).

Furthermore, analysis of the table indicates that the sign of the coefficient for farmers who have not received training on what to do in the event of animal contamination is favourable compared to those who have received training. These data reveal that the number of animals that died of anthrax in the breeders who did not receive training is substantially more significant than the number reported in the group who did receive training, i.e., roughly 11 more animals than the latter perished of the disease, as mentioned earlier.Also, the sign of significance is positive at the level of the district of Manta compared to the Boukoumbé c enter. Based on these results, breeders in the district of Manta reported about 30 more dead animals than breeders in the centre of Boukoumbé.

Furthermore, the linear regression showed that the composition of the herd also influenced the spread of this disease.

In addition, the sign of the coefficient of the model is negative at the level of breeders not knowing the mechanism of contamination by bacterial anthrax. Indeed, breeders without knowledge of the contamination mechanism recorded fewer cases of dead animals, i.e., around 7 heads less than those who knew the transmission mechanism.

The non-significance of the coefficients of the other variables (knowledge of bacterial anthrax and the other districts) leads to the conclusion that there is no statistically significant difference between the numbers of dead animals within these breeders.

IV. DISCUSSION

The analysis of the results initially indicated that the prevalence rate evolved gradually between 2005 and 2012. However, after this period, a gradual decrease in this rate was observed until 2014, when it was cancelled. Indeed, these results could be explained by the fact that the period from 2005 to 2012 marked an absence of veterinary agents and vaccination awareness sessions in the municipality of Boukoumbé. These are also the factors that contributed to the improvement of the situation after the year 2014 when we note an awareness organized by the then Regional Agricultural Centers for Rural Development (CARDER) and the Project to fight against anthrax which not only multiplied the agents' veterinarians in the municipality, i.e., 01 agents per district; but also actively participated in the awareness and vaccination campaign during each year. These public services make it possible to guarantee a stock of vaccines in an area at all times to allow rapid intervention in the event of outbreaks and to ensure serosurveillance (Diallo, 2016). Just like the prevalence of the diseases, cattle production dropped after 2012, the year when the Bacillus reached its peak. The multiplication of the cursed fields has led to a decrease in grazing space and thus makes it difficult to feed the animals. In fact, studies have shown that feeding in the livestock system alone accounts for more than 75% of final production.(De Quelen et al., 2021, Leger et al., 2021). This could justify the decline in production observed after the Bacillus peak as the number of farmers also decreased.

Concerning the favourable period, the analysis of the information collected led to the conclusion that the incidence of the disease seems to increase at the end of the dry season, rather at the beginning of the rainy season, that begins in the department of Atacora around February to March. This corroborates the results of some researchers who testify that anthrax in animals is seasonal and is observed mainly after a long drought followed by heavy rains or floods (AVIQ, 2016). Thus, anthrax is recognized as a disease that develops when favourable conditions are met (grazing animals, humidity, and moderate to high heat) (Afssa, 2016). It is indeed the period of appearance of the first grasses at ground level. This favors the inhalation or ingestion of Bacillus anthracis spores if they are present on the ground or the first grasses. This is also when the first waterholes reappear, and the herds gather around these waterholes, which may have been contaminated by the spores and where the first grasses also grow.

Several authors have unequivocally demonstrated the persistence of diseases on the soil. (Hugh-Jones and Blackburn, 2009, Saile and Koehler, 2006) looked into whether soil spores germinate, grow as vegetative bacilli, and then make spores. These studies show that spores can germinate and form stable populations of vegetative cells in the rhizosphere of fescue grass (Festuca arundinacea), even in a sterile environment. Furthermore, they showed that genes could move from plant to plant. The optimal germination temperature is 39 °C which drops to almost nothing at 18 °C (Davies, 1960). In nature, vegetative cells are fragile and die in harsh environments (Turnbull and Snoeyenbos, 1989, Turnbull et al., 1991, Bowen and Turnbull, 1992); therefore, the current research suggests the use of straw for large livestock animals. If the method fails for reasons stated above (cost, labor shortage, and climate change leaders of season change), the current findings encourage using a diverse range of crop plants for grazing. Cherkasski study (2002) and Popova et al. (2017) demonstrated that a wide range of crop plants (winter wheat, rye, maize, vetch, garlic, clover, alfalfa, and different kinds of grass) made infectious soil of Bacillus safe for grazing.

