

**SCHOOL OF PUBLIC HEALTH  
COLLEGE OF HEALTH SCIENCES  
UNIVERSITY OF GHANA**

**MAPPING AS A TOOL FOR PREDICTING THE RISK OF ANTHRAX  
OUTBREAKS IN NORTHERN REGION OF GHANA**

**BY**

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**“THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA,  
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## DECLARATION

I, Evans Nsoh Ayamdooh, do hereby declare that except for references to work done by other investigators which have been duly acknowledged, this thesis is the result of my own original research, and has not been presented, either in whole or in part, for another degree elsewhere.

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## DEDICATION

I dedicate this work to my wife: Dr (Mrs.) Yolanda Isabel Ayamdooh

My children: Evans Nsoh (Jnr) Poveda, Samantha Nsomah Ayamdooh and Anthony Nsobilah Ayamdooh and my friends.



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## ABSTRACT

**Introduction:** Livestock production in northern Ghana is vital in the food security and economic development of the people. The development of this sector is hindered by preventable livestock diseases. Outbreaks of Anthrax and other diseases of public health importance have been reported in Northern Region and have become endemic. To date, no comprehensive study has been conducted to know the risk of Anthrax Outbreaks in the region and the region continues to experience persistent unpredictable outbreaks. The aim of this study was to provide predictive maps to assess the association between soil pH, temperature, rainfall and Anthrax outbreaks.

**Methods:** A descriptive study was conducted with 10-years secondary data using ArcGIS 10.2 to create climate-based risk maps of the area using soil pH, temperature and rainfall as predictor variables. The monthly mean values of rainfall, temperature for ten years were calculated. The mean values and soil pH in each district were concentrated in the centroid of the district. The values were interpolated using the Kriging method to get values within the entire region. Evidence based constant raster values were created as weights for the three factors. The product of the soil pH and its weight was added to the product of the rainfall and its weight to create the soil pH and rainfall predictive map. The soil pH and rainfall predictive map finally added to the product of the temperature and its weight to get the final predictive map.

**Results:** Within 10-years period, there were 43 outbreaks confirmed. The deaths involved were 131 cattle, 44 sheep, 15 goats, 562 pigs with 5 human deaths and 22 developed cutaneous anthrax. The highest number of outbreaks occurred in Zabzugu-

Tatale (5), Yendi (5) and Savelugu-Nanton(5), seasonally, the dry season has the highest 56% and the highest of 9 outbreaks occurred in the month of April.

There was a well delineated distribution pattern and the regional predictive map was divided into three strata. Strata I which is the high risk/ hot spot area is made up of East Mamprusi, Bunkpurugu-Yunyoo, Gushiegu, Karaga, Yendi, Saboba-Chereponi, Yendi, Tamale Municipal, Nanumba North and South , East Gonja, and Zabzugu-Tatale districts.

Strata II is made up of West Mamprusi, Tolon Kumbungu, Savelugu-Nanton, Kpandai and Sawla/Tuna/Kalba districts and Strata III is made up of West Gonja, Central Gonja and Bole districts.

The likelihood of outbreaks occurrence and reoccurrence is higher in Strata I, Strata II and strata III respectively in descending order, due to the suitability of soil pH, temperature and rainfall as well as floods for the survival and dispersal of *B. anthracis* spore.

**Conclusion:** Spatial risk mapping of Anthrax outbreaks and distribution can help the policy makers develop a risk based surveillance system and focus on areas with high risk and develop strategies of mitigating Anthrax outbreaks and reoccurrence.

**Keywords:** Anthrax, Spatial risk mapping, Northern Region, Soil pH, Temperature, Rainfall.

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**LIST OF ABBREVIATIONS**

<b>°C</b>	Degree Celsius
<b>CBPP</b>	Contagious Bovine Pleuro-Pneumonia
<b>CVL</b>	Central Veterinary Laboratory
<b>D,DD</b>	Decimal Degree
<b>DVO</b>	District Veterinary Officer
<b>ESRI</b>	Environmental Systems Research Institute
<b>GDP</b>	Gross Domestic Product
<b>GPS</b>	Geographical Position System
<b>GIS</b>	Geographical Information System
<b>ha</b>	Hectare
<b>LDP</b>	Livestock Development Project
<b>mm</b>	Millimeters
<b>MoFA</b>	Ministry of Food and Agriculture
<b>OMC</b>	Organic Material and Calcium
<b>pH</b>	Potential of Hydrogen
<b>PPR</b>	Peste des Petits Ruminants
<b>RVO</b>	Regional Veterinary Officer
<b>SRID</b>	Statistics, Research and Information Department
<b>SS</b>	Sleeping Sickness
<b>USA</b>	United States of America
<b>VSD</b>	Veterinary Services Directorate
<b>WHO</b>	World Health Organization

## CHAPTER ONE

### 1.1 INTRODUCTION

Livestock production in northern Ghana is vital in providing food security and economic development to the people. It provides the meat, milk and eggs that give nourishment to the people. In addition, manure and traction power are available for use in crop production. Over a third of the income of farm families is derived from livestock production Karbo, (2000). However, livestock development in this area is challenged by problems including diseases and high mortality.

Livestock contributed 37% of household income, while crops contributed 33%, other sources 22% and remittances from down south 8% Karbo, (2000).

Northern Ghana holds 75% of the nation's cattle, 54% sheep, 57% goats, 55% pigs. An estimated 89% of the farmers in Northern Ghana rear livestock as well as crops MOFA, (2011).

Diseases and pests continue to be a setback to livestock production in Ghana. These result in high mortality, production and reproduction losses. Mortalities as high as 50 to 80 % have been recorded on farms involving diseases such as PPR in small ruminants, CBPP in cattle and Newcastle disease in poultry VSD, (2010). There have been several outbreaks of zoonotic diseases such as Rabies, Brucellosis and Anthrax, yet these diseases can be greatly reduced if not eliminated through vaccinations. The top of the list of outbreaks of zoonotic diseases is Anthrax. Anthrax is a peracute, acute, subacute and chronic febrile soil-borne infectious disease of all warm blooded animals including man.

*Bacillus anthracis*, the causative agent of anthrax is a multihost pathogen affecting human, livestock and wildlife populations.

### **Transmission of Anthrax**

Anthrax is none-contagious, direct animal-to-animal transmission occurs to an insignificant extent, apart from the circumstance of carnivores feeding on other victims of the disease. Transmission occurs essentially by the ingestion of spores dispersed into the environment.

Some scientists have demonstrated that haemophagous flies, such as tabanids and hippoboscids, play an important role in the transmission and spread of anthrax Blackburn *et al.*, (2007); Hugh-Jones & Blackburn, (2009).

Opare *et al.*, (2000) have shown that human behavior appears to play an important role in the spread of the disease among the population in Tamale municipality in northern Ghana. One key finding was that many of the respondents did not know the causes of anthrax and this appeared to lead to practices such as improper methods of carcass disposal, which perpetuate anthrax in the environment.

### **Pathogenesis**

Hilmas *et al.*, (2009) stated clearly that Anthrax infection involves a complex set of steps in its pathogenesis from spore uptake by immune cells, germination, and transport to local lymph nodes, production of deadly toxins, systemic spread, and ultimately death of the host.

The disease anthrax has been the subject of study for some 130 years. (Beyer & Turnbull, 2009) stated that despite this, surprisingly many unanswered questions remain

on the pathogenesis and epidemiology of the disease in animals and on the fate of the organism under various environmental conditions.

When virulent anthrax bacilli are injected sub-cutaneously into the susceptible host, the encapsulated organisms proliferate freely and appear to resist phagocytosis by leucocytes which accumulate in the lesion. If host resistance mechanisms fail to contain the infection, the bacteria reach the lymph nodes and spleen where they multiply and are ultimately released in a sudden burst. The levels of bacilli and toxin in the circulation then increase rapidly, leading to fever, coma and death within the space of a few hours. The primary site of action of the toxin is still unknown. Cardiac failure, increased vascular permeability, shock, hypoxia and respiratory failure have all been implicated as the cause. Respiratory failure is regularly seen and may be of cardiopulmonary origin or due to central nervous system depression.

### **Pathological lesions**

Twenhafel, (2010) used mice studying early pathogenesis and bacterial characteristics. Few pathologic changes occur in the mouse models but may include marked bacteremia and lymphocyte destruction in the spleen and mediastinal lymph nodes. Rabbits and guinea pigs rapidly develop fulminate systemic disease, and pathologic findings often include necrotizing lymphadenitis, splenitis, pneumonia, vasculitis and hemorrhage, congestion and edema in multiple tissues.

Nonhuman primates consistently develop the full range of classic lesions of human inhalational anthrax, including meningitis, lymphadenitis, splenitis, mediastinitis, pneumonia, vasculitis and hemorrhage, congestion and edema in multiple tissues.

### **Clinical signs in animals**

The clinical signs of anthrax vary from species to species. Both small and large ruminants are thought to be the most susceptible group within the class of mammalia. Generally, the disease progresses as a peracute or acute septicemia after an incubation period of 3–5 days (1–14 days possible), dependent on the infectious dose. Frequently the disease runs a peracute course as indicated by sudden staggering and recumbency without preceding visible signs. Death occurs within minutes with convulsions or spasms. Fever ( $>40^{\circ}\text{C}$ ), excitation or somnolence, dyspnea, cyanotic mucosae, edematous swellings in the neck region or the chest, abdomen or flanks, and colic are possible signs with death occurring within 12–13 h after first appearance of these symptoms Beyer & Turnbull, (2009) Blisters/ulcers may be apparent on the tongue or elsewhere in the oral cavity. Dying animals often bleed from nose and anus. Subacute or chronic infection has been reported but appears to be rare.

Horses generally suffer from the acute course of the disease, showing high fever ( $40\text{--}41^{\circ}\text{C}$ ), dyspnea, cyanosis, colic, bloody diarrhea, local edemas with necrotic centers and bloody exudates from body orifices.

Pigs are fairly resistant to anthrax. Possible general clinical signs are local changes, such as pharyngitis, hot painful edemas in the head and chest regions, and black necrotising papulae of the skin and mucosae. If the gut is involved icterus, vomiting, and diarrhea may be seen.

Carnivores, especially wild scavengers, are relatively resistant to infection with *B. anthracis*. However, no mammal is entirely resistant to the disease and cases in a wide variety of carnivores have been reported over the years (Hugh-Jones & Vos, 2002). Generally after an incubation period of 3–5 days, the animals may develop fever

(>40 °C), intestinal symptoms with anorexia and lethargy. Inflammation and edematous swelling of the neck region with swellings of the lips, jowls and tongue may be seen.

### **Clinical signs in humans**

Human anthrax has different forms of presentation, generally associated with the route of spore entry. Consequently, three main forms are classically differentiated and this can be cutaneous, inhalational, and gastrointestinal forms.

### **Cutaneous anthrax**

Friedlander *et al.*, (2002) indicated that the average incubation period varies greatly depending on the retrospective studies, from 2 to 6 days. A papule appears at the site of spore entry; through a lesion (spores are non-invasive). In the next 24 h, a ring of vesicles develops around the papule and local edema appears. Then the papule ulcerates and forms the black eschar characteristic of anthrax, while the edema extends a little farther from the lesion. Few systemic symptoms are recorded at this point: low fever and headache. It is at this step that either the infection is controlled, or severe extension is observed worsening the prognosis. Usually the eschar resolves after several weeks.

Brochier *et al.*, (1995) stated that anthrax affects mostly persons engaged in animal husbandry and cutaneous anthrax is 95% in human anthrax.

A more detailed look at the lesion discloses subepidermal edema, vessel thrombosis, tissue destruction, and hemorrhagic interstitium Oncu & Sakarya, (2003).

Doganay *et al.*, (2010) described the clinical picture in mild cases as characterized by a typical cutaneous lesion less than 4 cm in diameter and surrounded by an erythema and accompanied by low grade fever. The leukocyte count was also below  $10^4/\text{mm}^3$  in these cases. The clinical presentation of 11 severe cases of cutaneous anthrax was

characterized by fever, hemorrhagic bullous lesions surrounded by an extensive erythema and edema and leukocytosis (leukocytes count was over  $10^4/d$ ).

### **Inhalational Anthrax**

Holty *et al.*, (2006) postulated that untreated inhalational anthrax presents a biphasic clinical course. After an average incubation time of 4–11 days, an initial prodromal phase with non-specific symptoms appears, such as fever, sweats, fatigue, nausea or vomiting, confusion and dyspnea. At this stage, when the patient is admitted to the hospital, pleural effusion and mediastinal widening are usually observed. Then a hyperacute or fulminant phase develops, with sudden dyspnea, cyanosis, disorientation, coma and death occurring in circa 24 h. Due to the absence of specificity of the initial symptoms, late diagnosis is not uncommon and this has severe repercussion upon prognosis.

### **Oropharyngeal and Gastrointestinal Anthrax**

Gastrointestinal Anthrax is far less common than inhalational anthrax, but the mortality rate is extremely high, from 50 to 75%, even with early treatment. According to one case of a 15-year-old male, who was infected after ingesting half-cooked sheep meat, the incubation period for gastrointestinal anthrax varies from 2 to 5 days Mansour-Ghanaei *et al.*, (2002).

Beatty *et al.*, (2003) stated that this form develops after ingestion of food from animals infected by *B. anthracis*. Gastrointestinal Anthrax is the most frequent form of “digestive” anthrax. After an incubation period of 1–6 days, initial symptoms are non-specific (nausea, vomiting, mild diarrhea, fever and headache). Then severe symptoms may appear, such as acute hemorrhagic diarrhea, nausea, vomiting, abdominal pain, ascites, followed by shock and death (2–5 days after the onset). Oropharyngeal Anthrax

is generally localised in the oral cavity, the lesion is covered by a grey pseudomembrane and surrounded by edema. The main symptoms are usually sore throat, dysphagia and painful cervical adenopathy. Progression of the infection may lead to extensive swelling of the neck, acute respiratory distress, shock and death.

### **Meningoencephalitis Anthrax**

Lanska, (2002) in a study indicated that any of the above described forms of anthrax may develop into a usually fatal meningitis, characterized by intense inflammation of the meninges, edema and hemorrhage. In the USA 2001 anthrax cases, 38% of inhalational anthrax patients developed meningoencephalitis (Holty *et al.*, 2006).

### **Diagnosis**

Rapid presymptomatic diagnosis of *Bacillus anthracis* at early stages of infection plays a crucial role in prompt medical intervention to prevent rapid disease progression and accumulation of lethal levels of toxin Devine *et al.*, (1994).

Diagnosis of anthrax may consist of tentative and confirmatory procedures. A tentative diagnosis of anthrax may be established based on the prior knowledge of the epidemiology of the disease in a given environment; observations of clinical signs, information on grazing history and seasonal occurrence.

### **Treatment**

Durmaz *et al.*, (2012) concluded that a total of 251 isolates collected throughout Turkey and analyzed. All were found to be susceptible to vancomycin, quinolones, tigecycline, and linezolid, whereas they were resistant to ceftriaxone. It was also determined that only a limited number of animal isolates were resistant to penicillin G (one isolate; 0.63 %), doxycycline (one isolate; 0.63 %), erythromycin (one isolate; 0.63 %), and gentamycin (two isolates; 1.3 %). Fifty-eight isolates (23.1 %) were intermediately susceptible to

erythromycin. The percentage rate of the isolates susceptible to erythromycin at intermediate levels was 29 % (27 isolates) for those collected from humans and 19 % (31 isolates) for those collected from animal and environmental samples.

Telavancin demonstrated potent antibacterial activity against 15 strains of *Bacillus anthracis*, tested in vitro. In a mouse model of anthrax, cethromycin also demonstrated some efficacy against *Bacillus anthracis*.

