SPATIAL DISTRIBUTION AND KNOWLEDGE, ATTITUDE AND PRACTICES OF ANTHRAX AMONG PASTORALISTS IN WAJIR, ISIOLO AND MARSABIT COUNTIES, KENYA

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DECLARATION

This thesis is my original work and has not been presented for any degree or other certificates at any other University.

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DEDICATION

This thesis is dedicated to my mother Fatima Abdi Askar for her support, encouragement and motivation throughout the duration of my studies.

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ABBREVIATIONS AND ACRONYMS

ENM	Environmental Niche Modelling
AUC	Area Under the Curve
AVCD	Accelerated Value Chain Development
GIS	Global Information System
GPS	Geographic Positioning System
ILRI	International Livestock Research Institute
OIE	Office International des Epizooties
pH	Potential of Hydrogen
WHO	World Health Organization
ASALS	Arid and Semi-arid lands
UPMC	University of Pittsburgh Medical Center
KNBS	Kenya National Bureau of Statistics
SID	Society for International Development

ABSTRACT

Anthrax is an important zoonotic disease in Kenya causing high morbidity and mortality in both human, wild life and livestock. It is endemic and was reported in many parts of the country and periods outbreaks occur in Arid and Semi-arid lands (ASALS) such as Wajir, Isiolo and Marsabit. For future prevention of the disease, there is a need to develop the risk map of anthrax and assess the knowledge, attitude and practices of anthrax among pastoralists. The objectives of the current study were to 1. Map the spatial distribution of hotspots of anthrax in Wajir, Isiolo and Marsabit counties, 2. To identify the ecological parameters that influences the occurrence of anthrax in the three counties, 3. To assess the Knowledge, attitude and practices of the disease by pastoralists in the three counties. The study was cross-sectional whereby various areas of anthrax outbreaks were identified through the veterinary departments in the three study counties of Wajir, Isiolo and Marsabit. These areas were visited and using systematic sampling methods, a total of 400 households were visited. Data were collected through questionnaires administered via personal interviews. Information collected included demographic characteristics of the households, knowledge on anthrax, attitude and practices on the disease. The ecological niche model was developed to map the future occurrences of the disease. The ecological niche model predicted the occurrence of anthrax especially in areas adjacent to the points where previous anthrax cases had occurred. The model predicted an endemic status of the disease in all the three study counties. The model further identified some parameters which might be responsible for the persistence of anthrax in the environment including isothermality, temperature seasonality, precipitation of the wettest month, elevation and soil pH.

Pastoralists had adequate knowledge on anthrax. They correctly pointed out the clinical signs of anthrax in livestock such as sudden death, bleeding from body orifices and cutaneous sores. The indigenous knowledge was uniform in all the three counties. Despite that knowledge, they reportedly engaged in dangerous practices that would expose them to infection by anthrax. These practices included consumption of meat from suspect anthrax cases, opening of carcasses of dead animals, and throwing of anthrax suspect carcasses in bushes. Anthrax is a well known disease in this pastoral setting. There is a need for education programmes to be designed for this community especially with regard to proper handling of suspect anthrax cases. The continuous anthrax prevention efforts should be initiated through vaccination of livestock.

CHAPTER ONE: INTRODUCTION

1.1 Background

Anthrax is a highly contagious and virulent disease (Fulako, 2004). It mainly affects herbivorous animals, although all mammals and some avian species are susceptible to this disease. *Bacillus anthracis* is a gram positive, rod-shaped, and spore forming bacteria and produces this lethal sickness. It is peracute disease, death can occur within a short time; approximately twenty-four hours. As a result, those afflicted with the disease are largely found dead. This disease can be transmitted from infected animals including sheep, goats, cattle, pigs, buffaloes, or other wild animals to humans by direct or indirect contact with said animals and their by-products (Boron *et al*., 2002).

Bacilus anthracis exists in two forms, vegetative cells (inside the host) and spores for persistence in the soil or environment (Santelli *et al.*, 2004). Anthrax spores can be found naturally in soil and commonly affects domestic and wild animals around the world. It occurs in all food animals (cattle, sheep, goats) and horses which are susceptible to the organism. Pigs are more resistant than sheep and horses, where as dogs and cats are relatively resistant and birds are highly resistant (Boron *et al*., 2002). With unvaccinated animals living in endemic regions, anthrax can be a serious disease. While the causative agent of anthrax can be found in many parts of the world, cases occur commonly only in specific geographic locations. Anthrax outbreaks often occur in localities which are known to have calcareous and alkaline soil, intermittent episodes of flooding, and a warm environment (Anna R. S. *et al*., 2010).

There are endemic areas with more frequent outbreaks while other areas are subject to intermittent outbreaks due to weather changes. This can in turn lead to anthrax spores, which were initially inactive in the soil to rise into the surface of the ground. This causes herbivores grazing in such areas to swallow the spores. The spores then germinate inside the animals and subsequently the disease manifests (OIE, 2008).