Regarding the factors related to the variation in the number of dead animals from anthrax, the results of the linear regression model indicated that "training of breeders on what to do in the face of anthrax,"; "Knowledge of the mechanism of contamination," residence in the district of "Manta" and "vaccination of animals against anthrax" are the factors that significantly influence the spread of bacterial anthrax disease and resulting in the death of animals within holdings.

Indeed, in the current research, a few cases were reported by the breeder who received training compared to the untrained breeders. Grace et al. (2008) conducted a controlled trial in southern Mali to assess the impact of information services provided to livestock keepers to diagnose and treat bovine trypanosomiasis. They concluded that relatively simple information is mainly sufficient to reduce the incidence of certain animal diseases. Like training, the vaccination strategy has also proven to be positive in reducing the number of animals that die of anthrax on farms (Grace et al., 2008). These results confirm that the number and proportion of producers who have access to veterinary services, who regularly vaccinate their animals against certain specific diseases, and who treat their animals for tick-borne diseases; remain essential factors in disease control and, therefore, in improving the performance indicators of a given farm (FAO, 2016).

In addition to these two factors, it also appears that the proximity of the town centre generates a positive sign in reducing the number of dead subjects, while the breeders residing a few further from Boukoumbé centre, as in the district of Manta presented more cases of dead subjects. These results could be explained by the fact that the farther the breeders are from the main town, the less they benefit from veterinary services (care) and other services (awareness and training on dealing with different diseases).

Finally, there is a negative relationship between the number of dead animals on a farm and the lack of knowledge about the contamination mechanism. In other words, breeders who need better knowledge of the contamination mechanism have recorded fewer animals that died of anthrax.

The lack of knowledge of the mode of transmission of anthrax is related to the fact that farmers in the area have not received any training and have no knowledge of the disease. This leads farmers to attribute the death of animals due to anthrax to other diseases. This explains why the number of animals that die of anthrax in the herd is much lower than those who know about the disease (thus being able to make a good diagnosis and consequently know the number of animals that died of the disease).

Furthermore, the composition of the herd did not significantly influence the number of animals that died of anthrax. However, as shown by the coefficients of the linear regression model, goats and sheep are more sensitive than cattle. These results confirm those of Abadia-Barrero (2004), who specified that for animals, in order to decrease susceptibility to anthrax infection, we find small ruminants (sheep, goats), large ruminants (cattle) and domestic and wild equids; then come rodents, lagomorphs, and suids as well as certain birds (ostriches, muscovy ducks) (Higher Council of Public Hygiene of France, communicable diseases section, 2004).

V. CONCLUSION

All in all, the incidence of anthrax increases at the end of the dry season rather than at the beginning of the rainy season. This study contributes to the knowledge of the perceptions of anthrax by breeders in the municipality of Boukoumbé and especially on the factors associated with the evolution of this disease within the farms. The breeders of the municipality of Boukoumbé perceive certain aspects related to this disease, including its knowledge of the environment, the mechanism of contamination, the period, and the month of appearance of the disease. Furthermore, the study revealed that the intensity of the anthrax disease, characterized by the number of dead subjects within a farm, is influenced by several factors, including vaccination, the training of breeders, knowledge of the mechanism of contamination, and the locality where each farmer resides. Because of vaccinations and training, breeders have been able to keep anthrax from showing up on farms and from spreading. In addition, breeders living far from the common center are more exposed to the disease. The current research suggests the use of straw for large livestock animals.

These conclusions, therefore, challenge livestock development partners and political actors to readjust their intervention strategy in isolated areas such as the district of Manta through awareness sessions on the issue of vaccination and through training sessions on how to deal with this disease in order to include as many breeders as possible in the category of breeders not affected by this disease.