### **Vaccines**

The major veterinary vaccines in use throughout the world today for immunization against anthrax are derivatives of the live spores of *Bacillus anthracis* vaccine formulated by Sterne in 1937 and still use descendants of his strain 34F2; these are classified into two categories Randolph, (2004). Live attenuated vaccines, capsulated and atoxigenic Cap+/tox-: e.g. Pasteur vaccine and the other group are Live attenuated vaccines, not capsulated and toxigenic Cap-/tox+ ; e.g. Sterne and sexually transmitted infection( STI) vaccines Cornell *et al.*, (2004).

### **Outbreaks**

The disease has a world-wide distribution, but has declined in developed countries. Africa remains severely afflicted with major epidemic areas. (Lewerin *et al.*, 2010) reported that after 27 years with no detected cases, an outbreak of Anthrax occurred in a beef cattle herd in the south of Sweden. The outbreak was unusual as it occurred in winter, in animals not exposed to meat-and-bone meal, in a non-endemic country.

In Asia, Anthrax is widespread in the Philippines, South Korea, eastern India, and western China Liu *et al.*, (2013); Simonson *et al.*, (2009).

Anthrax remains endemic in many African countries causing significant losses in domestic animal populations Clegg *et al.*, (2007). In Africa it has been reported in

Cameroon Pilo *et al.*, (2011) , the Mago National Park Omo in Ethiopia Seboxa & Goldhagen, (1989); Shiferaw *et al.*, (2002), in Tanzania Hampson *et al.*, (2011) and at the Selousa National Reserve in Tanzania Gainer, (1987), the Luangwa valley Zambia Turnbull *et al.*, (1991), the Kruger National Park in South Africa Pienaar, (1967), Etosha National Park in Namibia Turnbull *et al.*, (1992).

In West and Central Africa Leendertz *et al.*, (2006) reported a new *Bacillus anthracis* found in wild chimpanzees and a gorilla. Anthrax was reported in the Gambia Heyworth *et al.*, (1975) and in Nigeria Okolo, (1985).

Anthrax outbreaks in Ghana have been reported since 1988 in the World Anthrax Data Site (<http://www.vetmed.lsu.edu/whocc/AnthraxStats2001-dataFiles/Africa/Ghana.htm>) and impacts negatively on the economy of the livestock industry and public health.

Anthrax is considered major non-contagious, zoonotic disease since ancient times, and outbreaks in Northern Ghana have caused devastating economic effects in the livestock sector and alarming public health concern.

There is sufficient evidence of increases of number of outbreaks and intensity as well as geographical expansion of the disease. Research in recent years indicates its cosmopolitan distribution, presenting the widest known latitudinal, longitudinal and altitudinal distribution. The distribution and frequency of outbreaks is known to be dependent upon environmental and human activities.

The recent changes in the region's rainfall pattern (being a cause of climate change) has played a critical role in the persistent decline in agricultural production as well as unprecedented proliferation of animal and human diseases.

It is well known and established that outbreaks of Anthrax are generally driven by human-induced environmental disturbances, flooding, drought or any other environmental disturbances that brings the spores to the surface of grazing lands, where grazing animals can be exposed.

The ecology of the disease in northern Ghana is not well known due to the unpredictable and ever changing nature of the outbreaks and the influence of the climate and other factors.

The use of Geographical Information Systems (GIS) tools allows for visual inspection of the data by mapping the locations of anthrax outbreaks. The use of modern spatial or temporal statistical and epidemiological methods allows for further exploration and modeling of the disease data to gain deeper knowledge of the disease and area specific behavior.

This work seeks to use the tools of GIS to predict the risk of outbreaks of Anthrax in the Northern Region of Ghana. This work will not only serve to find use for the several routinely generated data by Veterinary Services Directorate, but will also pioneer continuous epidemiological and spatial analysis of the routine data to guide departmental actions.

## **1.2 Problem statement**

The highest concentration of livestock in Ghana is in the three northern regions, where outbreaks of anthrax in livestock have occurred in the past and in some instances human involvement.

Anthrax has therefore been considered endemic in Ghana due to the high frequency of outbreaks.

One of the difficulties in predicting the outbreaks lies in their intermittent and variable nature, with considerable variation in the species affected and the associated environmental and climatic conditions.

The ecology, risk and distribution of anthrax outbreaks in Northern Ghana are not well known.

Mapping the risk of Anthrax outbreaks is therefore important from the perspective of public health, wildlife conservation and livestock economies.

### **1.3 Rationale**

The spatial analysis and mapping risk of Anthrax outbreaks in an endemic area is very limited worldwide. In Kazakhstan, studies has been conducted to understand the geographic distribution of *B. anthracis* and Anthrax outbreaks using Geographical Information System (GIS), Mullins *et al.*, (2011), spatial analysis Epp *et al.*, (2010) and molecular genotyping techniques.

The Northern Region of Ghana remains the region with the highest concentration of livestock and it is the region that most Anthrax outbreaks occurred in the country between 2002-2001 (Appendix I).

This work can be used as a policy making tool and a cost effective method of strengthening surveillance system with the predictive maps.

This research methodology can equally be applied to other research works related to livestock and zoonotic diseases whose pathogens survival and transmission are environmentally related.

### 1.4 Conceptual Framework

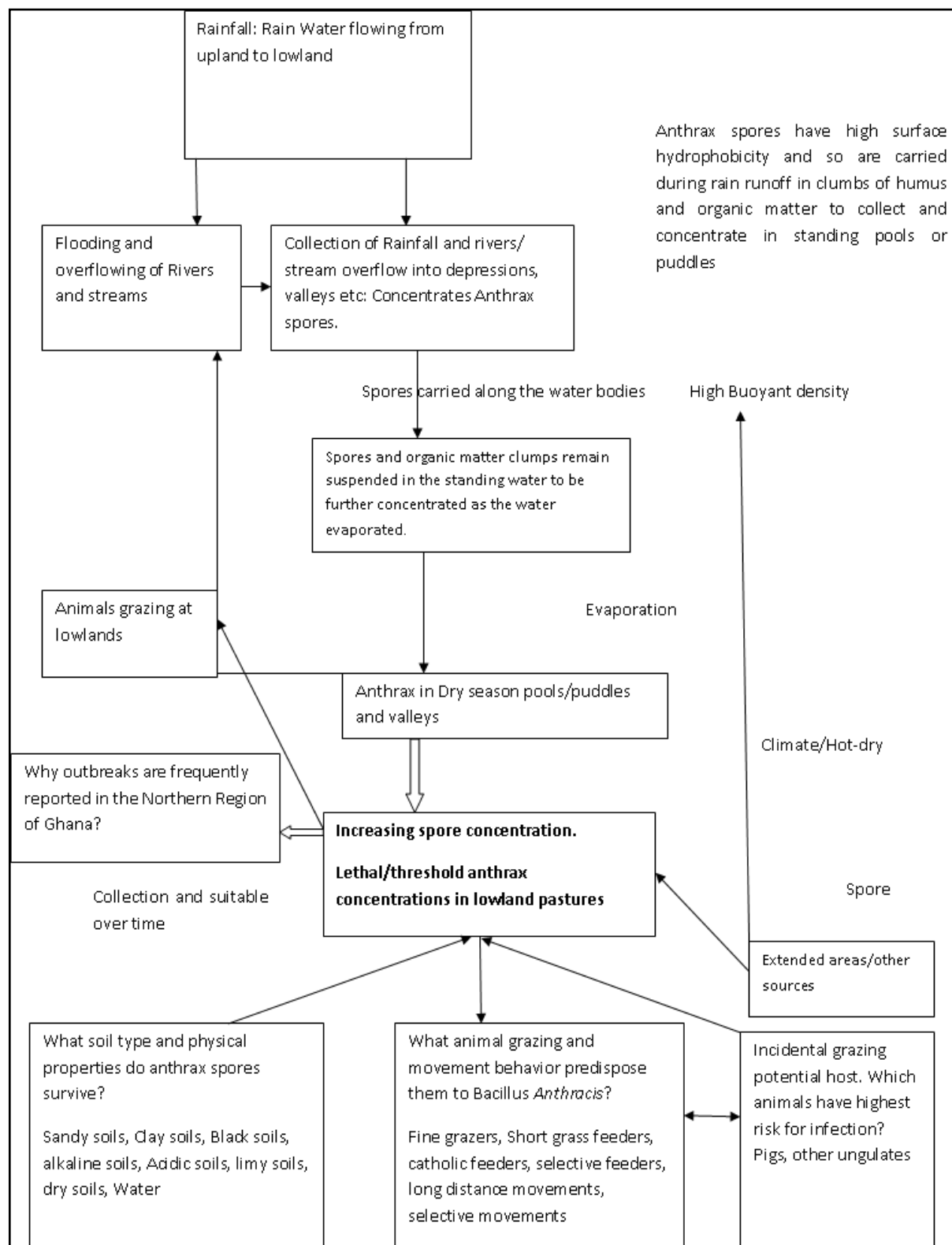


Figure 1: Conceptual Framework of Anthrax.( Adapted from Senhte, (2011))

## **1.5 Study objectives**

### **1.5.1 General Objective:**

To generate predictive risk maps of Anthrax outbreaks in Northern Region of Ghana

### **1.5.2 Specific Objectives:**

- To determine the seasonal trend of Anthrax outbreaks in Northern Region of Ghana.
- To determine climatic factors such as rainfall and temperature pattern in Northern Region of Ghana.
- To determine soil pH distribution in Northern Region of Ghana.
- To predict the risk of Anthrax outbreaks in the Northern Region of Ghana using spatial tools in ArGIS.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 Global distribution of anthrax

Anthrax is globally distributed, having been reported by all continents that are densely populated with animals and humans. Anthrax outbreaks in animals in almost 200 countries worldwide are recorded by The World Anthrax Data site. <http://www.vetmed.lsu.edu/whocc/AnthraxStats2001-dataFiles>.

The occurrence of Anthrax is generally decreasing worldwide, it still persist in most developing countries. In some countries in Latin America like Bolivia, Peru and Mexico, it is enzootic due to ineffective control programs. In Australia there have been intermittent outbreaks of anthrax with a sudden and severe epidemic occurring in northern Victoria in 1997 Turner *et al.*, (1999).

Animal anthrax is still regarded as endemic in several countries of southern Africa, central Asia, including several of the Asian countries of the former Soviet Union, certain regions of China, the Indian sub-continent, in small pockets of the USA and certain regions of South America. Sporadic cases occur in southern Europe and less frequently in northern Europe in areas where land had been contaminated in the past by the effluents of tanneries or wool processing factories (Beyer & Turnbull, 2009).

In Asia, Anthrax is widespread in eastern India, Mongolia, The Philippines, South Korea and western China. In Papua New Guinea, anthrax has been reported in pigs. Anthrax is an endemic zoonosis in Turkey, particularly in the eastern part. The incidence of the disease in Turkey has been decreasing with economic and social changes, strict animal vaccination programs and education of farmers Doganay, *et al.*, (2010).

Worldwide, outbreaks of anthrax has now become uncommon in most part of developed countries such as Europe, North America and Australia, but remains a significant problem in West Africa, Spain, Greece, Turkey, Albania, Romania and in Central Asia and a few foci in wild animals in African national parks.(Hugh-Jones, 1999).

Munang'andu *et al.*, (2012) indicated that in Zambia, anthrax is one of the major threats to livestock and people in the Western part of the country. This area is also endemic for clostridia infections Munang'andu *et al.*, (1996) suggesting that it is endowed with ecological factors that favor the survival of spore-forming bacteria. The prevalence of anthrax in Western Zambia has previously been reviewed and the role of anthropogenic pressure on the epidemiology of the disease demonstrated Munang'andu, *et al.*, (2012); Siamudaala *et al.*, (2006).

In West Africa, anthrax has been reported in several countries indicating its existence in sub-Sahara Africa. Domingo, (2000) wrote that anthrax has probably occurred for centuries in Togo, although veterinary reports only confirm its presence after 1950. Cattle, and less often sheep and goats, are affected. Other species appear to show no clinical signs. Twenty years ago, anthrax was identifiable in almost all regions of Togo, but today the disease is reported regularly only in the Savannah and Kara regions. It is a seasonal disease with peak numbers of cases reported between March and June coincident with the onset of the rainy season. Paradoxically, in affected regions, man is often the indicator species, owing to unregulated slaughter and the habit of some rural people of eating meat from cadavers.

Coulibaly & Yameogo, (2000) reported that in 1997, 13 outbreaks of anthrax were identified in six provinces of Burkina Faso (Nahouri, Namentenga, Poni, Sanmatenga, Sourou, and Zoundweogo). The disease was identified in animals before and after slaughter.

In Ghana although considered as one of the most important zoonotic diseases taking the greatest toll on livestock and human lives VSD, (2010) no comprehensive study has been done to determine the distribution of Anthrax except to upper East, Upper West and Northern region as well as Northern Volta. Regions have recorded history of periodic anthrax epidemics causing widespread disease among and domestic animals the historical records (appendix I).

### **2.2.1 Occurrence of Anthrax**

The annual incidence of human anthrax infection is estimated between 20,000 and 100,000 from all the continents and the vast majority is cutaneous form Oncu & Sakarya, (2003).

The prevalence of anthrax was estimated to be 0.012% in cattle in Burkina Faso by Coulibaly & Yameogo, (2000).

From August 2009 to October 2010 Islam *et al.*, (2013) recorded 14 outbreaks of anthrax which included 140 animal and 273 human cases in 14 anthrax-affected villages in Bangladesh.

## **Risk factors**

Ecological and genetic factors that govern the occurrence and persistence of anthrax reservoirs in the environment are obscure. Smith *et al.*, (1999) postulated that spatial and temporal distribution of the different genotypes indicates that anthrax epidemic foci are independent, though correlated through environmental clues.

Man-made environmental alterations comprising dams, irrigation systems and canals can all have profound influences on the ecology of pathogenic agents and their reservoirs and vectors. As these man-made and natural features dry out they often provide the ecological requirements - pH 7.5, water temperature of 27°C and high organic content - for anthrax bacillus incubation Ebedes, (1977).

There is limited data available to define the geographic extent of environmental variables that support long-term *B. anthracis* survival, but current literature suggests that *B. anthracis* likely replicates in the animal host and can then survive as spores for long periods in specific soil environments (Smith *et al.*, 1999).

Williams *et al.*, (2013) determined the contribution of the exosporium, the outer layer of the *Bacillus anthracis* spore, to soil attachment. It is well known that persistence of spores in soil and their ability to infect animals has been linked to a range of factors which include the presence of organic material and calcium (OMC), pH > 6.0, temperatures above 15.5 degrees C and cycles of local flooding which are thought to transport buried spores to the surface.

In parts of the USA with calcium-rich neutral-to-alkaline soil livestock anthrax mortality rates analysed for 1945–1955 were more than 21 times greater than losses in other areas Smith *et al.*, (2000).

The interfaces between temporarily flooded areas and the surrounding landscapes may thus become important epidemiological zones. Flood plains that occur regularly and seasonally in arid and semiarid zones are important epidemiological features and often provide seasonal foci of several reservoir hosts and vectors Woodford, (2009).

Turcutyucov *et al.*, (2003) stated that Anthrax is associated with special soil conditions such as having a humus content of more than 1% (from 2%– 4%), with the humus layer more than 0.15–0.3 meters, pH 4–7, and high moisture even in the dry months usually (August or September) and recommended so, despite the worldwide threat of anthrax bioterrorism, anthrax should also be investigated at the local level.

The analysis of Munang'andu *et al.*, (2012) demonstrated that occurrences of anthrax outbreaks varied according to season and also concluded that differences in precipitation were significantly associated with the occurrence of anthrax outbreaks ( $\chi^2(2) = 4.75$ ,  $p < 0.03$ ), indicating that the likelihood of outbreaks occurring was higher during the dry months when human occupancy of the floodplain was greater compared to the flooding months when people and livestock moved out of this region.