Anthrax can be present in several different clinical forms, depending on the host factors, strain-specific factors, and the route of infection. In herbivorous animals, anthrax usually occurs as an acute septicemia with a high fatality rate and is usually characterized by hemorrhagic lymphadenitis. In horses, pigs, dogs and humans, it is often less acute although still potentially fatal (Fukao, T, 2004). On the basis of route of infection, there are three clinical forms of anthrax such as cutaneous (skin), gastrointestinal (ingestion) and pulmonary through inhalation of spores (Goossens P. L, 2009).

Humans usually acquire the disease after close contact or proximity with infected animals or their tissues (Dixon T. C. *et al*., 1999). Anthrax is an occupational disease that can be found among hide/skin handlers, veterinarians, agricultural workers, and handlers of wool and bone products. In most situations, human anthrax cases occur only occasionally and intermittently.

In Kenya, sporadic cases of anthrax are reported from all parts of the country, although most cases are reported in the former Rift Valley Province and some central counties (Diesfeld H. J. *et al.*, 1978). When anthrax cases occur, they are usually associated with human deaths as a result of eating uninspected meat.

1.2 Problem Statement and Justification

The main constraints hindering the productivity of the livestock sector in most sub-Saharan countries are diseases, poor nutrition, poor breeding policies, and management. Anthrax is among the most common diseases in sub-Saharan countries (Lughano K and Dominic K, 1996). While anthrax is peracute, contagious and a highly infectious disease in both humans and animals, it is one of the most neglected diseases in Africa. In many areas of Africa, anthrax is an endemic disease. In Kenya, there are reports of anthrax cases in different counties such as Nakuru, Wajir, Turkana, Marsabit, and Muranga. In northern Kenya, people practices pastoral way of living in which they move their animals in search of pasture and water. Due to this, there is inevitably frequent contact between wild animals and livestock.

In these areas, the ecology and distribution of *Bacillus anthracis* is poorly understood despite the continuous cases found in humans, livestock, and wildlife. Information remains scanty about the spatial distribution and the factors favouring the survival of the spores and the subsequent outbreaks. Unreliable reporting systems and poor diagnosis makes it challenging to estimate the true incidence of anthrax. The little information available is point prevalence in some wild animals, which cannot be used to predict the future occurrences of the disease.

It is therefore important to develop a risk mapping of anthrax and predict the future occurrence localities. Risk mapping of the disease might not be helpful alone. It is therefore paramount to assess the knowledge and practices of farmers regarding anthrax. The results from this study will help concerned authorities develop outbreak responses and control strategies. Maps generated will also be used to guide risk-based anthrax surveillance strategies in both livestock and wild animals.

1.3 Study hypothesis

i. There are no mapped spatial distributions of anthrax hotspots in Wajir, Isiolo and Marsabit counties, Kenya.

ii. There are no factors which perpetuate the occurrence of anthrax outbreaks in the three counties.

iii. Knowledge, attitude and practices on anthrax in these areas is highly variable Objectives

1.4.1 General Objective

To determine the spatial distribution of anthrax and assess the knowledge, attitude and practices of pastoralists to anthrax in Wajir, Isiolo and Marsabit Counties, Kenya.

1.4.2 Specific Objectives

i. To map the spatial distribution of anthrax hotspots in Wajir, Isiolo and Marsabit counties, Kenya.

ii. To identify ecological factors that influence the occurrence of anthrax in the three counties.

iii. To assess the knowledge, attitude and practices of the disease by pastoralists in the three counties.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Anthrax is an acute infectious disease that is caused by *B. anthracis*, which is a gram-positive, rod shaped, spore forming bacillus. World Health Organization reports have asserted that the spores of *B. anthracis* can exist and remain in certain soils for a range of about 30 to 90 years. The disease makes way into the body through skin abrasions and ingestion. However, if the soil is found to be dry enough, the disease may be contracted through inhalation and subsequently multiplies to produce exotoxins. Anthrax is a disease that can be found in herbivorous mammalians, and therefore, may also occasionally affect humans (WHO, 2006).

2.2 The disease and causative Agent

Anthrax is characterized by septicemia, enlargement of the spleen (splenomegaly) and infiltration of subcutaneous and subserosal tissues by a gelatinous material (Lughano K and Dominic K, 1996). The causative organism *B. anthracis* is a gram-positive, non-motile, and non-haemolytic spore forming rod (Figure 2.1). The virulence of *B. anthracis* is determined by the capsule, as well as by the exotoxins, oedema and lethal factor. Anthrax is caused by the polymer of amino-acid (D-glutamate). Unlike most of the other spore-forming bacteria, *B. anthracis* has a polysaccharide capsule which influences the shape of the bacterium. It forms one of the principal virulence factors of the bacteria and is used to inhibit host defense systems (Shafazand *et al*., 2001).

A large factor contributing to *B. anthracis'* virulence is a capsule that enhances the bacteria's ability to evade host defenses, as well as induce septicemia (Mock M *et al*., 2001) The capsule is charged negatively, thus it restricts the macrophages from surrounding and killing the *B. anthracis*

(Spencer R. C, 2003).