APPENDIX

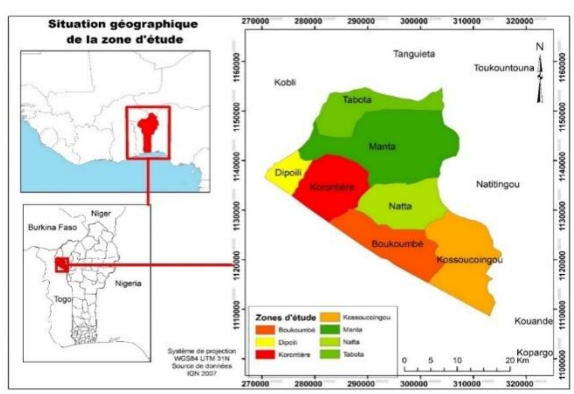

Figure 1: Presentation of the study environment

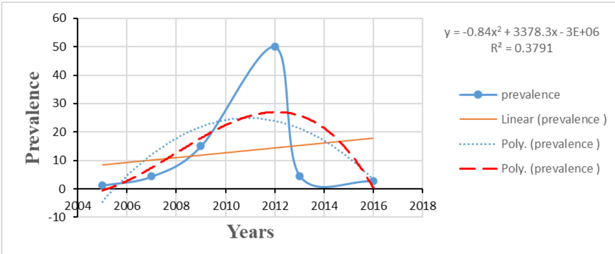

Figure2: Evolution of the prevalence of bacterial anthrax from 2005 to 2016

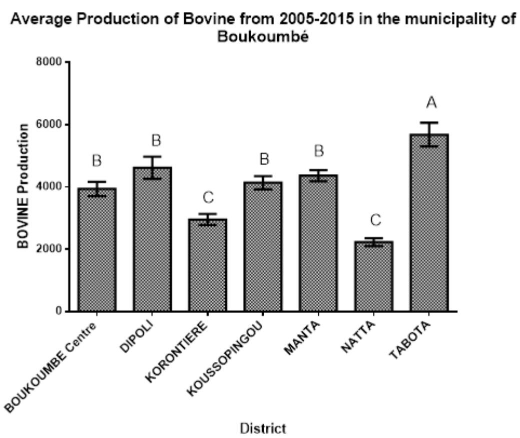

Figure 3: Average production of Bovine from 2005-2015

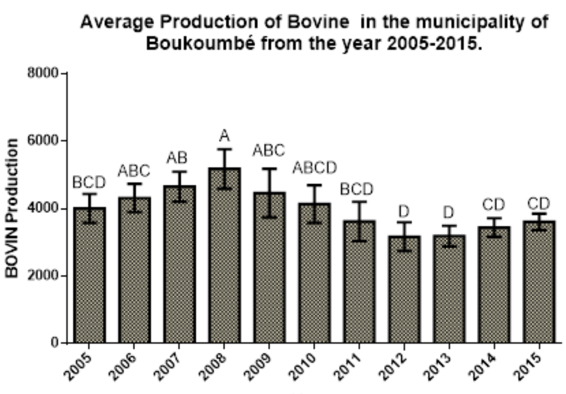

Figure 4: Average production of bovine in the municipality of Boukoumbé between 2005-2015

Table 1: Proportion difference of the diseases in different district of Boukoumbé during 2005-2016

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	Locality Proportion		Proportion difference	Z	P-Value
	Locality i	Locality j			
I vs II	0.0040	0.0034	0.00062	0.24	0.8077
I vs III	0.0040	0.0011	0.00290	3.18	**0.0015***
I vs IV	0.0040	0.0012	0.00278	2.67	**0.0076***
I vs V	0.0040	0.0009	0.00312	3.24	**0.0012***
I vs VI	0.0040	0.0045	-0.00051	-0.18	0.8597
I vs VII	0.0040	0.0009	0.00309	2.92	**0.0035***
II vs III	0.0034	0.0011	0.00228	2.54	**0.0112***
II vs IV	0.0034	0.0012	0.00216	2.11	0.0352
II vs V	0.0034	0.0009	0.00250	2.67	**0.0075***
II vs VI	0.0034	0.0045	-0.00113	-0.61	0.5442
II vs VII	0.0034	0.0009	0.00247	2.41	**0.0162***
III vs IV	0.0011	0.0012	-0.00012	0.02	0.9841
III vs V	0.0011	0.0009	0.00022	0.19	0.8482
III vs VI	0.0011	0.0045	-0.00341	-3.73	**0.0002***
III vs VII	0.0011	0.0009	0.00019	0.08	0.9371
IV vs V	0.0012	0.0009	0.00034	0.35	0.7253
IV vs VI	0.0012	0.0045	-0.00329	-3.14	**0.0017***
IV vs VII	0.0012	0.0009	0.00031	0.24	0.8127
V vs VI	0.0009	0.0045	-0.00363	-3.72	**0.0002***
V vs VII	0.0009	0.0009	0.0005	0.24	0.8121
VI vs VII	0.0045	0.0009	0.00360	3.34	**0.0008***