Forkuo, (2011) in a study created a district level map indicating flood hazard prone areas of Northern Region of Ghana and the final flood hazard map was classified into four hazard categories by natural breaks and concluded that there is no defined pattern in the disposition. In the central northern side of the area four districts depict very high hazard situation (West Maprusi, Tolon-Kumbungu, Tamale Municipal and Savelugu-

Nanton) and high areas are East Mamprusi and East Gonja district, the medium are, Gushiegu, Karaga, Saboba-Chereponi, Yendi and Nanumba North and South and West Gonja in which the river almost runs through its middle depicts medium hazardous zone.

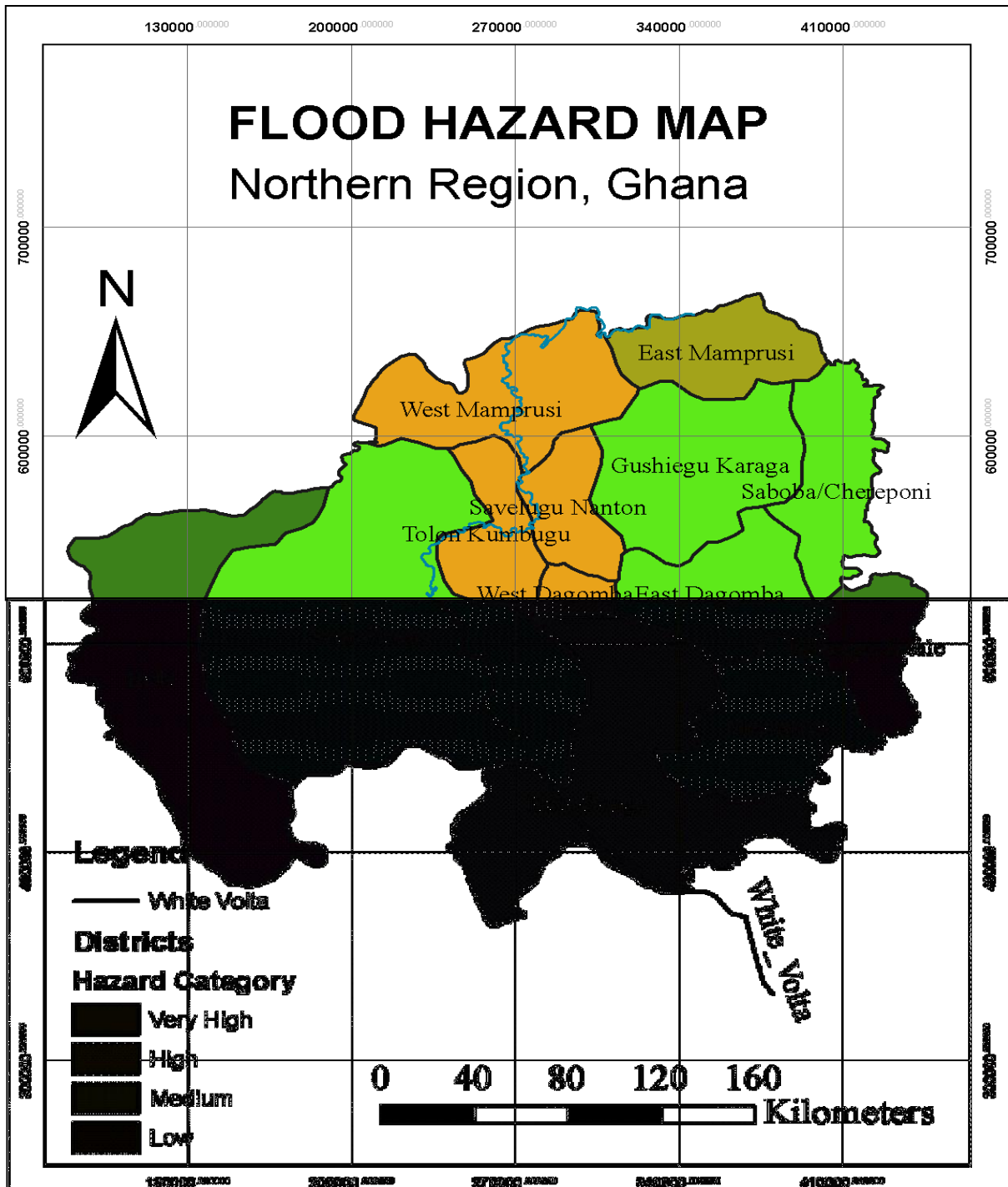


Figure 2: Flood Hazard map of Northern Region of Ghana Forkuo, (2011).

### 2.3 Geographical Information System in disease mapping

The Geographical Information System (GIS) is an emerging field being applied in all spheres of developmental activities especially in the area of disease control.

GIS is a software system that stores, organizes, analyses and retrieves data according to spatial relationships and allows automation of map construction to demonstrate spatial relationships. It has great promise for epizootiological studies as long as the disease-related information is recorded in a format compatible with other data such as climate, forest type, stream location, topography and human demography that are stored in other databases Berry, (1993); Woodford, (2009).

GIS and related technologies like remote sensing are increasingly used to analyze geographical distribution of diseases as well as relationships between pathogenic factors (causative agents, patients, vectors and hosts) and their geographic environments.

Recent studies Aikembayev *et al.*, (2010) tried to understand the geographic distribution of *B. anthracis* and outbreaks in Kazakhstan using GIS, spatial analysis and molecular genotyping techniques.

Investigations carried out by Volkova *et al.*, (1988) with the use of the mapping method have revealed that the distribution of localities with stationary unfavorable situation in anthrax throughout the area is linked with the agrochemical properties of soils. The number of the foci of anthrax on neutral and weakly alkaline soils has proved to be considerably higher than in soils with low pH values. No relationship between the content of humus in soils and the distribution of localities with stationary unfavorable situation in anthrax throughout the area has been detected. The results of investigations

carried out with the use of the mapping method permit experts to make forecasts and to examine the ecological aspects of the projects carried out in the area.

In a retrospective study aimed at assessing the spatial and temporal distribution of anthrax and to identify risk areas in Zimbabwe using GIS, Chikerema *et al.*, (2012) found hot-dry season to be significantly ( $\chi^2=847.8$ ,  $P<0.001$ ) associated with the occurrence of anthrax in cattle, and the disease was found to be approximately three times more likely to occur during this season compared to other seasons. Anthrax outbreaks demonstrated a gradual temporal increase from an annual mean of three outbreaks for the 5-year period. The majority of outbreaks (83.7%) were recorded in rural areas, and 11 districts were found to be at a higher risk than others.

Kracalik *et al.*, (2014) applied spatial and temporal statistical approaches in a geographic information system to describe changes and their findings provided evidence of a changing incidence and a shift in the geographic patterns of human anthrax. These findings highlighted the importance of proper livestock disease management to mitigate human disease and the need for dynamic surveillance that takes into account changes in the distribution of disease.

Norstrom, (2001) stated that basic and analytical applications of GIS in epidemiology can help in visualizing and analyzing geographic distribution of diseases through time, thus revealing spatio-temporal trends, patterns, and relationships that would be more difficult or obscure to discover in tabular or other formats. GIS can provide a means to meet the demands of outbreak investigation and response, where understanding the spatial spread and dynamics of an outbreak is central to the design of prevention and control strategies.

GIS can be used to predict the disease occurrence and /or seasonality based on the climatic and /or environmental characteristics of a certain area and the information about the climatic and/or environmental requirements of a certain parasitic species. These predictions can be extremely useful in the decision support for disease intervention.

Fuentes *et al.*, (2005) presented results of the use of Geographical Information Systems (GIS) forecast model to conduct an epidemiological analysis of human and animal fasciolosis in the 15 central part of the Andens Mountains in Peru, Bolivia, and Chile. The GIS approach enabled them to develop a spatial and temporal epidemiological model to map the disease in the areas studied and to classify the transmission risk into low, moderate and high risk area so that areas requiring the implantation of control activities can be identified.

A geographical information system (GIS) model for mapping the risk of fasciolosis in cattle and buffaloes was develop for the kingdom of Cambodia by Tum *et al.*, (2004), using determinants of inundation, proximity to rivers, land use, slope, elevation and the density of cattle and buffaloes. The model estimates that 28% of Cambodia is potentially at risk of fasciolosis with areas of high and moderate risk concentrated in the southern and central Cambodia.

The use of geographical Information Systems (GIS) allows for visual inspection of epidemiological data by mapping the spatial and temporal locations of anthrax cases in a specific layer. By combining this layer with layers containing other temporal or spatial data (altitude, land-cover or land-use, rainfall, temperature, flooding areas etc.) one can

examine if there are possible correlations between data layers or between trends among data layers.

Cherkasskiy, (1999) stated that maps will greatly enhance the value of spatial analysis and conducted a study with the objective of assembling a reference handbook, "Register of stable anthrax sites in the Russian Federation", containing organized information on more than 10 000 anthrax foci occurring during the past 100 years. Such a study makes it possible to identify regions characterized by the highest concentrations of stationary anthrax sites in Russia, to identify trends in expressed activity of such sites through the periodic emergence of disease in humans and animals, and to determine the factors contributing to the formation of such trends. In doing this, it makes it possible to develop contingency plans for different risk locations (i.e. high risk of persistent infection, high risk of sporadic occurrence, low risk areas, etc.) in terms of anthrax in Russia, to identify high risk areas and develop a differentiated strategy of vaccination and other control strategies, and to develop preventive recommendations to reduce risk in high risk areas.

Cherkasskiy, (1999) further recommended the incorporation of powerful Geographic Information System (GIS) electronic mapping technology so that natural geographic features, such as soil type, climate, etc., can be compared with anthrax distributions in Russia using standard GIS and statistical analysis.

Application of modern spatial or temporal statistical and epidemiological methods allows for further exploration and modeling of the data to gain deeper insight into the data collected during an outbreak Waller & Gotway, (2004) .

Lin, (2010) postulated that the Cow anthrax is biogeochemical disease, and its geographical distribution is related closely to the environmental factors of habitats and has some spatial characteristics, and therefore the correct analysis of the spatial distribution of Anthrax in cattle for monitoring and the prevention and control of anthrax has a very important role.

(Blackburn *et al*, 2007) suggested that certain variables can be used because of the previously discovered relationship between *B. anthracis* and specific parameters of precipitation, temperature, normalized Difference Vegetation Index and elevation.

Nisha *et al.*, (2005) investigated an outbreak of fever in a village in southern India. Spatial analysis was done with the help of Geographical Information Systems software (GIS) and demonstrated a centrifugal spread of cases from the most affected street until it involved the entire village. This was the first experience in producing a geo-referenced map of a village area and in spatial analysis. GIS is therefore a novel and simple tool for outbreak investigations and the spatial analyst adds additional information to the data collected.

Mindell & Barrowcliffe, (2005) developed a computer model, using a geographical information system (GIS), to quantify potential health effects of air pollution from a new energy from waste facility on the surrounding urban population. The availability of GIS and dispersion models on personal computers enables quantification of health effects resulting from the additional air pollution new industrial development might cause. This approach could also be used in environmental impact assessment. Care must be taken in

presenting results to emphasize methodological limitations and uncertainties in the numbers.

With the objective of integrating spatial mobility and other attributes with GIS and network approaches in order to develop a predictive spatial model of presence of rinderpest Ortiz-Pelaez *et al.*, (2010) identified point locations and areas with high risk of presence of rinderpest and their spatial visualization as a risk map which will be useful for informing the prioritization of disease surveillance and control activities for rinderpest in Somalia. The methodology applied here, involving spatial and network parameters, could also be applied to other diseases and/or species as part of a standardized approach for the design of risk-based surveillance activities in nomadic pastoral settings.

Rutto & Karuga, (2009), in a study to map the spatial and temporal distribution of Sleeping Sickness (SS) and determine possible risk factors associated with the disease in western Kenya concluded that seasons influenced disease incidences with higher numbers of SS cases being recorded during the wet seasons. Gender and age determined the disease occurrence with most productive age groups being at higher risk. Areas with high livestock populations had low human population densities and had higher SS cases.

## CHAPTER THREE

### METHODS AND MATERIALS

#### 3.1 Study Design

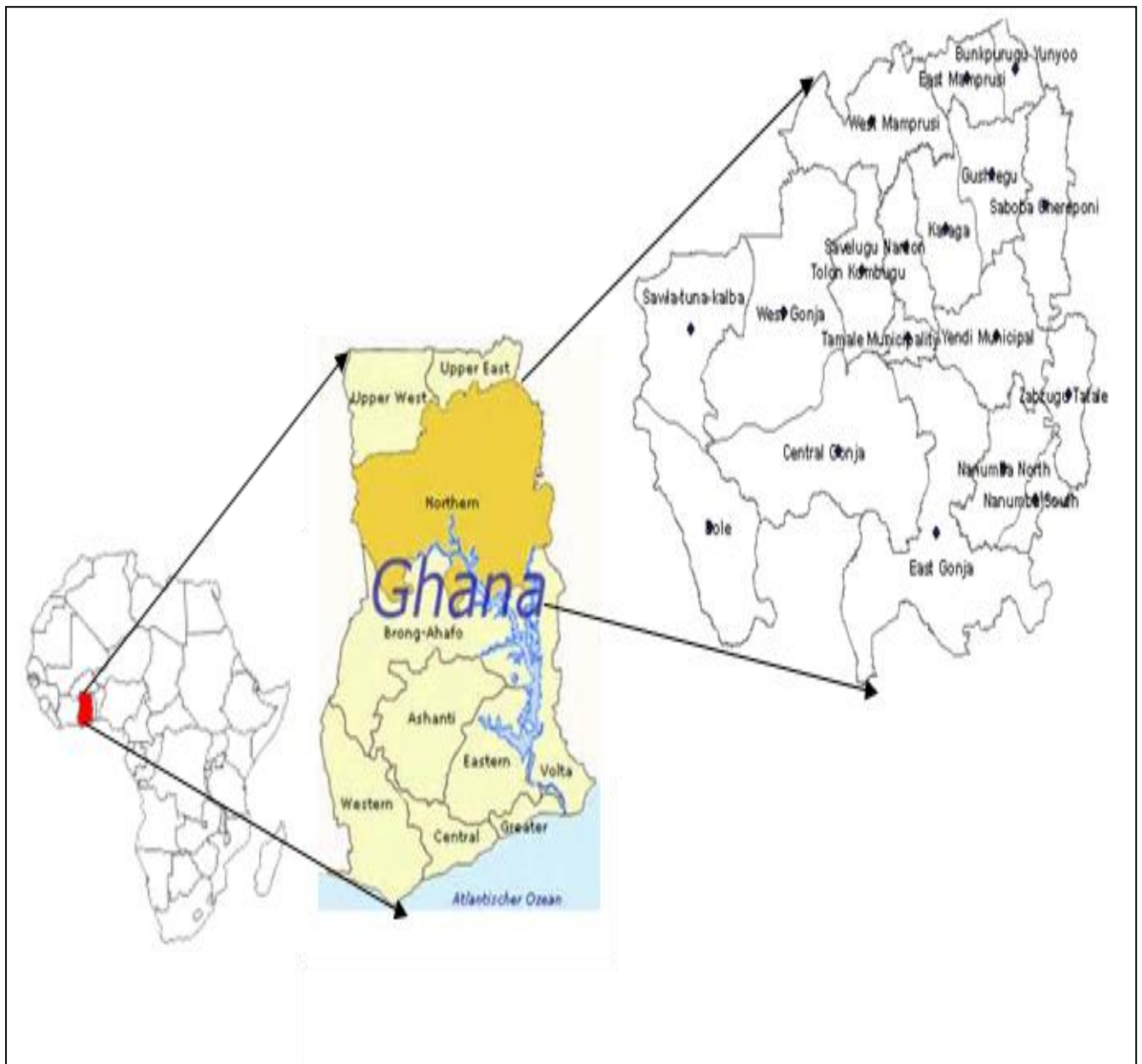
This is a descriptive study in which spatial tools in ArcGIS 10x are used to perform risk mapping using 10 years secondary data of Rainfall, Temperature, and Soil pH of the various districts and also flood map of Ghana as predictor variables. Secondary data on Anthrax outbreaks in the Northern Region from January 1, 2003 to December 31, 2012 were collected to map out the spatial distribution of the outbreaks.