The vegetative *Bacillus anthracis* cells contain an extensive peptidoglycan s-layer protein. These polysaccharides function in anchoring the protective s-layer to the bacterium cell wall (Carter G.R *et al*., 2004). Figure 2.1 shows the microscopic appearance of *B. anthracis.*

Anthrax can be used as an instrument of biological warfare because:

(i) This organism is extremely deadly, particularly when transmitted through inhalation

(ii) Anthrax spores can live and be utilized for up to 90 years, and it is easily produced in large amounts for relatively reduced costs.

(iii) It is not complicated to make this substance ready to use as a weapon and administer, this can affect thousands of people at the same time.

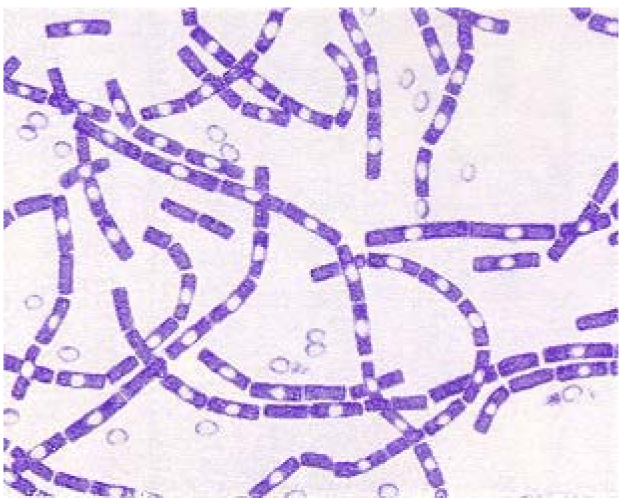

Figure 2.1: Microscopic appearance of *Bacillus anthracis* in gram stain

Source (http://textbookofbacteriology.net/Anthrax.html)

2.3 Virulence Factors

The ability of *Bacillus anthracis* to cause disease depends on two important virulence factors.

2.3.1 The anthrax toxin

The anthrax toxin is encoded by plasmid pXO1 (184.5 kilobase pairs [kbp]) and composed of three proteins namely edema factor (EF) which is a calmodulin-dependent adenylate cyclase (Leppla SH, 1982), lethal factor (LF) which is a zinc metalloprotease (Klimpel *et al*., 1994) that inactivates mitogen-activated protein kinase *In vitro* (Duesberry *et al*., 1998), and protective antigen (PA) which acts as the receptor-binding component mediating entry of either EF or LF into target cells (Leppla, 1984). The three components of anthrax toxins act in binary combinations to produce two distinct reactions in experimental animals (Moayeri M and Leppla SH, 2011). Co-injection of PA and EF (a combination termed "edema toxin") intradermally produces edema, while co-injection of PA and LF causes death in susceptible animals. However, none of the three individual proteins is toxic to animals. The anthrax toxin is thought to hinder the immune response mounted by the host against the infection.

2.3.2 Anthrax capsule

The capsule is encoded by plasmid pXO2 (95.3 kbp), a poly-D-glutamic polymer that interferes with phagocytosis. The infection starts when the endospores of *Bacillus anthracis* penetrate the body via lesions, ingestion, or inhalation. They are then phagocytosed by macrophages and transferred to the regional lymph nodes. Inside the macrophages, they germinate and become vegetative bacteria (Ross, 1957) that are then released from macrophages and reach the blood stream, after multiplying in the lymphatic system, causing massive septicemia. Both virulence factors are expressed by the organism in this process and the derivative toxemia has a methodical effect that results in the death of the host (Dixon T. C. *et al*., 1999).

2.3 Geographical distribution

Anthrax is thought to have originated from sub-Saharan Africa and has a worldwide distribution, although the area prevalence varies with the soil, climate and the efforts put in for control. *Bacilus anthracis* lives in soils worldwide but they are isolated from a certain environments (Slonczewski *et al*., 2010). While anthrax is a disease known to be occur universally, it's likelihood of manifestation is in drier agricultural regions such as South and Central America, Asia, Africa, Southern and Eastern Europe, the Caribbean, and the Middle East. However, it is riskier in countries that do not employ standardized public health programs for measures (WHO, 2006)

2.4 Zoonotic risk

According to OIE (2008), anthrax is a zoonotic disease which is transmitted between animals and humans. Over 95% of woolsorters disease cases are of the cutaneous form, which is generally an outcome of not handling infected animal by-products such as hides, hair, carcasses, meat or bones properly. It is crucial that veterinarians and other animal handlers wear protective gears when dealing with animals or specimens from suspected anthrax cases. The OIE suggests that animal handlers should not touch their body or face after handling suspected animals or products. Eating infected meat may result in the gastrointestinal form of anthrax.