Legend
District I =MANTA
District II=DIPOLI
District III=NATTA
District IV=KORONTIER
District V=KOUSSO
District VI=TABOTA
District VII=BOUKOUMBE CENTER

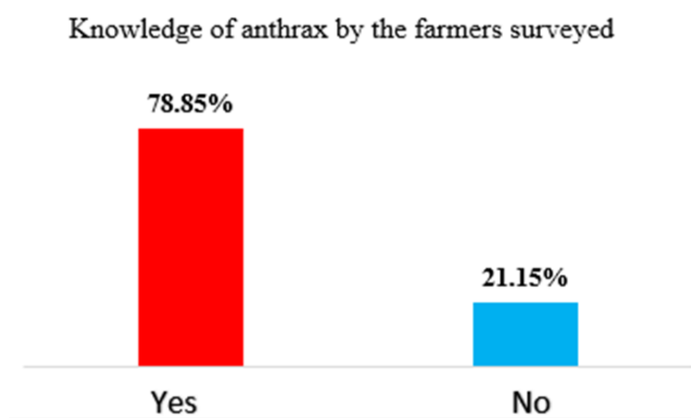


Figure5: Knowledge of anthrax by the farmers surveyed

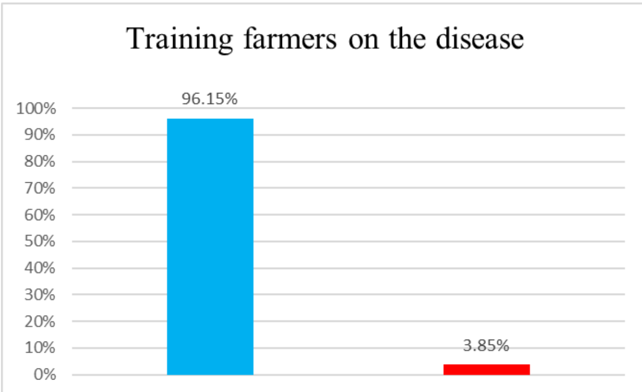
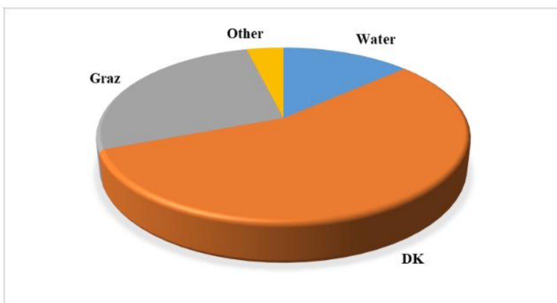


Figure6: Training of breeders on the disease. Source: Survey carried out in the field during the 2018 internship.



Legend: Graz: Animal grazing on infected land, other: Direct or indirect contact, DK: Unknown.

Figure7: Source of infection for animals.

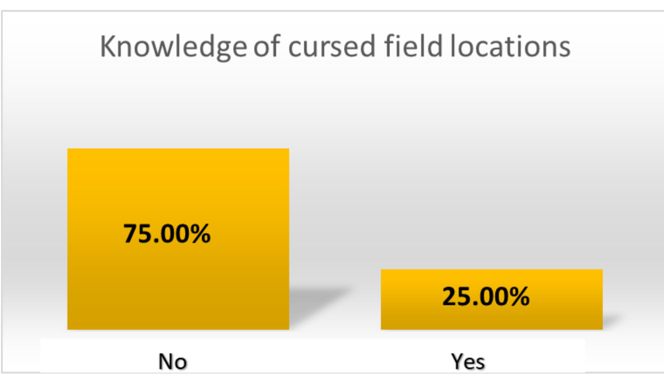


Figure8: Knowledge of Burry yard locations. Source: Survey carried out in the field during the 2018.