#### 3.2 Study Area

The study area was determined using the political borders of the districts of Northern Region. The Northern Region is made up of 20 but for the study, 18 districts are taken due to the location of the metrological stations which are Bole, Bunkpurugu/Yunyoo, Central Gonja, East Gonja, East Mamprusi, Gushiegu, Karaga, Nanumba North, Nanumba South, Saboba-Chereponi, Savelugu/Nanton, Sawla/Tuna/Kalba, Tamale Municipal, Tolon/Kumbungu, West Gonja, West Mamprusi, Yendi and Zabzugu/Tatale.

The region lies between longitude  $1^{\circ} 12''$  E and  $3^{\circ} 15''$  W and latitude  $10^{\circ} 30''$  N and  $11^{\circ} 10''$  N.

**Figure 3: Map of study site, Northern Region, Ghana.**



The Northern Region, which occupies an area of about 70,383 square kilometres, is the largest region in Ghana in terms of land area. It shares boundaries with the Upper East and the Upper West Regions to the north, the Brong Ahafo and the Volta Regions to the south, and two neighbouring countries, the Republic of Togo to the east, and Cote D'Ivoire to the west. Available land for agricultural production – 4.9 million ha (About 70% land mass), out of which 1,000,000 ha is under Crop Production (representing 16% of the 4.9 million ha.). Part of the remainder is used for rearing livestock and the rest of approximately 2.5 million hectares is potentially available for agricultural purposes. 10% of the Volta River falls in the region.

### **3.2.1 Climate, Vegetation and Soil**

The climate of the region is relatively dry, with a single rainy season that begins in May and ends in October. The amount of rainfall recorded annually varies between 750 mm and 1200 mm. The dry season starts in November and ends in March/April with maximum temperatures occurring towards the end of the dry season (March-April) and minimum temperatures in December and January. The harmattan winds, which occur during the months of December to early February, have a considerable effect on the temperatures in the region, which may vary between 14°C at night and 40°C during the day. The Region also falls in the onchocerciasis zone, vast area is still under-populated and not prone to cultivation.

The soil type in the districts of the region does not vary widely. The soils types are savannah Ochrosols, which develops under rainfall average between 800mm and 1500mm. They are predominantly medium sandy loams in both uplands and the valleys.

There are also patches of gravel to stony land. Alluvial sand can be found along the river banks.

The main vegetation is classified as vast areas of grassland, interspersed with guinea savannah woodland, characterized by drought-resistant trees such as the acacia, baobab, shea nut, dawadawa, mango, and nim trees.

### **3.2.2 Demography**

The population of the region is 1,820,806, representing 9.6 per cent of the country's population. The sex ratio for the region as a whole is 99.3 males per 100 females. About 73.0 per cent of the population of the region is rural. At the regional level, four out of every five adults are illiterate. The main industrial activity in the Northern Region is Agriculture (70.9%) comprising largely of farming, animal husbandry, hunting and forestry.

The region continues to be sparsely populated. Despite having the largest land area of the country, it has the lowest population density at each of the censuses since 1960. The region's population is dispersed with no significant concentration in specific districts. The low population density of the region may be the result of the interplay between a harsh climate and ecology, migration and poverty. This may suggest a relatively low population pressure on the land. The bulk (71.2%) of the economically active population in the region is employed in Agriculture.

### 3.2.3 Livestock production

The Northern Region remains the region with the highest concentration of livestock and it is the region that most Anthrax outbreaks occurred in the country since the first case that was reported in 2003-2012.

**Table 1: Poultry and Livestock production in the Northern Region by districts**

<b>ANIMAL</b>	<b>MAJOR DISTRICTS OF PRODUCTION</b>
Cattle	East Mamprusi, West Mamprusi, Bunkpurugu, Tamale, Zabzugu/Tatale
Sheep & Goats	Savelugu/Nanton, Tamale, West Mamprusi, East Mamprusi
Pigs	Kpandai, Tolon Kumbungu, Saboba, Chereponi
Poultry	Tamale, Tolom Kumbungu, Savelugu/Nanton, Bole
Fish	Central Gonja, West Mamprusi, East Gonja

### 3.3. Variables under study and predictors for mapping and analysis

#### Variables related to the environment

- Rainfall of each district per month
- Temperature (Maximum, Minimum and Mean) of each district per month
- Soil pH

#### Variables related to the outbreaks

- Community/village
- District
- Region
- Date (Month/day/ Year) for seasonality
- No. affected =Cattle, Sheep, goats etc
- Geographical positioning system coordinates

### **3.4 Data Management**

Experienced field workers were used in the data collection to ensure quality data collection. During the data collection, the principal investigator supervised the field workers and data collected was randomly crosschecked from the participants for correctness. Data cleaning and verification was done. Data was printed out and cross checked by two independent meteorological officers on rainfall and temperature with the original files and all the necessary corrections made on Microsoft Excel spreadsheet to ensure good quality data and void of duplications. Missing data was excluded from the analyses where necessary. All Anthrax outbreaks coordinates which were not in Degree Decimal (d,dd) were retaken with the GARMIN GPS.

### **3.5 Data collection**

#### **3.5.1 Outbreaks**

The outbreaks data (Appendix III) collected covered the period from January, 2003 to December 31, 2012 from the Veterinary Services Directorate (VSD) of the Ministry of Food and Agriculture (MoFA). These data were drawn from the following sources:

1. Monthly reports and outbreaks reports (appendix II) of District Veterinary Officers (DVO) of the 18 districts of Northern Region of Ghana. These activities include abattoir reports, clinical activities, vaccinations of livestock and medical prophylaxis. These reports were gathered by the office of the Regional Veterinary Officer at the Regional office of Ministry of Food and Agriculture.
2. Annual reports from the Central Veterinary Laboratory (CVL), in charge of laboratory analysis. This is the major veterinary laboratory for the northern sector of Ghana, which diagnoses Anthrax and other diseases. It is also responsible for distribution and production of anthrax spore vaccines.

3. Database of Epidemiology Unit of Veterinary Services Directorate, Headquarters, Accra
4. Quarterly reports of Livestock Development Project (LDP) (2004 -2009). This project supported the development of livestock subsector in the area of production and animal health in some selected districts; Northern Region 11 districts. The support to animal health delivery included the control of major livestock diseases, namely vaccinations of livestock against diseases such as Peste des Petits Ruminants (PPR), Anthrax, Contagious Bovine PleuroPneumonia (CBPP) and Blackleg.

### **3.5.2 Rainfall and Temperature data**

Data of climate variables (Appendix IV) such as rain and ambient temperature was obtained from the monthly reports of Meteorological Department of the Ministry of Science and Technology of Northern Region. These bioclimatic data were collated from 14 active Meteorological stations in the Northern Region. They are: Bimbila, Bole, Central Gonja, Chereponi, West Gonja, East Mamprusi, Saboba, East Gonja, Savelugu-Nanton, Sawla-Tuna-Kalba, Tamale, West Mamprusi, Yendi and Zabzugu-Tatale.

### **3.5.3 Soil pH**

Data on soil pH (Appendix IV) of the various districts was obtained from soil Research Institute of the Council for Scientific and Industrial Research Institute in Kwadaso, Kumasi of Ashanti Region.

### **3.6 Data Analysis**

#### **3.6.1 Descriptive statistics**

Descriptive data analysis was done using frequencies and cross tabulations on Excel spreadsheet. The data captured on Microsoft Excel software as a relational database for editing, validation, verification and generation of descriptive statistics.

The temporal distribution of the outbreaks was determined by examining the yearly and seasonal patterns. This was done by pooling the respective monthly outbreak data over the period under study. For seasonal analysis, the year was divided into 2 seasons: (1) Rainy season (May – October) (2) Dry season (November-April). The small number of identified outbreaks during the period of the study (10yrs) limits the ability to conduct complex statistical analysis to evaluate the association between Anthrax outbreaks and the season. For yearly analysis, the outbreaks of the respective years were added together and percentages calculated to identify the year with higher percentage of outbreaks.

The spatial distribution was calculated as the number of outbreaks per district during the 10 years period.

Since the geo-referenced data of outbreaks sites was available, distribution maps were generated using ArcGIS 10 to demonstrate the spatial spread of the outbreaks.

#### **3.6.2 Mapping**

Three (3) factors namely: rainfall, temperature and soil pH were selected for the study. Selection of these three predictor variables was based on previous reports on factors that influence *B. anthracis* spore survival in the environment Dragon & Rennie, (1995). The monthly mean of the values of these factors for ten years were calculated. The mean values in each district were concentrated in the centroid of the district.

Spatial interpolation assumes that samples taken at nearby locations are expected to have more similar values than samples taken farther apart Miller, (2004). Spatial interpolation can therefore predict the rainfall, temperature and soil pH of a region by estimating the values at unmeasured locations based on values at measured locations.

The values were interpolated using the Kriging method to get values within the entire region. The Kriging method uses semivariance to measure spatial correlation in sampled values. A semivariogram measures the strength of statistical correlation in measured values as a function of distance. It assumes the values that are close to each other in space are more alike. The existence of spatial dependence in a dataset can be found by small semivariance in data points that are close to each other and larger semivariances in data points that are farther apart Tobler, (1970). Semivariance is computed by the following equation:

$$\gamma(h) = \frac{1}{2} [Z(x_i) - Z(x_j)]^2$$

Where  $\gamma(h)$  = semivariance between known data points,  $x_i$  and  $x_j$ , separated by a distance  $h$ ,

$Z$  = attribute value.

For all the studied points of semivariogram plots, the difference squared between values of each pair of locations was plotted on the y-axis and the distance separating each pair of those measurement values were plotted on the x-axis.

The equation to calculate average semivariance is:

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} \{Z(x_i) - Z(x_i + h)\}^2$$

Where  $\gamma(h)$  is the average semivariance between sample points separated by distance  $h$ ,

$N$  is the number of pairs of sample points

$Z$  is the attribute value.

A Kriging Interpolation model predicts surfaces better than other models when data are checked for outliers and errors. If the data follow a normal distribution, Kriging is the best unbiased method of predicting a surface ESRI, (2012). However, spatial prediction does not require the data to be normally distributed, because Kriging is the best linear unbiased method of predicting a surface Negreiros, (2010).

A predictive or hazard map, i.e. a map that highlights areas which are suitable for the survival of anthrax spores and re-occurrence of anthrax outbreaks was prepared by weighting and overlaying climate factors as well as soil pH. For weighting of the different factors and their ranking, opinion of experts in Anthrax was solicited and available literature was incorporated into the final decision.

### **Soil pH maps**

The soil pH is a critical and very important element for the survival of anthrax spores to the extent that Hugh-Jones & Blackburn, (2009) the global distribution of anthrax is largely determined by soils with high calcium levels and a pH above 6.1, which foster spore survival. The soil pH values of the districts below 6.1 are classified low, values

between 6.1 - 6.25 are classified medium and values above 6.3 are classified high to produce the class map of soil pH. The Low, Medium and high were weighted at 0.1, 0.2 and 0.6 respectively to produce the weighted map of soil pH. The interpolated values were used to produce the soil pH distribution map of the region.

### **Rainfall and flood hazard**

Rainfall has direct and indirect influence on the outbreaks of *B. anthracis*. Elad, (2014) suggest that reemergence of anthrax, even after decades, has occurred following disturbance and heavy rainfall. The monthly mean rainfall values of the various districts between 75.4mm – 91.4mm were classified as Low, values between 91.5mm -100mm were classified as medium and values above 100mm were classified as high. The Low, Medium and High were weighted at 0.2, 0.3 and 0.5 respectively to also produce the weighted maps. The interpolated values were used to produce the rainfall distribution map of the region.

### **Temperature maps**

Temperature plays an important role in the survival of anthrax spores in the soil. Van den Bossche & Coetzer, (2008) stated that pathogens which spend a period outside the host are sensitive to changes in temperature and humidity; these pathogens include the infective spores of anthrax and blackleg. The monthly mean temperature values of the various districts between 27<sup>o</sup> C - 28<sup>o</sup> C were classified Low, and values between 28<sup>o</sup> C- 29<sup>o</sup> C were Medium and values between 29<sup>o</sup> C and above were classified as high. The Low, Medium and High were weighted at 0.2, 0.3 and 0.5 respectively to produce the temperature weighted map. The interpolated values were used to produce the temperature distribution map of the region.

### **Predictive maps**

The constant raster of 0.5, 0.3 and 0.2 were created based on expert's opinion as weights for soil pH, rainfall and temperature respectively according to their influence on Anthrax outbreaks. The re-classified layers of soil pH, rainfall and temperature were multiplied by the constant raster 0.5, 0.3 and 0.2 respectively.

- 1) The product of the soil pH and its standard weight was added to the product of the rainfall and its standard weight. The sum of the two layers produced the Soil pH and Rainfall predictive map.
- 2) The Soil pH and Rainfall predictive map was finally added to the product of the temperature and its standard weight to get the final predictive map.

### **Goodness of fit of Model**

The goodness of fit of the model could be determined through Residual plot or cross validation. Another method is detailed modelling of related data sets such as easy to measure values or comparison with independent data such as satellite data or other aerial imagery.

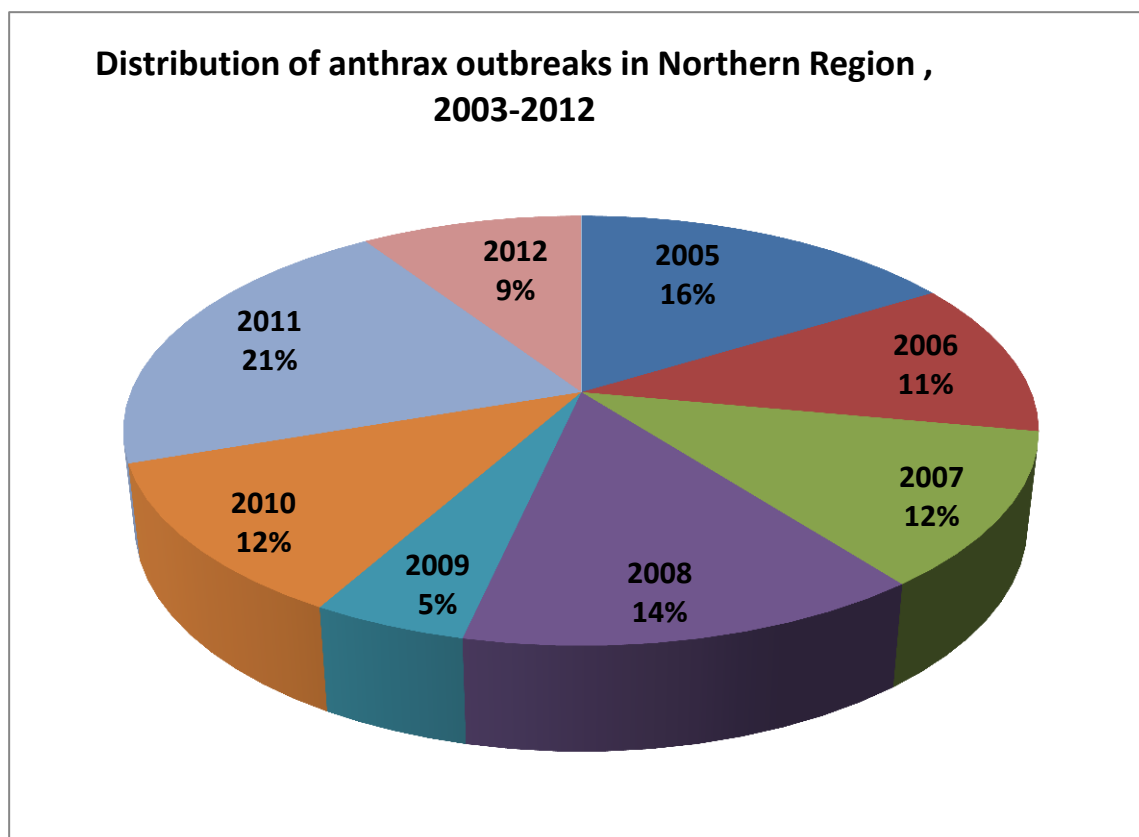
The accuracy of hot spots in the final predictive map was assessed by comparing the predictive map with the spatial distribution of Anthrax outbreaks in the study area.