2.5 Transmission of the disease

The bacteria enter into the body by ingestion, inhalation or through the skin via abrasions. The distribution of this organism within a given area may be transmitted through living and non-living carriers such as dogs, insects, water, wild birds, fecal contamination from infected animals, and other carnivores (Radostitis O.M. *et al*., 2007). The introduction of anthrax into a clean area occurs via contaminated animal products, for example: fertilizers, bone meal, wool, and hides. Although infection through inhalation is considered relatively insignificant, it is still essential to monitor and recognize the possibility of animal's inhalation of contaminated dust. Wool sorters disease in humans results most commonly when workers in the wool and hair industries inhale the spores, yet still—within these industries, cutaneous anthrax is more common (Radostitis O.M. *et al*., 2007). Typically, animals contract the disease through the consumption of contaminated soils or feeds. These poisoned animals then disgorge the bacilli during the terminal hemorrhage stage through all their body orifices. Once exposed to the air, the vegetative forms sporulate. The spores that are thus formed are resistant to numerous disinfectants and conflicting environmental conditions and can stay within the contaminated soil for many years.

Anthrax is a seasonal disease and climate can play a direct or indirect role in the way in which the animal gets into contact with anthrax. For instance, an animal may graze nearer to the soil in drier seasons when the grass is sparse and shorter. Figure 2.2 shows the infection cycle of anthrax in animals.

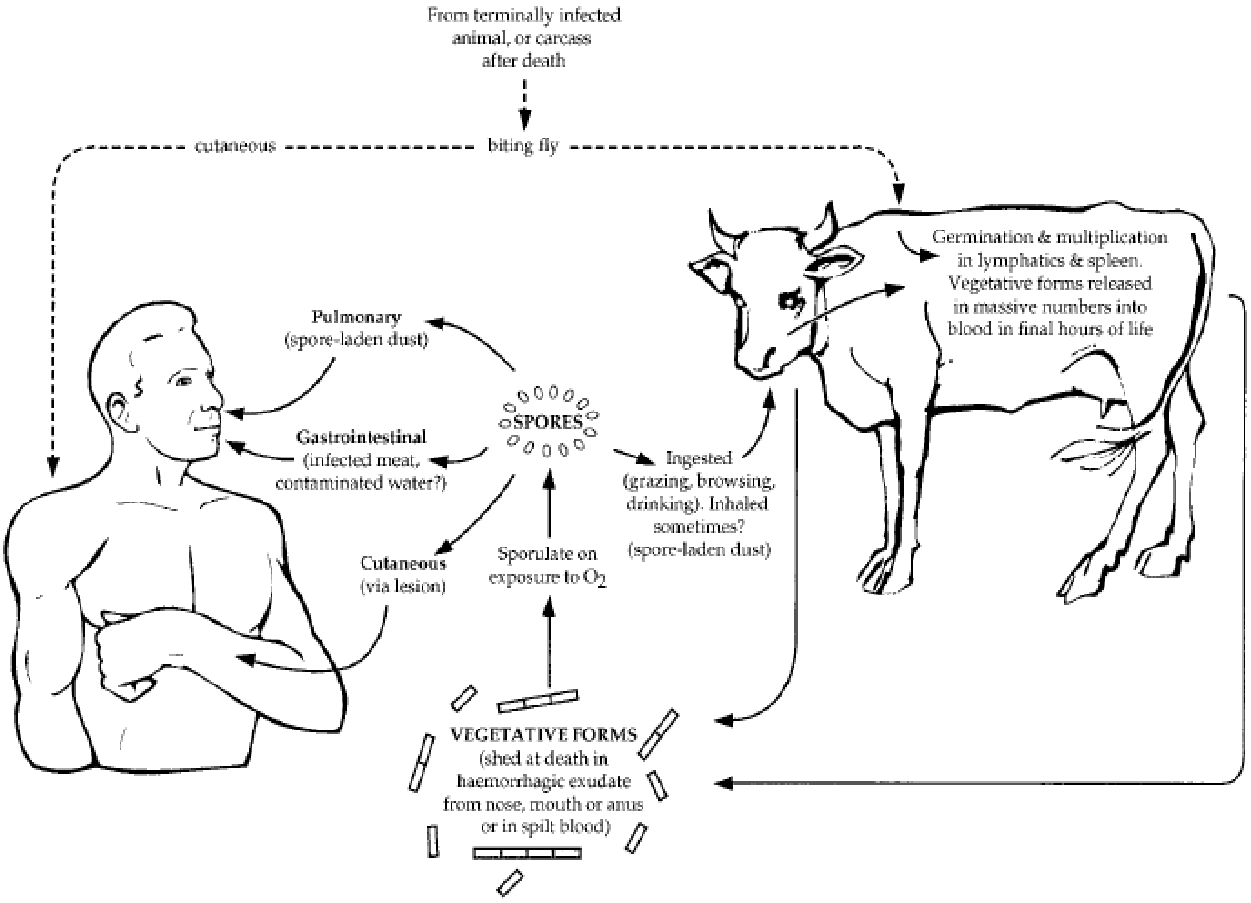

Figure 2.2- Cycle of anthrax infection in livestock

Source: (WHO, 2008)

2.6 Pathogenesis of the disease

In the development of this disease, *B. anthracis* gains entry through a lesion in the skin, or it wriggles its way into the pulmonary system via inhalation and/or ingestion. Subsequently, the spores begin formation and transmission thus follows into the lymphatic system, where these spores then initiate the multiplying phase. The bacteria are then sifted out by the host's spleen during the incubation period. Next, the system rapidly wears down, where there is a sudden loss of ability for the host to function efficiently. This is found to be due to the toxin action during the last few hours of life. Action of a toxin breaks the endothelial cell lining of the blood vessels, resulting in internal bleeding (Dixon T. C. *et al*., 1999). The anthrax toxin is thought to be crucially involved in the two stages of infection. In the Initial stages of infection, the anthrax toxins aim at the immune system to ensure its survival in the host, as well as to facilitate dissemination. Tissues are targeted in the systemic disease and as a result, induces lethality (Mahtab M. *et al*., 2015).