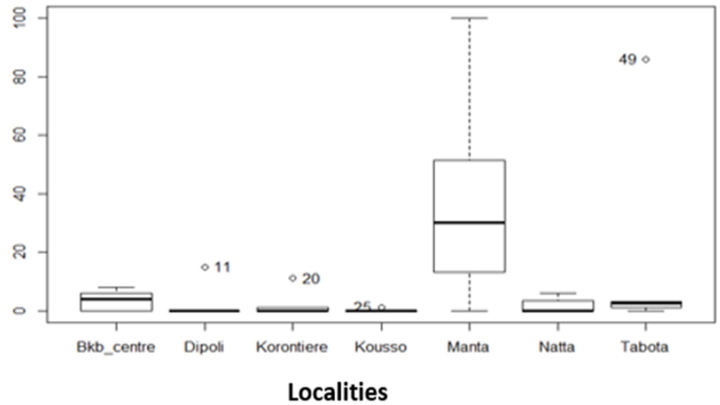


Figure 9: Box plots showing the number of dead animals by locality.

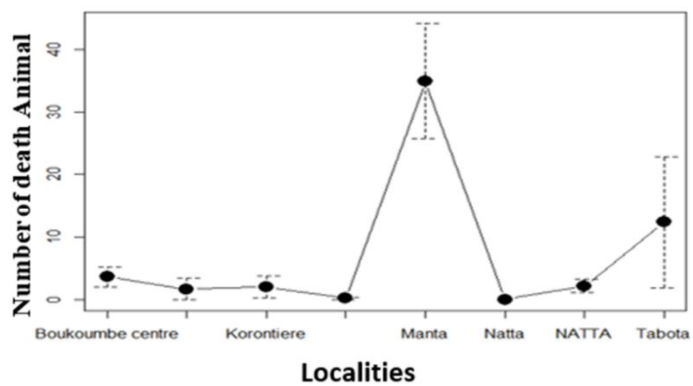


Figure 10: Average number of dead animals per locality.

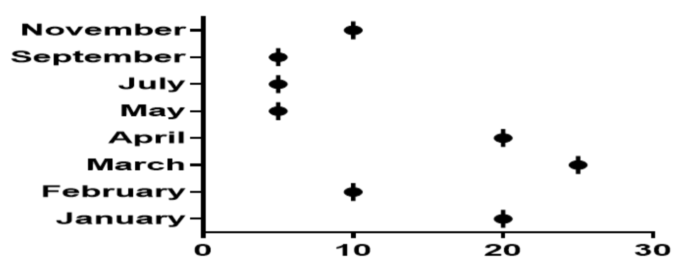


Figure 11: Month of onset of outbreaks (compilation 1990-2016).

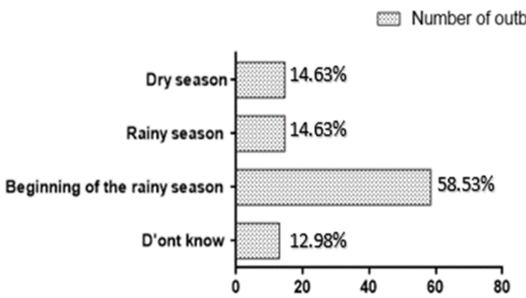


Figure 12: Period of disease onset (Survey)

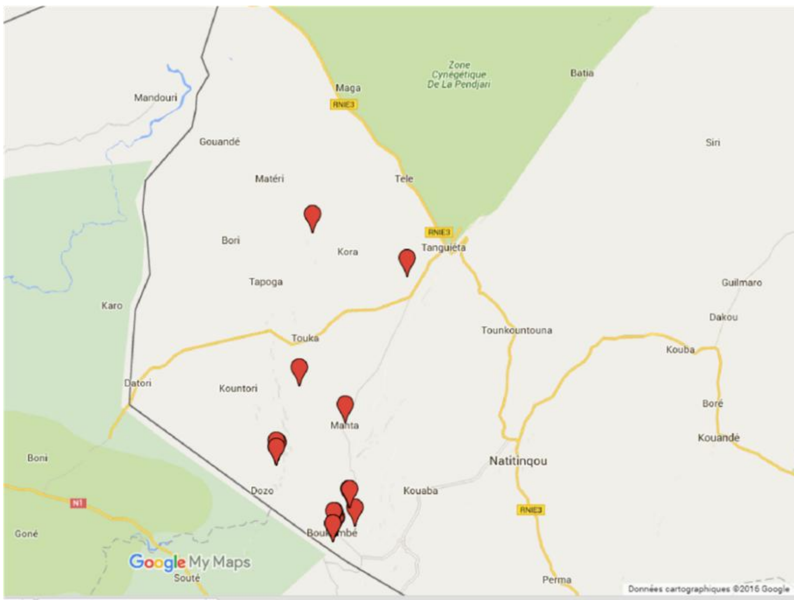


Figure 13: Map of the spatial distribution of anthrax outbreaks in Atacora (1994-2016).