## CHAPTER FOUR

### RESULTS

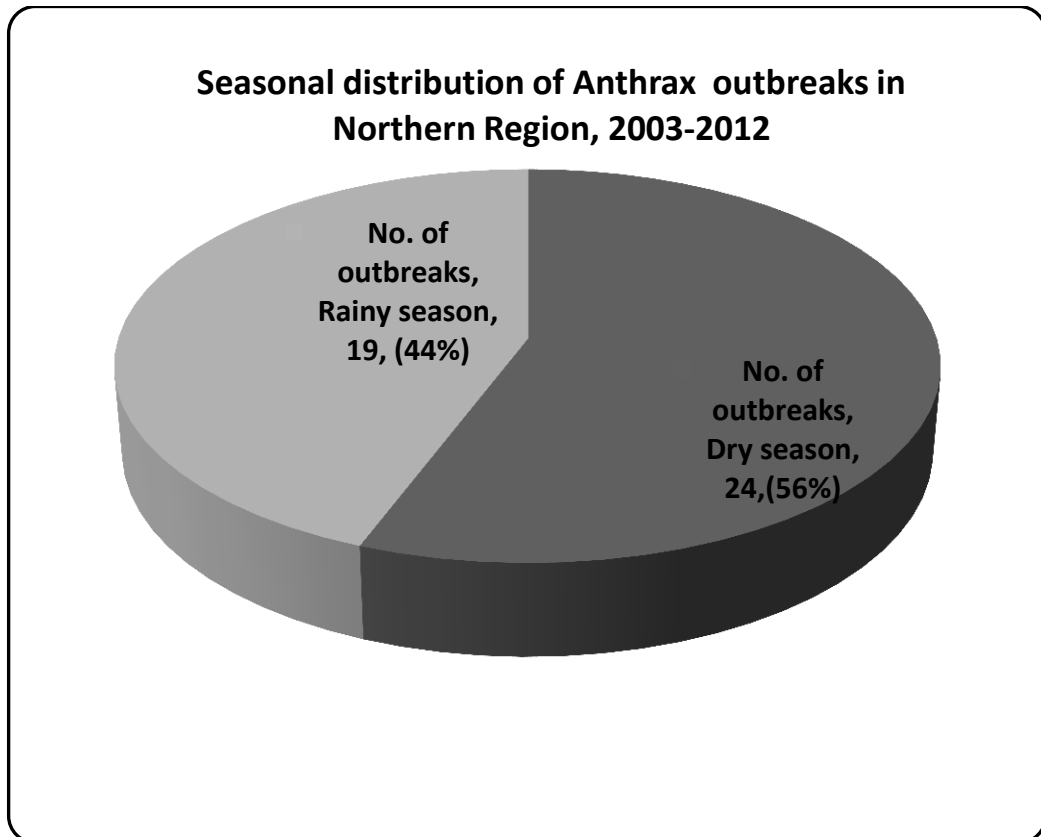
#### 4.1 DESCRIPTIVE

Within this 10-years period, there were 43 outbreaks confirmed. The deaths involved were 131 cattle of 26 outbreaks, 44 sheep of 12 outbreaks, 15 goats in 4 outbreaks, 562 pigs with 5 human deaths and 22 people developed cutaneous anthrax. The highest number of outbreaks occurred in 2011, 21% of the total outbreaks, followed by 2005, 2008, 2010, 2007, 2006, 2012 and 2009 in descending order, however, there were no outbreaks in 2004 and 2003 (figure 4).



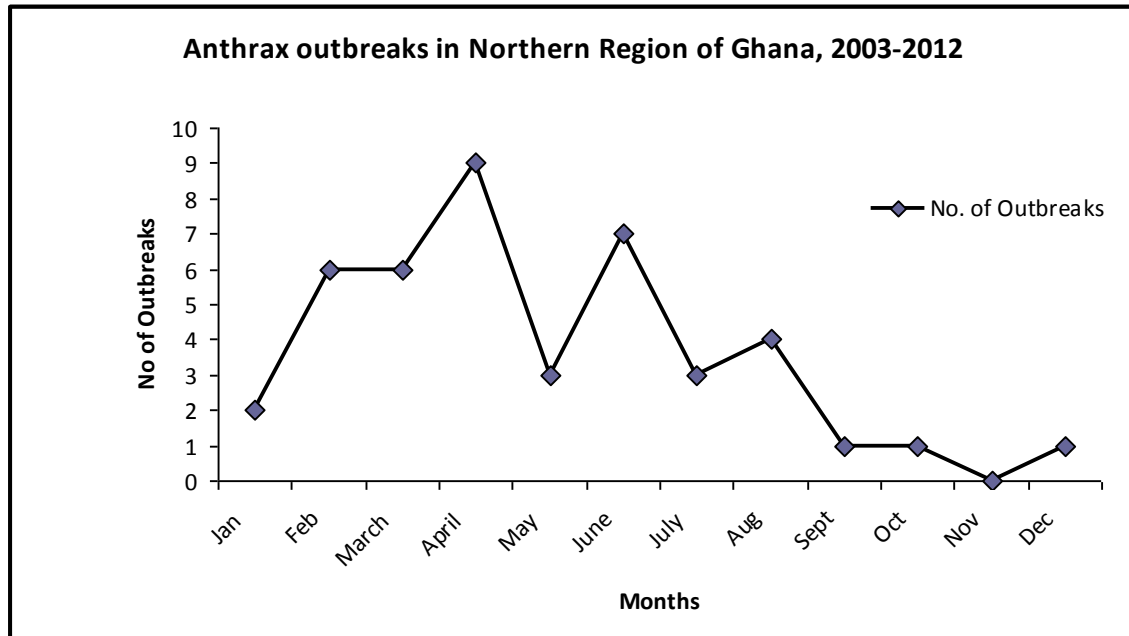
**Figure 4: Distribution of Anthrax outbreaks in Northern Region, 2003-2012**

Figure 5 shows the seasonal distribution of Anthrax outbreaks in Northern Region. The highest percentage (56%) of the outbreaks occurred during the dry season.



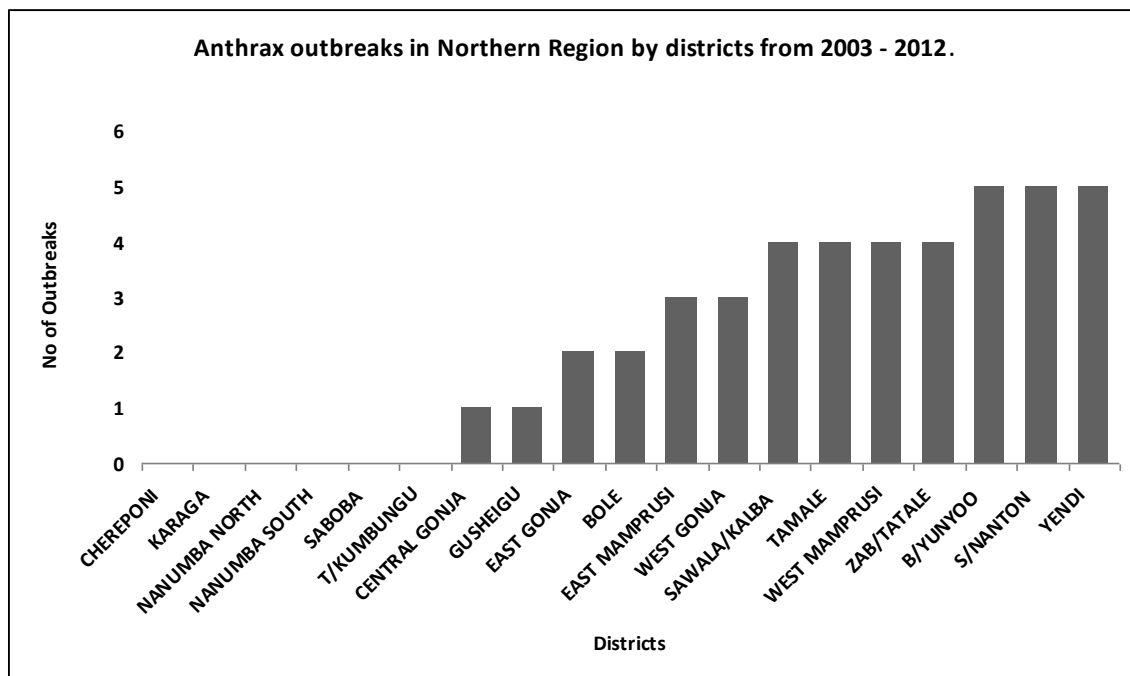
**Figure 5: Seasonal distribution of Anthrax outbreaks in Northern Region, 2003-2012**

Figure 6 shows the monthly distribution of anthrax outbreaks during the 10 year period. The highest number (9) of outbreaks occurred in April and the lowest in November.



**Figure 6: Monthly distribution of Anthrax Outbreaks in Northern Region, 2003-2012**

The districts that experienced the highest number of outbreaks are Bunkpuruguyoyoo (5), Savelugu-Nanton (5) and Yendi (5). The districts that did not experience outbreaks during this period are Saboba, Chereponi, Nanumba North and South, Karaga and Tolon-Kumbungu. (Figure 7).



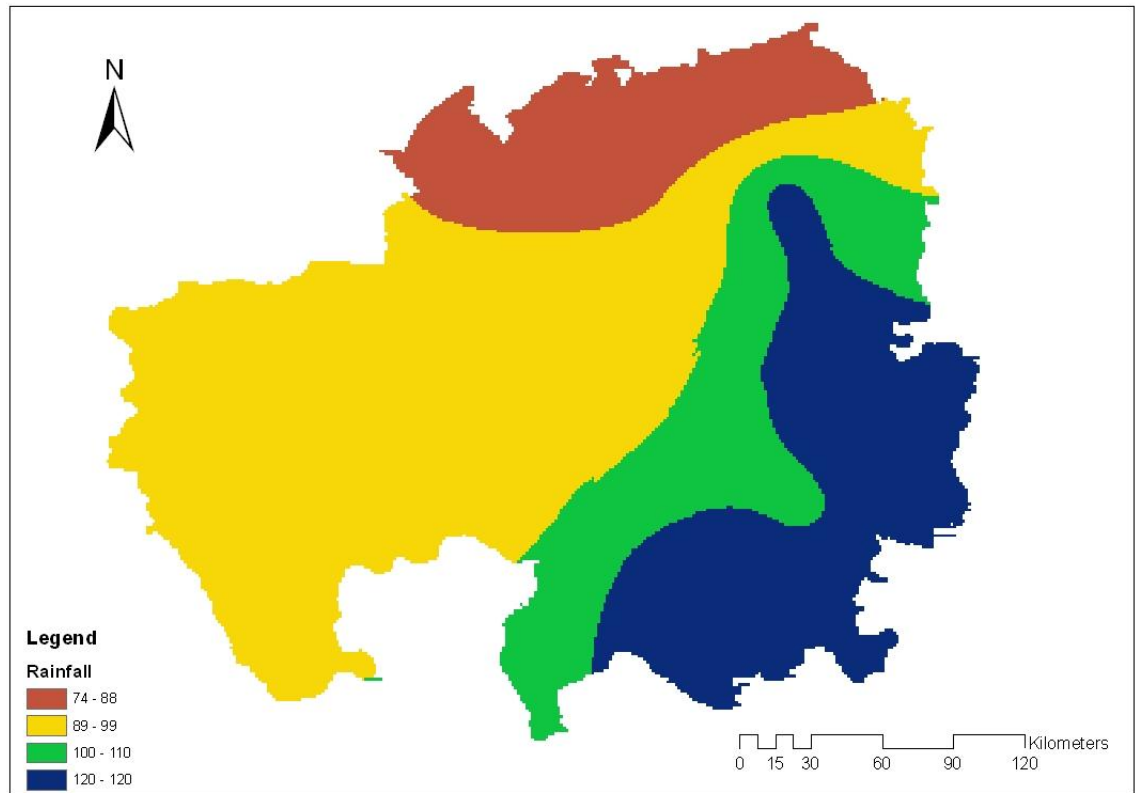
**Figure 7: Anthrax outbreaks in Northern Region by districts from 2003 - 2012.**

### **Rainfall pattern in the Northern Region of Ghana**

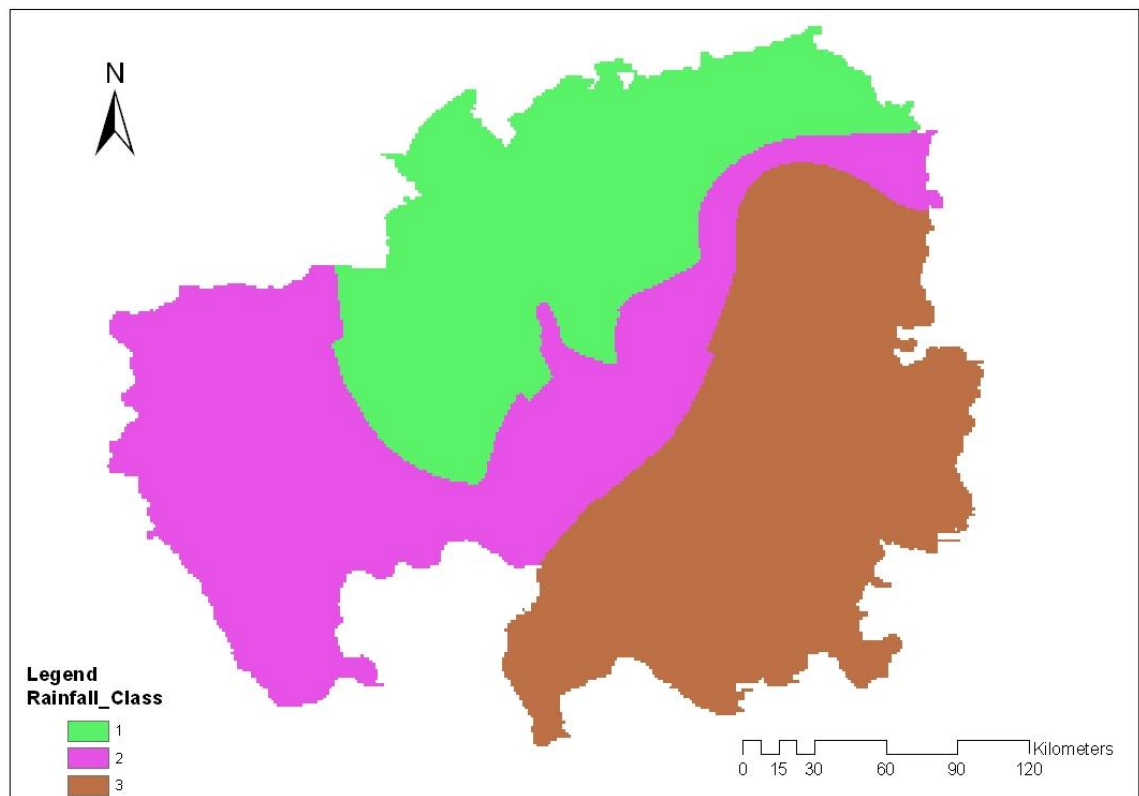
Rainfall distribution (figure 8), rainfall classified map (figure 9) and rainfall weighted map (figure 10) shows that the eastern belt such as East Gonja, Nanumba North and South as well as Saboba and parts of Yendi experienced very high rainfall and may experience flooding and erosions.

Eight of the districts thus Bole, Sawla/Tuna/Kalba, Tolon Kumbungu, West Gonja, Central Gonja, Tamale municipal, Savelugu Nanton and Karaga out of twenty experienced medium monthly rainfall of 87.4mm to 98.8mm.