When the spores are ingested, infection is found in the mucus membrane through the breaking of the epithelial tissues, eruption of the hosts enamel, or the scratches from tough fibrous foods. The organisms are resistant to phagocytosis, which may—in part—be due to the existence of the body-D-glutamic acid capsule, and further multiply in regional draining lymph nodes, which then makes its way through the lymphatic vessels into the blood stream; This is followed by septicemia with an overwhelming invasion of all body tissues. *B. anthracis* produces a lethal toxin that causes edema and tissue damage. Death results from shock and acute renal failure and terminal anoxia (Slonczewski *et al*., 2010). In pigs, localization is restricted to the lymph nodes of the throat ensuing only after the attack of the upper part of the digestive tract. Such systems often result to fatal septicemia (Radostits *et al*., 2007).

2.7 Clinical Manifestations of the disease

2.7.1 Symptoms of anthrax in animals as described by (WHO, 2006) includes:

i. In ruminants, the following symptoms suggest anthrax. They include short periods of fever and disorientation, bleeding from any and all openings of the animal, subcutaneous hemorrhages, and/or sudden death.

ii. In pigs like carnivores and primates, the clinical manifestation is confined to the neck, where there is a swelling of the lymph nodes, face, and neck (local oedema), specifically, mandibular and pharyngeal and/or mesenteric. The incubation period ranges from 36 to 72 hours.

Initial indications pointing to an anthrax epidemic is if there is one or more sudden deaths found in the livestock. Additional red flags involve affected animals resisting food, and milk production lessening. Symptomatic of the systemic phase, animals begin to have trouble breathing, refrain from eating and drinking, and become distressed. Furthermore, swelling begins to form in the submandibular fossa, and temperature also increases. On the condition that the animal’s body rejects the treatment (does not respond), it will subsequently fall into a coma. Once the animal wakes up, it is typical that it dies due to shock.

2.7.2 Symptoms of anthrax in humans

According to the University of Pittsburgh Medical Center (UPMC) Center for Health Security (2014) there are 4 forms of naturally occurring human anthrax infection (Table 2.1):

i. When spores invade the body through cuts or lesions in the skin, it is termed cutaneous anthrax. A characteristic of this type of infection is, at the source of the abrasion the individual often discovers a sore that advances into a painless ulcer that is roofed by a black scab. This form of anthrax accounts for roughly 95% of reported human anthrax cases. Significantly, cutaneous anthrax does not only occur through breaks in the skin, it can also manifest as a result of an aerosol attack.

ii. Consumption of meat contaminated with *B. anthracis* results in gastro-Intestinal (GI) anthrax. Since consumption begins at the oral cavity, the mouth, throat and intestinal tract may be infected. The GI anthrax is believed to manifest due to vegetative bacteria instead of spores, which shows that GI anthrax is not expected to occur from being exposed to aerosolized spores.

iii. Inhalational anthrax is the effect brought about after breathing in *B. anthracis* spores into the lungs. It is the most lethal form

iv. The fourth and final form of this disease is injection related anthrax. As a recent occurrence, there have been several reported instances in Europe where intravenous drug users inject heroin that is infected with *B. anthracis* spores. It is the most lethal form of anthrax in man.

Table 2.1: Types of anthrax in human

Anthrax Infection	Incubation Period	Signs and Symptoms	Lethality
Inhalational	Ranges from as little as 2 days following exposure to spores to as long as 6 to 8 weeks after exposure	Initial symptoms are fever, headache, and muscle aches. If untreated, the disease progresses to shortness of breath, chest discomfort, shock, and death. Meningitis may complicate the clinical course. Chest imaging reveals widening of the mediastinum, enlargement of and bleeding into lymph nodes, and bloody fluid collections around the lungs.	Historical data suggest that the case fatality rate of untreated inhalational anthrax may be as high as 90%. With appropriate treatment, a fatality rate of approximately 50% or less may be expected.
Cutaneous	Range of 1 to 12 days following exposure; incubation period is typically closer to 1 day	The first symptom is a small sore at the point of infection that develops into a blister and later into a painless ulcer covered by a black scab. Often there is marked swelling around the ulcer.	Approximately 20% of persons with cutaneous anthrax may die if not treated with appropriate antibiotics. With appropriate antibiotic treatment, the death rate is approximately 1%.
Gastrointestinal	Typically 1 to 6 days following exposure	Oropharyngeal: Symptoms are fever, ulcers in the back of the mouth and throat, severe sore throat, difficulty swallowing, and lymph node and neck swelling. Intestinal: Initial symptoms are nausea and vomiting. The disease may progress rapidly to bloody diarrhea, abdominal pain, and shock.	Without antibiotic treatment, gastrointestinal anthrax results in the death of more than 40% of affected persons.[10]
Injection related	1-2 days after injection	Inflammation or abscess at the injection site sometimes progressing to cellulitis or necrotizing fasciitis. Some patients progress to sepsis without extensive local infection.	Of reported cases, 30% of patients died despite aggressive medical therapy.