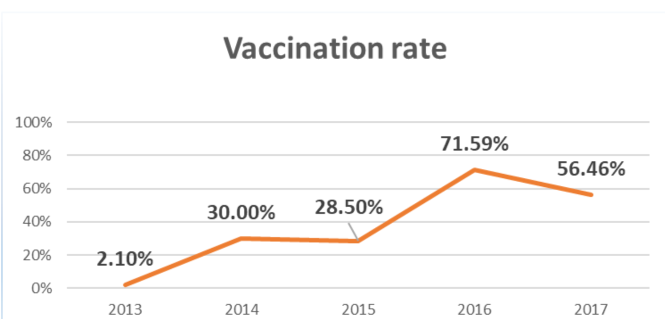


Figure 14: Evolution of the vaccination rate against anthrax in the municipality of Boukoumbé (2013-2017).

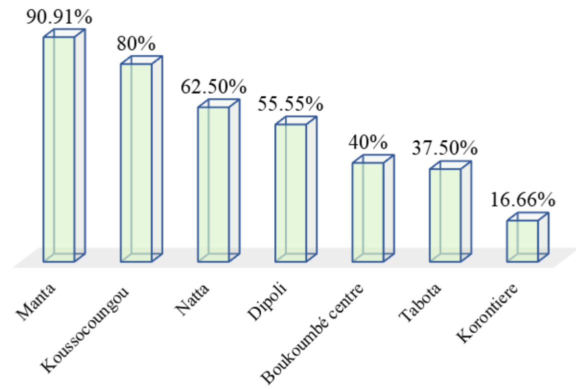


Figure 15: Rate of breeders who vaccinate their animals against anthrax

Table 2: Breakdown of respondents and number of animals by locality

DISTRICT	BREEDERS	CATTLE	SHEEP	GOATS
BOUKOUMBE	5	225	81	94
DIPOLI	9	744	373	179
KORONTIERE	6	248	110	47
KOUSSOPINGOU	5	47	15	40
MANTA	11	915	126	135
NATTA	8	456	268	153
TABOTA	8	50	42	68
TOTAL	**52**	**2685**	**1015**	**716**

Table 3: anthrax's local name in different language

Languages	**Names**
DITAMARI	Tanatonta
M'BELME (YINDE)	Kenatoke
PEUHL	Pidouè, Daamon, Djouke
HAOUSSA	Dadji, Gandji
BIALI	Latou

Table 4: Estimation of the linear regression model on the evolution of the number of dead animals from bacterial anthrax.

Variables	Coefficient	Standard. Err.	t	P>t	Confidence Interval (95%)
Conduct training					
Yes	--	--	--	--	--
Nope	10.86	16.08	0.675	**0.0250***	43.16
Knowledge of the contamination mechanism					
Yes	--	--	--	--	--
Nope	-6.527	6.26	-1.042	**0.00465****	6.05
Knowledge of BACTERIDIAN CHARCOAL					
Yes	--	--	--	--	--
Nope	-10.71	7.45	-1.436	0.157	4.26
Localities					
Boukoumbe center	--	--	--	--	--
Dipoli	-1.93	10.49	-0.184	0.854	19.20
Kofrontiere	-1.60	11.39	-0.140	0.88	21.35
Koussocoungou	-3.4	11.90	-0.286	0.776	20.57
Manta	31.40	10.15	3.09	**0.00339****	51.84
NATTA	-1.975	10,728	-0.184	0.85	19.63
Tabota	8.77	10.73	0.818	0.42	30.38
Livestock composition					
More cattle	--	--	--	--	--
More sheep	5.24	9.26	0.566	**0.013***	23.85
More goats	6.38	8.76	0.727	**0.027***	23.97
Vaccination					
Yes	--	--	--	--	--
Nope	4,942	6.25	0.791	**0.043***	18.61

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