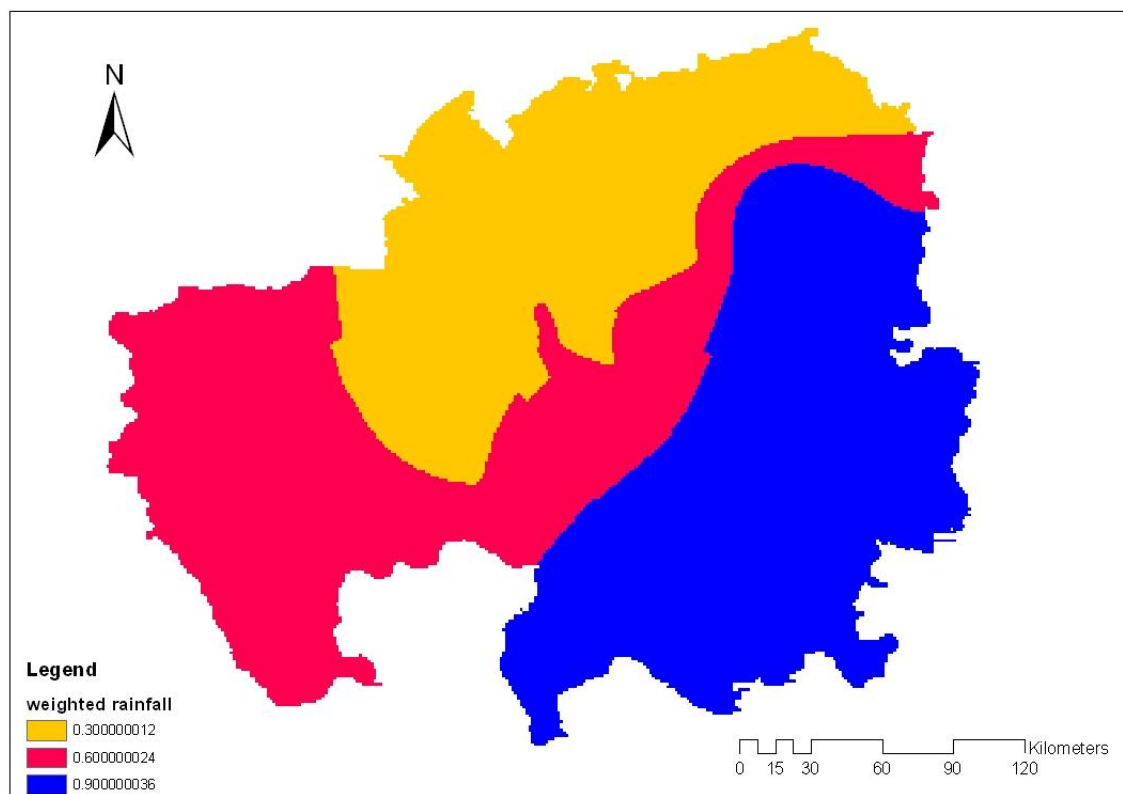
The rest of the 3 districts, East and West Mamprusi and Bunkpurugu-Yunyoo experienced low rainfall. These are the districts that historically experience flooding and severe drought. The north eastern part of Northern Region was severely affected by the August 2007 floods.



**Figure 8: Rainfall distribution map of Northern Region, 2003 -2012**



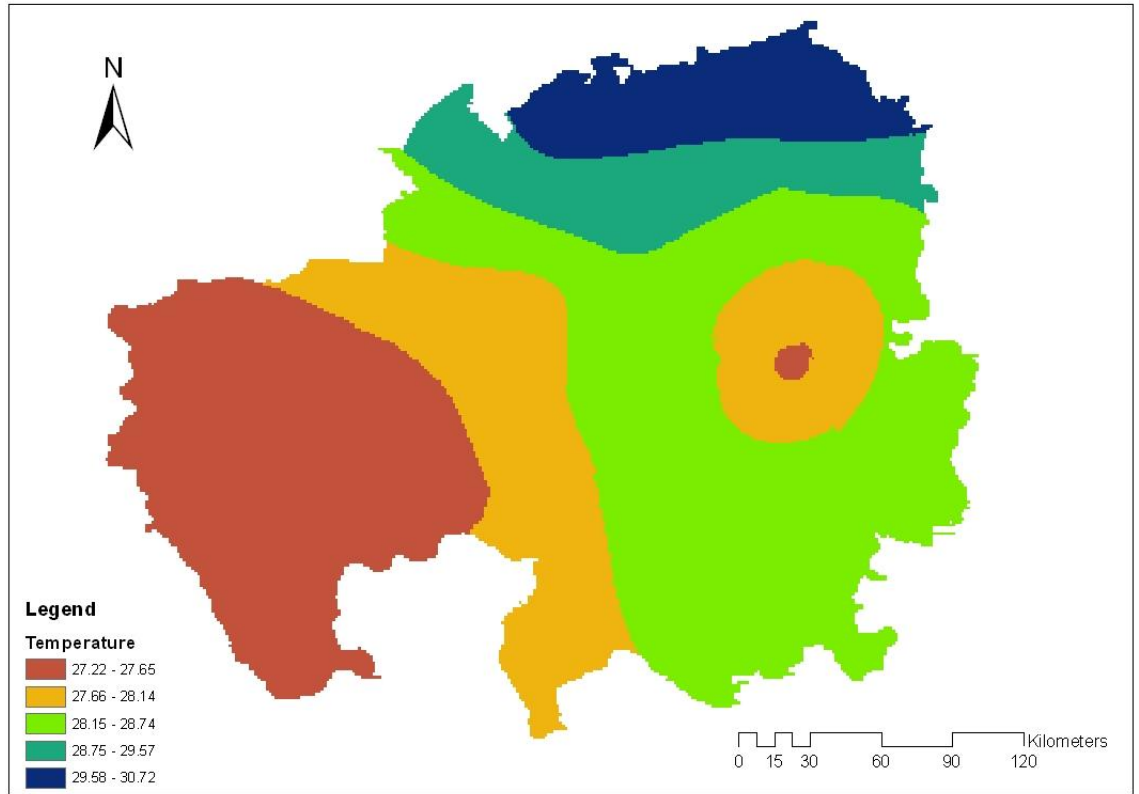
**Figure 9: Rainfall classified map.**



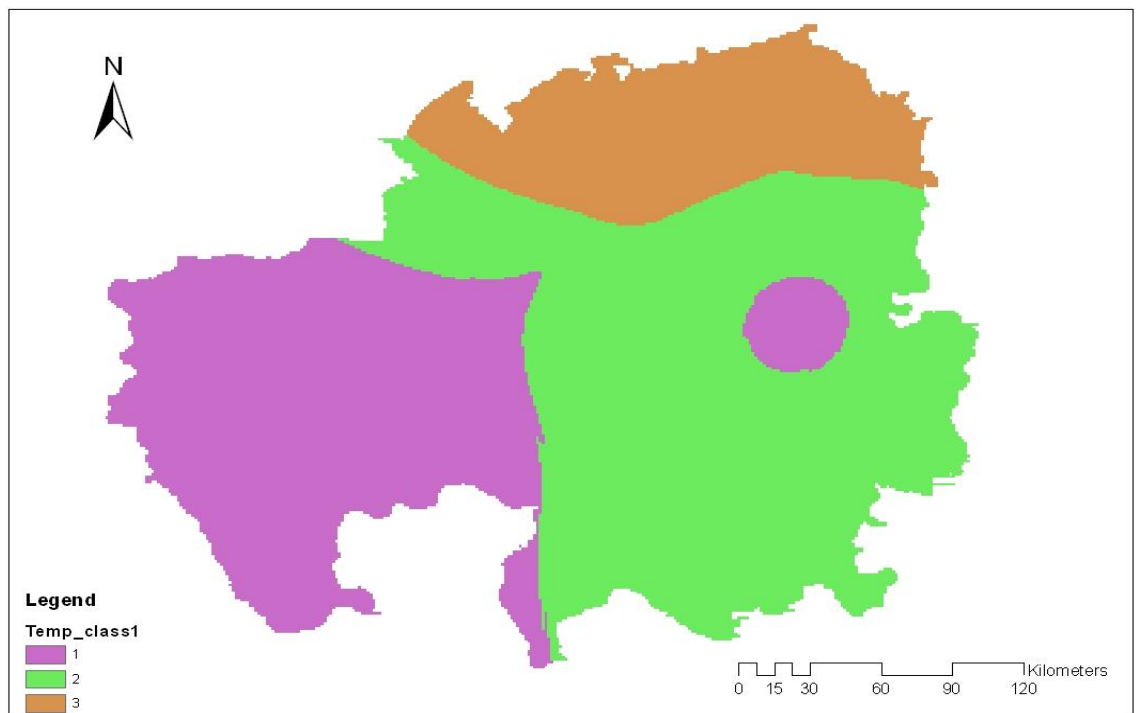
**Figure 10: Rainfall weighted map of Northern Region of Ghana, 2003 -2012**

### **Temperature pattern in the Northern Region of Ghana**

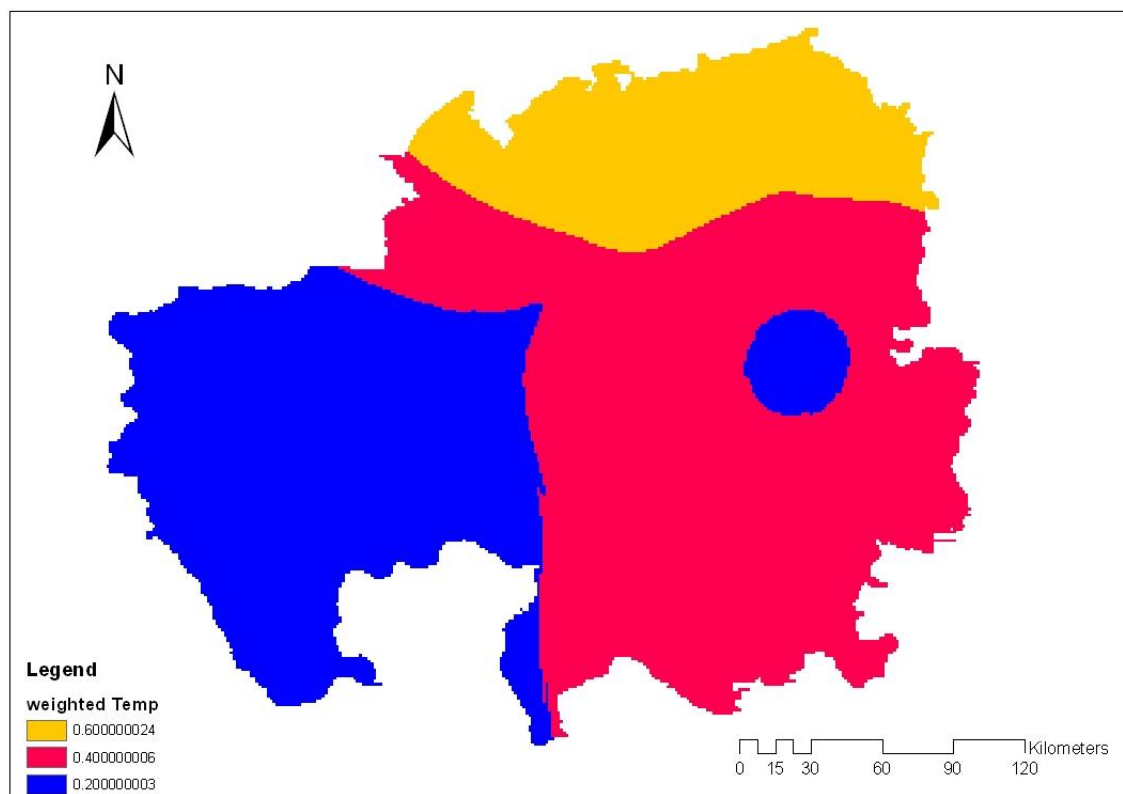
The temperature distribution pattern does not follow the administrative demarcations as illustrated in the distribution map (figure 11), the classified map (figure 12) and the temperature weighted map (figure 13). Four districts in the western corridor namely Bole, Sawla/Tuna/Kalba, West and Central Gonja experienced low temperatures but the rest Tolon Kumbungu, Tamale municipal, East Gonja, Nanumba North and South, Zabzugu/Tatale, Saboba Chereponi experienced medium temperatures of 27.9°C – 28.6°C. The districts in the northern belt Gushiegu, Karaga and Savelugu-Nanton experienced high temperatures ranging from 28.7°C -29.5°C and very high in East and West Mamprusi to Bunkpurugu-Yunyoo recording temperatures between 29.6°C-30.7°C.



**Figure 11: Temperature distribution in Northern Region, Ghana, 2003-2012**



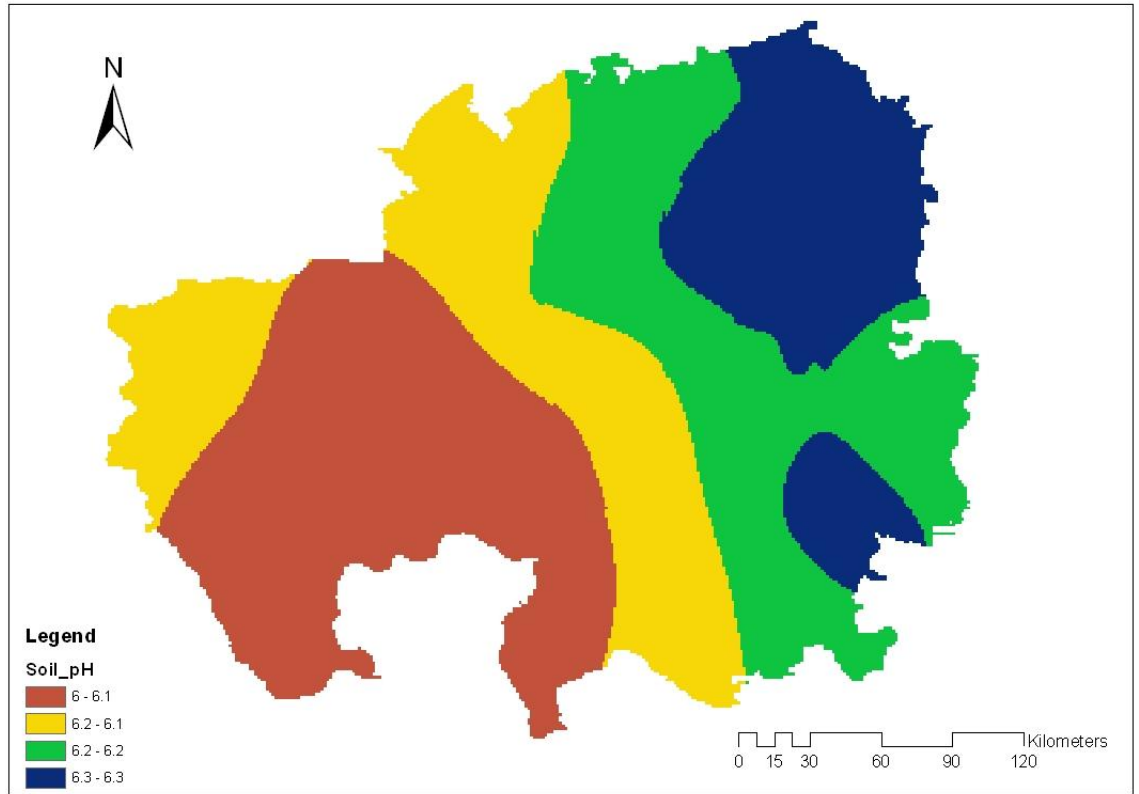
**Figure 12: Temperature classified map.**