Source: (UPMC Center for Health Security, 2014)

2.8 Differential diagnosis of anthrax in animals

In cattle and sheep the differential diagnoses are:

i. Clostridial infections, bloat, lightning strike, acute leptospirosis, bacillary hemoglobinuria, anaplasmosis, acute poisonings by bracken fern or sweet clover (Goodman D.E., 2001).

In horses:

ii. Acute equine infectious anemia, purpura hemorrhagica, colic, lead poisoning, lightning strike, sunstroke (Georgia department of public health, 2008).

In swine:

iii. Acute hog cholera, african swine fever, pharyngeal malignant edema

2.9 Reservoir/Host Species

Domestic animals including cattle, sheep, goats, horses, donkeys, swine, and dogs, wild herbivores, wild carnivores (Georgia department of public health, 2008).

2.10 Ecology of anthrax

According to Iowa State University Center for Food Security and Public Health (2007), *B. anthracis* has been considered an "obligate pathogen". While most members of the *Bacillus* genus are saprophytes, *B. anthracis* is believed to multiply internally within the host. In the external environment, they merely survive as latent spores. If the aforementioned is found to be true, then spores derived from the dead remains of animals can be the only cause of exposure for animals. There is a possibility that rain, carnivores, and other agents can further scatter and spread the disease to new regions. Between heavy rainfall and arid seasons the spores may intensify, resulting in outbreaks that may in turn erupt among grazing animals. Incubator hypothesis proposes that anthrax spores may only germinate and divide in the environment to a certain degree, if and only if certain conditions are met. It is believed that this boosts the army of *B. anthracis* in incubator areas where anthrax disruptions then occur. As disputed as the incubator hypothesis may be, what was factual was that the *B. anthracis* spores have recently demonstrated germination on top of, and surrounding the roots of grass in a simple plant system.

Plasmid transfer between *B. anthracis* isolates was also described in this system (Iowa State University Center for Food security and Public Health, 2007).

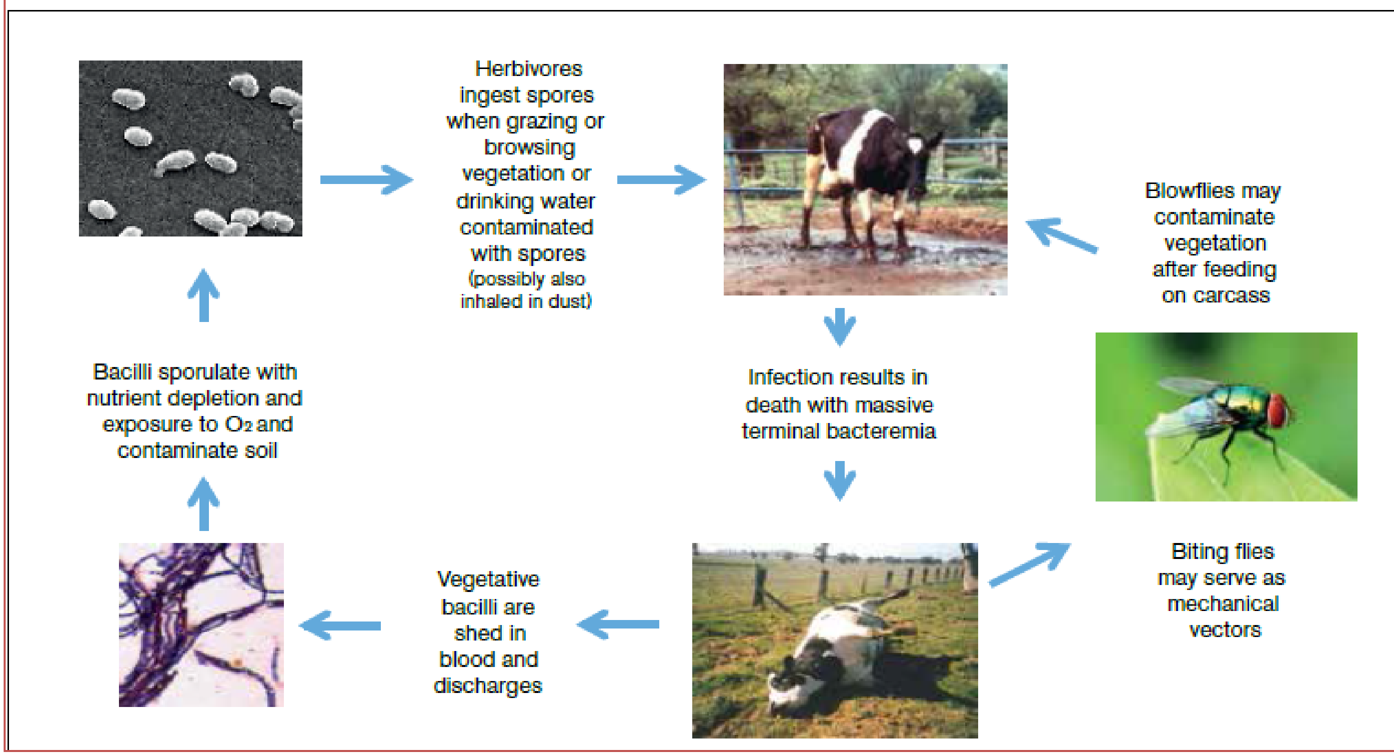

Figure 2.3: Ecology of anthrax (Sean Sh. *et al*., 2016)