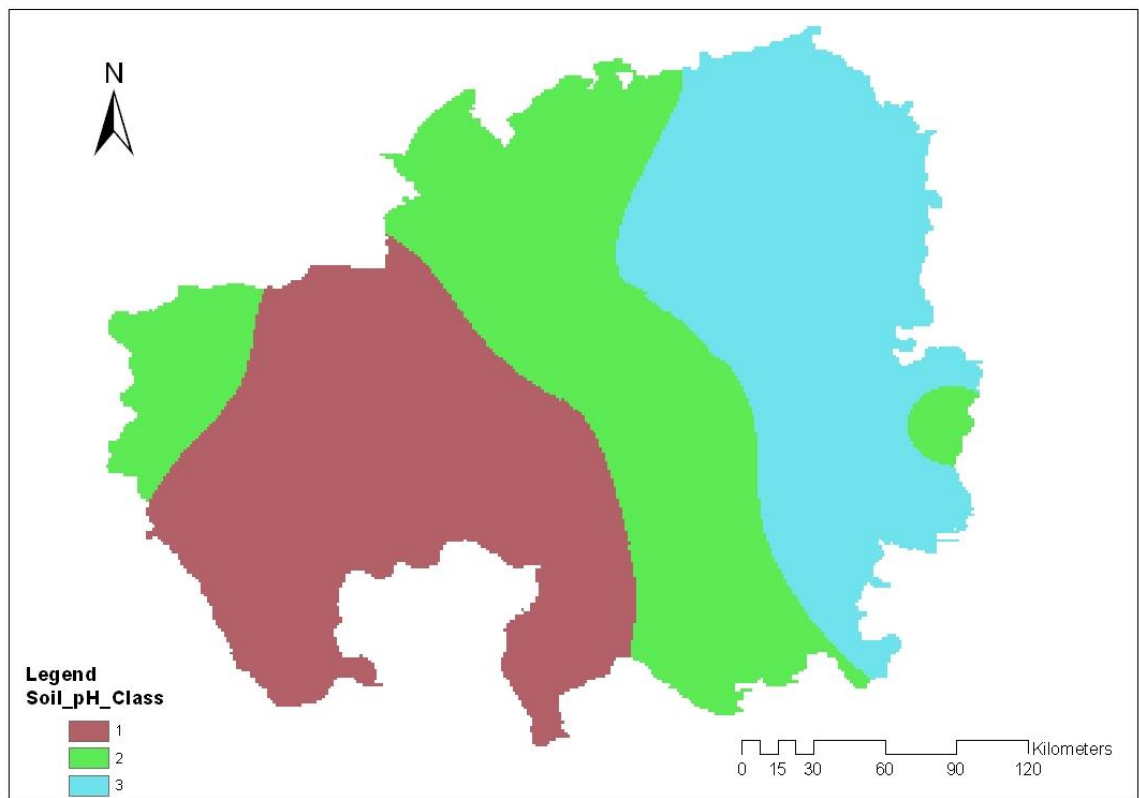
**Figure 13: Temperature Weighted map of Northern Region of Ghana, 2003-2012**

### **Soil pH distribution in the Northern Region of Ghana**

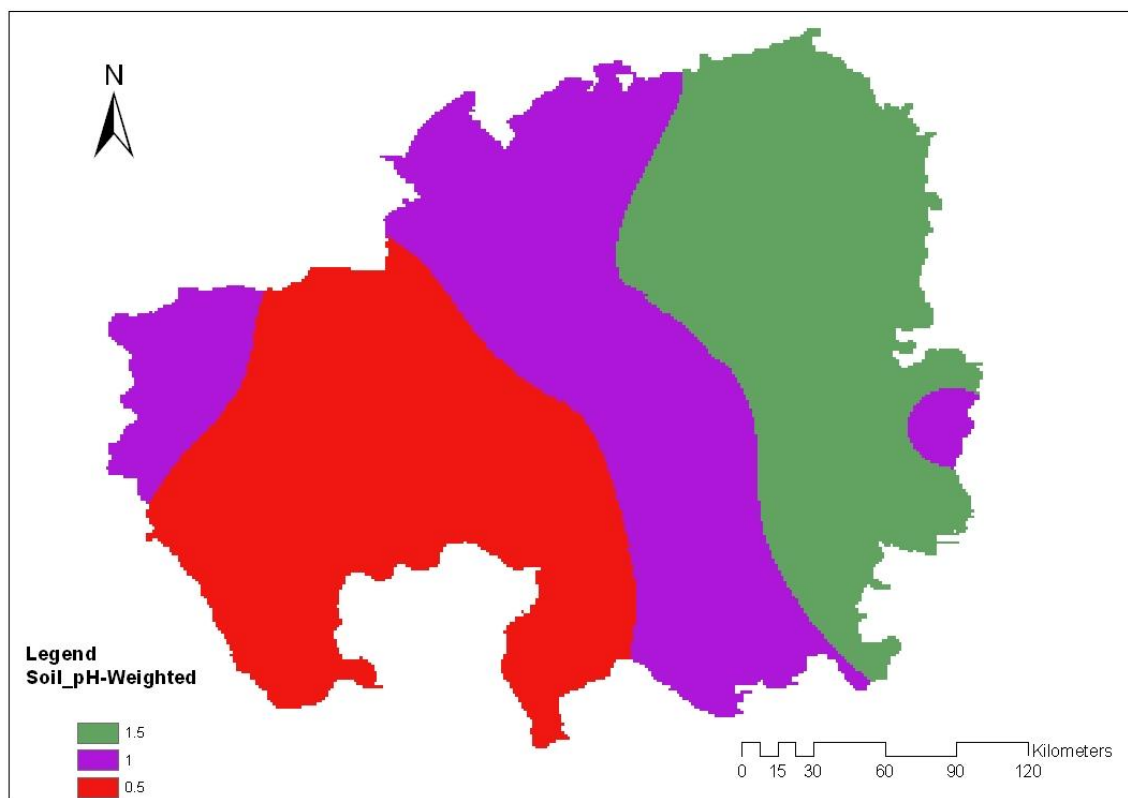
The soil pH distribution map (figure 14), soil pH classified map (figure 15) and soil pH weighted map (figure 16) clearly shows the distribution of this important predictor variable in the northern region of Ghana. Areas with low soil pH covers Bole, Central and West Gonja and the southern part of East Gonja precisely Kpandai. The medium soil pH covers East Gonja, Tamale Municipal, Tolon Kumbungu, Sawla/Tuna/Kalba and western part of West Mamprusi. The areas classified as high soil pH are western part of West Mamprusi, East Mamprusi, Savelugu-Nanton, Yendi and Zabzugu/Tatale. The districts ranked very high soil pH are Bunkpurugu-Yunyoo, Gushiegu, Karaga, Saboba Chereponi.



**Figure 14: Soil pH distribution in Northern Region of Ghana, 2012**



**Figure 15: Soil pH classified map of Northern Region of Ghana**



**Figure 16: Soil pH weighted Map of Northern Region of Ghana, 2012.**

### **Predictive Maps**

The Kriged generated maps below shows the distribution of soil pH, 10 years period of temperature and rainfall pattern in the Northern Region of Ghana.

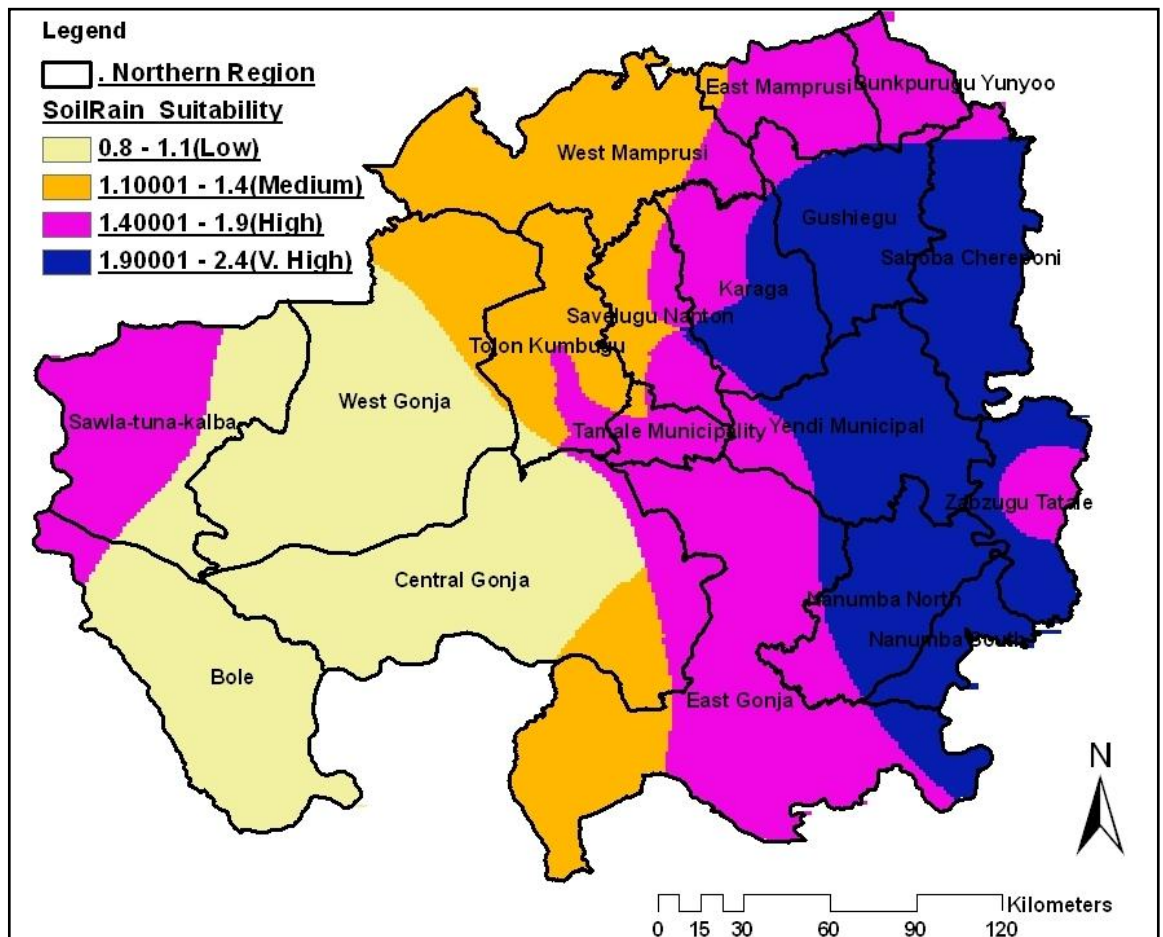
Computing of the two layers soil pH weighted map (figure 16) and rainfall weighted map (figure 10) yielded the soil pH and rainfall Predictive map in 4 classes by natural breaks using ArcGIS software (figure 17). The classes are as follows:

**Low risk Class:** West Gonja, Central Gonja and Bole

**Moderate risk Class:** West Mamprusi, Tolon kumbungu, Savelugu-Nanton and Kpandai in East Gonja.

**High Risk Class:** East Mamprusi, Bunkpurugu-Yunyoo, Tamale Municipal, East Gonja, Sawla/Tuna/Kalba, and Zabzugu Tatale

**Very High Risk class:** Gushiegu, Karaga, Yendi, Saboba, Chereponi, Nanumba North and South.



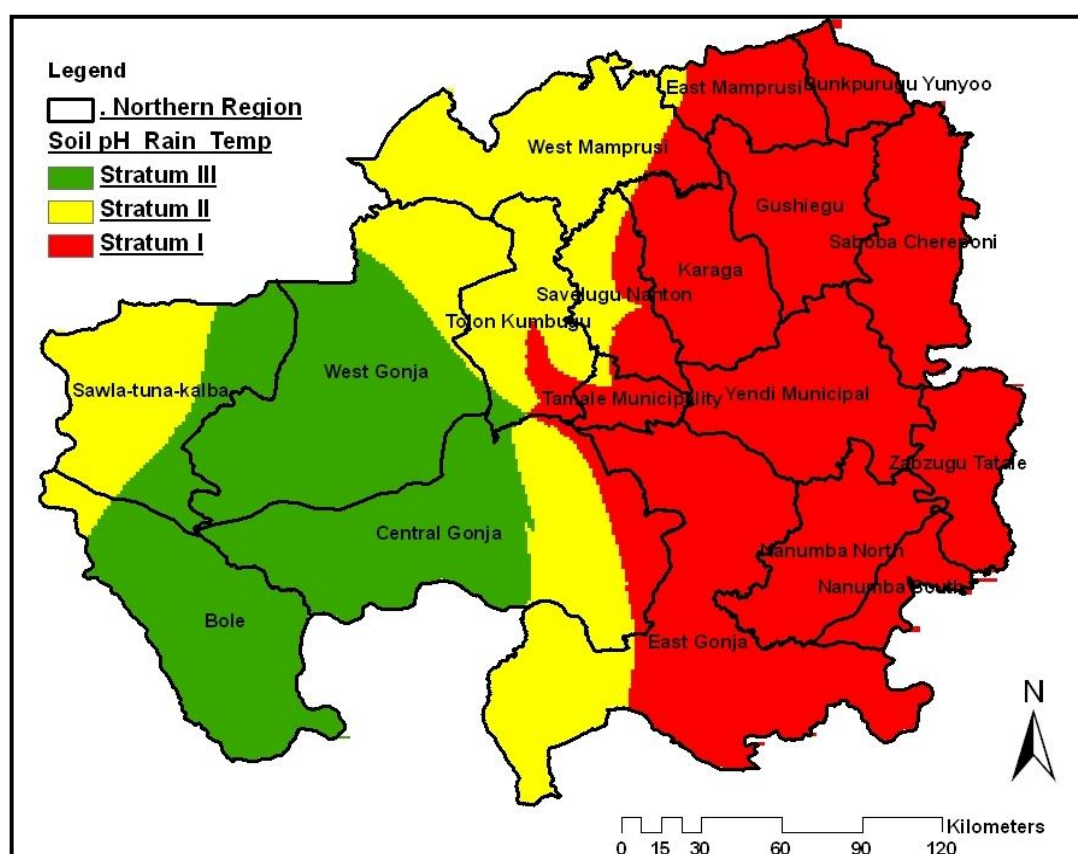
**Figure 17: Soil pH and Rainfall predictive map of Northern Region, Ghana 2003 -2012**

The same method as mentioned above was used to generate the final climate-based risk map by computing the weighted temperature map ( figure 13) and soil pH and rainfall predictive map (figure 17). The final predictive map (figure 18) has been stratified considering high risk areas as hot spots (stratum I), moderate risk areas as stratum II and the low risk area as stratum III.

**Stratum I:** East Mamprusi, Bunkpurugu-Yunyoo, Gushiegu, Karaga, Yendi, Saboba Chereponi, Tamale Municipal, East Gonja, Nanumba North and South and Zabzugu-Tatale.

**Stratum II:** West Mamprusi, Tolon Kumbungu, Savelugu-Nanton, Kpandai and Sawla/Tuna/Kalba.

**Stratum III:** West Gonja, Central Gonja and Bole.



**Figure 18: Final predictive map of anthrax outbreaks in Northern Region of Ghana.**

A final module validation map was produced by overlaying the maps of soil pH, rainfall predictive map, the 10 years Anthrax outbreaks distribution and the distribution of the meteorological stations in the Northern Region.