2.11 Diagnosis of the disease

Rapid pre-symptomatic diagnosis of *B. 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 (Ayamdooh, E. N, 2016). The following are some of the diagnostic tests.

2.11.1 Ascoli Test

Ascoli (1911) developed a test for the detection of thermostable anthrax antigen in animal tissue being used for byproducts. This uses antiserum raised in rabbits to produce a precipitin reaction. The test lacks specificity in that the thermostable antigens of *B. anthracis* are shared by other *Bacillus spp*., and is dependent on the probability that only *B. anthracis* would proliferate throughout the animal and deposit sufficient antigens to give a positive reaction.

2.11.2 Direct Microscopy

Bacillus anthracis produces a capsule in vivo and either giemsa or polychrome methylene blue stains are used to demonstrate the capsule which is of diagnostic importance. The capsule material is more abundant if the blood smear has been taken from recently dead animals. Polychrome methylene blue stained smears reveal square ended, blue rods in short chains surrounded by pink capsular materials. In case of giemsa stained smears, the capsule is reddish (Quinn P.J. *et al*., 2003).

2.11.3 Serology

Anthrax diagnosis with enzyme-linked immunosorbent assay (ELISA) in animals that have survived infection is possible. However specific antigen for this test is expensive and the test is more a research tool than of practical day-to-day value in the field (WHO, 2008).

2.12 Treatment of the disease in animals

Bacillus anthracis are susceptible to penicillin, chloramphenicol, streptomycin, tetracycline and erythromycin. Treatment should continue in humans for at least five days (Hirsh D.C *et al*.,, 1999). However, in acute anthrax, antimicrobial treatment is often useless. Treating animals with antibiotics twenty-four hours post infection proved to protect the animals, however, ending treatment resulted in the animals death. In conjunction with antibiotics, employment of a protective antigen vaccine resulted in complete protection even post-treatment. Levy H. *et al.,* (2011) explain that if an animal's treatment was put off to later than twenty-four hours after infection, they would then develop varying levels of bacteremia and toxemia.

2.13 Prevention and Control

In Kenya, anthrax is a notifiable disease. Of primary importance is that the local animal health authorities be contacted and informed for supervision and control measures to be taken. There are specific rules and regulations to be adhered to for any case of anthrax. For instance, in the case of the disposal of an infected carcass, incineration or deep burial is a necessary precaution and measure. For animal survivors, isolation and treatment is imperative in the control of further outbreaks. Vaccination of susceptible animals and a quarantine of the infected location for approximately three weeks following the last discovered cases ensure that the infection does not spread. Needless to say, milk produced from animals who are afflicted with the disease must be disposed off properly under proper health regulation guides. Utilization of 10% sodium hydroxide to disinfect burns and fences is also a very crucial and mandatory preventive measure. To sterilize utensils, boil them for at least 30 minutes. This way the spores will die. As for surface spores, use 3% acetic acid solution at a rate of eight liters per square meter (Hirsh D. C *et al*., 1999).

Vaccination has great value in the control of the disease. While the vaccine is a great measure and sufficient as a protectant, it can—on occasion—provoke severe side effects/reactions. A new vaccine extracted from a virulent strain of *Bacillus anthracis* has been prepared. This inoculant provides immunity to the animal for only up to one year. However the vaccines prepared from non-living capsular antigens do not give adequate immunity (Sharma S. N and Adlakha S.C., 2008).

In the case of a disease outbreak, the farm in question should be placed under quarantine so as not to further disperse the infection. Vaccination of animals in the vicinity, and the proper removal of carcasses and discharge are part and parcel of the animal disease control program, which greatly diminishes the likelihood of further human exposure. The delivering of meat and milk from the farm under quarantine is strictly banned in such circumstances, as a preemptive measure to ensure there is absolutely no entry into the human food chain. Discontinuation of infection sources is a vital start in the cycle of infection. Relocating unaffected animals to another area that is free from infection is also a crucial step in curbing the disease from further outbreak. On the condition that flies are an issue, also consider fly control options. Prevention of *B. anthracis* exposure through imported animal products demands that such material be disinfected with formaldehyde. It is also necessary to sterilize bioendemic meals. This can be done by using dry heat (150°c per 3 hours), or steam (115°c for 15 minutes) (Hirsh D. C. *et al*., 1999).