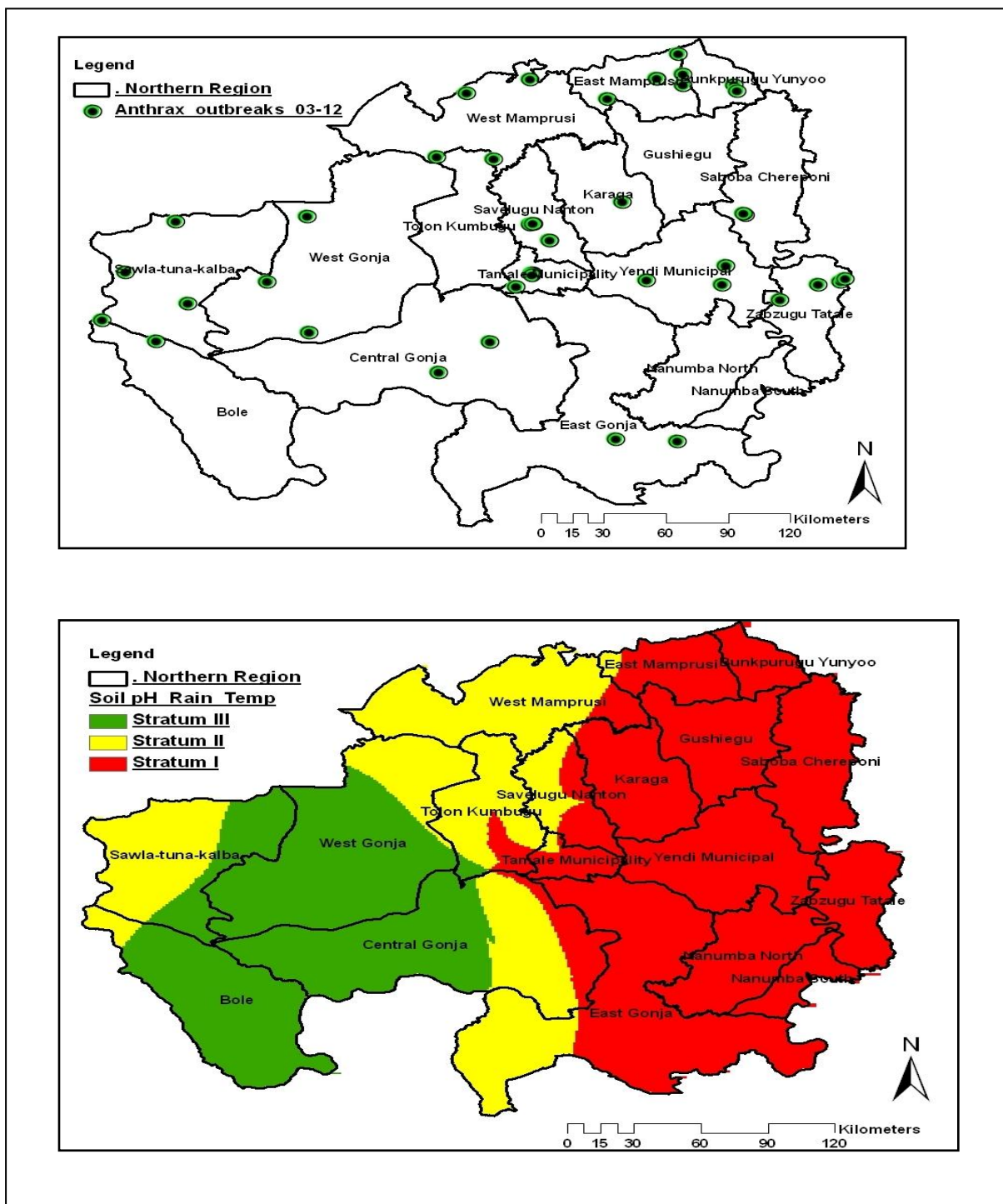


Figure 19: Comparative map of risk prediction and Anthrax outbreaks in the Northern Region.

## CHAPTER FIVE

### DISCUSSION

The present study provides a preliminary baseline data and opens the door to make significant changes in future research and surveillance efforts of this important but neglected public health disease. This study may be one of the extensive and most detailed predictive studies of this disease affecting livestock and humans in Ghana and demonstrates that soil pH, rainfall and temperature are the key drivers for endemicity and persistent outbreaks of Anthrax.

This study clearly provides an anthrax spore suitability mapping and stratification in an endemic area in Ghana. In total 43 outbreaks recorded during the 10 years period of study with a peak in April and the highest in Bunkpurugu-Yunyoo, Savelugu/Nanton, and Yendi followed by Zabzugu/Tatale, West Mamprusi and Tamale Municipal all from middle belt to north eastern belt of the region and the highest occurred in 2011.

Our findings show a significance influence of seasonal variation on anthrax outbreak occurrences. The majority of the outbreaks occur at end of the dry season and early part of the rainy season which is associated with perennial shortage of livestock feed forcing animals to graze very low and are more likely to acquire the Anthrax spores. The records in a single outbreak, shows high pig mortality of 500 in Bole. This could be attributed to poor biosecurity measures which includes pigs being reared on free range and can easily unearth shallow buried anthrax carcasses. Bole and Sawla-Tuna-Kalba are on the main route from Upper West where animals are being sold and transported to the southern sector.

Similar studies have been carried out elsewhere. (Blackburn *et al.*, 2007) utilized multiple environmental variables including measures of temperature, precipitation, soil, and vegetation to establish a potential distribution model of *B. anthracis* in the United States based on the relationship between known occurrence data and environmental variables in proximity to the data. The study emphasized the utility of being able to identify environmental parameters that support *B. anthracis* survival in order to delineate areas that may be at a higher risk of having an anthrax outbreak.

In the present study, with the assistance of the maps, the low and high risk areas can be highlighted, and the environmental factors contributing to the process of causation can be related to diseases using overlaying techniques. Rytönen, ( 2004) emphasised that GIS overlay techniques, are suitable for searching simultaneously spatial patterning and the risk factor associations of two or many diseases of interest.

Outbreaks have been associated with heavy rains and flooding which are hypothesized to unearth spores Durrheim *et al.*, (2009); Lewerin *et al.*, (2010). The eastern corridor of the region, notably the north eastern part of the region, was the hardest affected area during the August, 2007 floods in the country and that area remains prone to floods. (Forkuo, 2011) in a study found similar results and created a district level map indicating flood hazard prone areas of Northern Region of Ghana and classified into four hazard categories by natural breaks and concluded that there is no defined pattern.

The vegetation in the eastern corridor area is mainly savannah grass land with much human activity and livestock movement, hence there is a direct correlation as reported by

Munang'andu, *et al.*, (2012) that the number of anthrax outbreaks was high during the period when the human population density on the floodplain was high.

The maps produced illustrated that with the soil pH, the eastern corridor of the Northern Region is more suitable for the anthrax spore survival. Our finding as reflected coincided with Dragon & Rennie, (1995); Hugh-Jones & Blackburn, (2009) that soils with pH above 6.1 to alkaline have shown to be important geographical determinants of anthrax occurrence because of increased spore survival. The finding also shows spatial association as significant number of the outbreaks in the 10 year period has occurred from the middle part of the region to the eastern part specifically north eastern portion.

Although the results of rainfall as a predictor seems a poor explanatory variable in other research work Brandes & Brandl, (2007) did not find any statistical relationship between the number of cases reported and meteorological data (rainfall, mean temperature), contrary, our results established that the reoccurrence and outbreaks of Anthrax and rainfall have a well establish association. It is well established that the areas in the Eastern corridor has the highest rainfall but then the north eastern part of the region has the lowest rainfall.

Our work coincided with Dragon & Rennie, (1995) that anthrax outbreaks may be associated with Temperature and high soil moisture. The soil pH and rainfall predictive map generated is stratified into high risk stratum, moderate risk stratum and low risk stratum similar to Cherkasskiy, (1999) who in doing this, makes it possible to develop contingency plans for different risk locations (i.e. high risk of persistent infection, high risk of sporadic occurrence, low risk areas, etc.) in terms of anthrax and also identify

high risk areas and develop a differentiated strategy of vaccination and other control strategies, and to develop preventive recommendations to reduce risk in high risk areas.

The high risk area is (Stratum I) made up of the following districts: East Mamprusi, Bunkpurugu-Yunyoo, Gushiegu, Karaga, Yendi, Saboba Chereponi, Yendi, Tamale Municipal, East Gonja, Nanumba North and south and Zabzugu-Tatale. Notably are some districts like Gushiegu, Karaga, Nanumba North and South in this stratum that has not experienced any outbreak but once occurred, the spore has the potential to survive for longer period due to the bioclimatic and the soil pH suitability for its survival. Low risk area stratum III is made up of West Gonja, Central Gonja and Bole.

## CHAPTER SIX

### CONCLUSION AND RECOMMENDATIONS

#### 6.1 Conclusion

- The Kriged generated risk maps have identified three areas in the Northern Region. Stratum I is identified as hot spot areas. The second strata (Strata II) consisting of moderate risk areas has also been identified, mainly the middle belt from south to the northern part of the region and the third strata (Strata III), also extends from South-West to North-West of the region except Sawla-Tuna-Kalba.
- In the light of these results, it is apparent that there is an association between soil pH and risk of Anthrax outbreaks in the Northern Region of Ghana.
- Temperature and rainfall are predictor variables that helps explain the risk of Anthrax outbreaks in the Northern Region of Ghana.
- In an environment with soil pH  $>7$  and monthly mean rainfall below 108mm and monthly mean temperature of 28°C and above, *B. anthracis* has great adaptability and survival capacities, enabling them to survive and disperse in the environment with heavy floods.

## **6.2 Recommendation**

Predictive maps generated can be used by the Veterinary Services Directorate as a guide to strengthen disease surveillance in the northern region

The methodology can also be used for other diseases whose epidemiology is environmental related as part of a standardized approach for the design of risk-based surveillance activities.

Anthrax potential outbreak area maps can be improved using other sophisticated modeling techniques with satellite maps to make prediction more accurate.

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**Appendix II: Format of Veterinary Disease Outbreak Records**

VETERINARY SERVICES DIRECTORATE  
**OUTBREAKS OF SCHEDULED DISEASES REPORTING FORMAT (VF1)**

**BACKGROUND DATA**

1) Date of outbreak	2) Date outbreak reported to Vet	3) Date of investigation by Vet	4) Date of final field diagnosis	5) Husbandry practice	6) Region	7) District	8)Town /Village	9)Community	10) Longitude	11) Latitude

**EPIDEMIOLOGICAL DATA**

7: *Bov, C0ap,Ovi,Can ,Equ etc	12) Age group most affected	13) Sex most affected	14) No. of cases (sick plus dead)	15) No. of in contacts	16) No. Dead	17) No. destroyed	18) No. Slaughtered	19) No. at risk	20) Any human involvement and number affected	21) Any human deaths and number

## CLINICAL DATA

22) History and clinical signs observed
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23) Post mortem lesions/signs
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24) Tentative diagnosis
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25) Differential diagnosis
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26) Samples taken
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27) Date samples sent to laboratory (indicate laboratory)
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28) Date laboratory results received
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29) Control measures including any treatment given:
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30) Name and grade of reporting officer

### Appendix III: Anthrax Outbreak records of Northern Region, 2003-2012

Year	District	Month	Village	Cattle	sheep	goats	pigs	Human deaths	North	WE
2012	Zabzugu/Tatale	March	Nachoma	12	0	0	0	0	9.36775	0.53635
2012	Savelugu/Nanton	April	Pong-Tamale	0	0	0	59	0	9.68748	-0.83051
2012	Bole	June	Bole	0	0	0	500	0	9.03284	-2.48938
2012	East Gonja	June	Adamape	0	7	0	0	0	8.47856	-0.47433
2011	Central Gonja	August	Butey	1	0	0	0	0	8.85565	-1.24845
2011	East Mamprusi	April	Nalerigu	1	0	0	0	0	10.49422	-0.28210
2011	West Gonja	August	Galamsey	2	0	0	0	0	9.73340	-1.82430
2011	Yendi	February	Kpandaaya	1	0	0	0	0	9.72707	0.10257
2011	Yendi	March	Sakblek	2	0	0	0	0	9.73721	0.09227
2011	Gushiegu	July	Gaa	10	0	0	0	0	9.80713	-0.43910
2011	West Mamprusi	April	Kunkua	4	0	0	0	0	10.41876	-1.11983
2011	Tamale Municipal	February	Prison Farms	0	0	0	3	0	9.40488	-0.83735
2011	Tamale Municipal	October	Changli	0	2	0	0	0	9.39623	-0.83631
2010	East Mamprusi	June	Tighiri	2	0	0	0	0	10.49410	-0.28211
2010	West Gonja	September	Hanga-line	0	1	0	0	0	9.08330	-1.81660
2010	Yendi	March	Nagami	2	0	0	0	0	9.33889	-0.00320
2010	Zabzugu/Tatale	June	Nakpale	0	1	0	0	0	9.35000	0.51660
2010	East Gonja	February	Kumidi	2	0	0	0	0	8.46444	-0.20606
2009	West Gonja	March	Damongo	0	1	1	0	0	9.02305	-1.02306
2009	Bunkpurugu-Yunyoo	April	Napkanduri	2	0	0	0	0	10.63330	-0.18330
2008	East Mamprusi	June	Brugu	5	0	0	0	0	10.38330	-0.50000
2008	Yendi	July	kuga-Yendi	3	0	0	0	0	9.44495	0.01333
2008	Zabzugu/Tatale	June	Tokoradi-tatale	8	0	0	0	0	9.33333	0.41667
2008	Zabzugu/Tatale	June	Nafongyili	0	0	11		1	9.25000	0.25000
2008	Bunkpurugu-Yunyoo	January	Sagbeni	4	0	0	0	0	10.42472	0.07345
2008	Tamale Municipal	February	Fooshegu	0	6	0	0	0	9.33448	-0.90618
2007	Savelugu/Nanton	January	Gbumgbum	0	8	2	0	0	9.59119	-0.75836
2007	West Mamprusi	February	Kpatorigu	8	0	0	0	0	10.05000	-1.00361
2007	West Mamprusi	March	Katigiri	4	0	0	0	1 (4 cutaneous)	10.06111	-1.25000
2007	Bunkpurugu-Yunyoo	April	Bunbuna	3	0	0	0	2	10.45346	0.06050
2007	Bunkpurugu-Yunyoo	April	Nasuan	0	1	1	0	18 (Cutaneous)	10.51660	-0.16660
2006	Sawla-Tuna-Kalba	April	Gbinyiri	3	0	0	0	1	9.36667	-2.00000
2006	Yendi	May	Dejado-tenting	0	1	0	0	0	9.36677	-0.33445
2006	Savelugu/Nanton	April	P-Tamale	0	1	0	0	0	9.68676	-0.82590
2006	Savelugu/Nanton	February	Bunglungu	0	14	0	0	0	9.59119	-0.75836
2006	Bunkpurugu-Yunyoo	March	Jimballi	14	0	0	0	0	10.45872	-0.16740
2005	Bole	July	Jankulakura	6	0	0	0	0	9.15172	-2.72394
2005	Sawla-Tuna-Kalba	December	Nyoli	11	0	0	0	1	9.70609	-2.40222
2005	Sawla-Tuna-Kalba	April	Jentilpe	11	0	0	0	0	9.24521	-2.35093
2005	Sawla-Tuna-Kalba	May	Bugali	5	0	0	0	0	9.42243	-2.62120
2005	Savelugu/Nanton	May	P-Tamale	1	0	0	0	0	9.68090	-0.84614
2005	West Mamprusi	August	Silinga	4	0	0	0	0	10.49553	-0.83681
2005	Tamale Municipal	August	Ward-K	0	1	0	0	0	9.41003	-0.83512

**Appendix IV: Summary of temperature, rainfall and soil pH data of Northern Region 2003 -2012**

<b>District</b>	<b>Soil_pH</b>	<b>Mean monthly rainfall.</b>	<b>Mean Monthly Temperature</b>
Bole	6	94.749	27.24
Bunkpurugu-Yunyoo	6.5	80.749	30.84
Central Gonja	5.95	92.311	27.63
East Gonja	6.05	116.126	28.37
East Mamprusi	6.1	75.375	30.17
Gushiegu	6.3	91.404	28.59
Karaga	6.2	91.404	28.59
Nanumba North	6.35	106.360	28.2
Nanumba South	6.3	116.126	28.1
Saboba/Chereponi	6.2	102.153	28.32
Savelugu/Nanton	6.25	91.404	28.67
Sawla-Tuna-Kalba	6.15	95.236	27.42
Tamale Municipal	6	92.136	28.74
Tolon/Kumbungu	6.25	92.136	27.74
West Gonja	5.9	91.344	27.63
West Mamprusi	6.1	80.749	29.89
Yendi	6.25	112.512	27.32
Zabzugu/Tatale	6.1	115.066	28.82