2.14 Prioritization of zoonotic diseases in Kenya

Sporadic cases and outbreaks in wildlife were reported in many areas (Table 2.2) and diverse species are involved. Outbreaks were reported in Nakuru National Park with large mortalities of buffalo, rhino, antelopes in 2016. Other major outbreaks, 2006 – Grevy's zebra, 2010 – hippos, 2011- Rothschild giraffes, Turkana, Marsabit, and Muranga (Munyua *et al.*, 2015).

Table 2.2: Prioritization of Zoonotic diseases in Kenya

Disease	Overall ranking by criteria					Normalized Final scores
	Severity of illness	Epidemic potential	Socio-economic impact	Prevalence of disease in humans or animals	Available Intervention	
Anthrax	5	2	1	4	1	1
Trypanosomiasis	1	4	1	9	3	0.94
Rabies	4	5	3	5	1	0.93
Brucellosis	9	4	1	1	2	0.89
Rift Valley fever	9	1	1	2	5	0.87
Echinococcosis (Hydatidosis)	7	7	6	3	3	0.73
Non Typhi Salmonellosis	12	2	6	7	1	0.7
Q fever*	11	6	5	1	4	0.69
Mycobacterium spps	7	6	2	8	7	0.67
Influenza and pandemics	8	8	2	9	6	0.64
Cysticercosis	12	8	4	5	3	0.62
Dengue	7	2	7	3	10	0.6
Leptospirosis	7	8	4	5	3	0.6
Schistosomiasis	11	8	9	3	3	0.58
Yellow fever	6	10	5	11	5	0.54
Rickettsiosis	10	8	10	6	3	0.52
Taeniosis*	14	9	7	5	3	0.51
Sarcopsis*	14	11	5	7	3	0.5
Cryptosporidiosis	13	9	8	4	4	0.49
Leishmaniasis	7	8	9	10	6	0.49
Ebola	2	14	4	13	9	0.48
Marburg	3	14	5	13	10	0.42
Crimean-Congo hemorrhagic fever	5	11	6	9	10	0.42
Antimicrobial resistance*	14	3	7	9	8	0.42
Dermatophylosis	14	12	9	9	3	0.36
Cryptococcosis	12	12	10	9	4	0.36
Listeriosis	12	14	5	12	5	0.35
Aspergillosis	12	13	9	11	5	0.34
MERS-CoV*	14	16	6	8	10	0.34
Plague	14	15	9	13	6	0.32
Chikungunya*	10	9	9	8	10	0.31
West Nile Virus	10	12	9	10	10	0.24
Histoplasmosis*	13	15	10	13	5	0.22
Diphyllobothriosis	14	17	9	13	4	0.19
Hanta virus fever*	8	17	8	13	10	0.17
Lassa fever*	9	17	9	13	10	0.13

Source: (Munyua *et a*l., 2015)

Prioritization of these zoonotic diseases were based on the severity of illness, epidemic potential, socio-economic impact, prevalence of the disease in human or animals, interventions and consistency ratio.

2.15 Ecological Niche Modelling

Mapping the spatial distribution of anthrax was done using environmental niche modeling. Also known as species distribution modelling, (ecological) niche modelling, predictive habitat distribution modelling, and climate envelope modeling. It refers to the process of using computer algorithms to predict the distribution of species in geographic space on the basis of a mathematical representation of their known distribution in environmental space (realized ecological niche). The environment is in most cases represented by climate data (such as temperature, and precipitation), but other variables such as soil type, water depth, and land cover can also be used. These models allow for interpolating between a limited number of species occurrence and they are used in several research areas in conservation biology, ecology and evolution.

According to Robert J. Hijmans and Jane Elith (2017) the following steps are usually taken during this modelling:

i. Locations of occurrence of a species (or other phenomenon) are compiled;

ii. Value of environmental predictor variables (such as climate) at these locations are extracted from spatial databases;

iii. The environmental values are used to fit a model to estimate similarity to the sites of occurrence, or another measure such as abundance of the species;

iv. The model is used to predict the variable of interest across the region of interest (and perhaps for a future or past climate).

The workflow of this model uses occurrence and environmental data to model ecological niches. It combines species occurrence data with environmental datasets in the form of georeferenced raster layers (such as temperature, precipitation, salinity) to generate potential distribution models (Blackburn J. K. *et al.,* 2007).

2.16 Ecological data of the model

The ecological data used in mapping are usually free and available from GIS databases. Bioclimatic variables are derived from the monthly temperature and rainfall values in order to generate more biologically meaningful variables. These are often used in ecological niche modeling (e.g., BIOCLIM, GARP). The bioclimatic variables represent annual trends (e.g., mean annual temperature, annual precipitation) seasonality (e.g., annual range in temperature and precipitation) and extreme or limiting environmental factors (e.g., temperature of the coldest and warmest month, and precipitation of the wet and dry quarters). A quarter is a period of three months (1/4 of the year).

(http://www.worldclim.org/bioclim)

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study area

This study was undertaken in Wajir, Marsabit and Isiolo counties of Kenya (Fig. 3.1). These counties are inhabited mostly by the Somali, Gabra, Boran, Rendille, Samburu, Turkana and Daasanach communities among others.

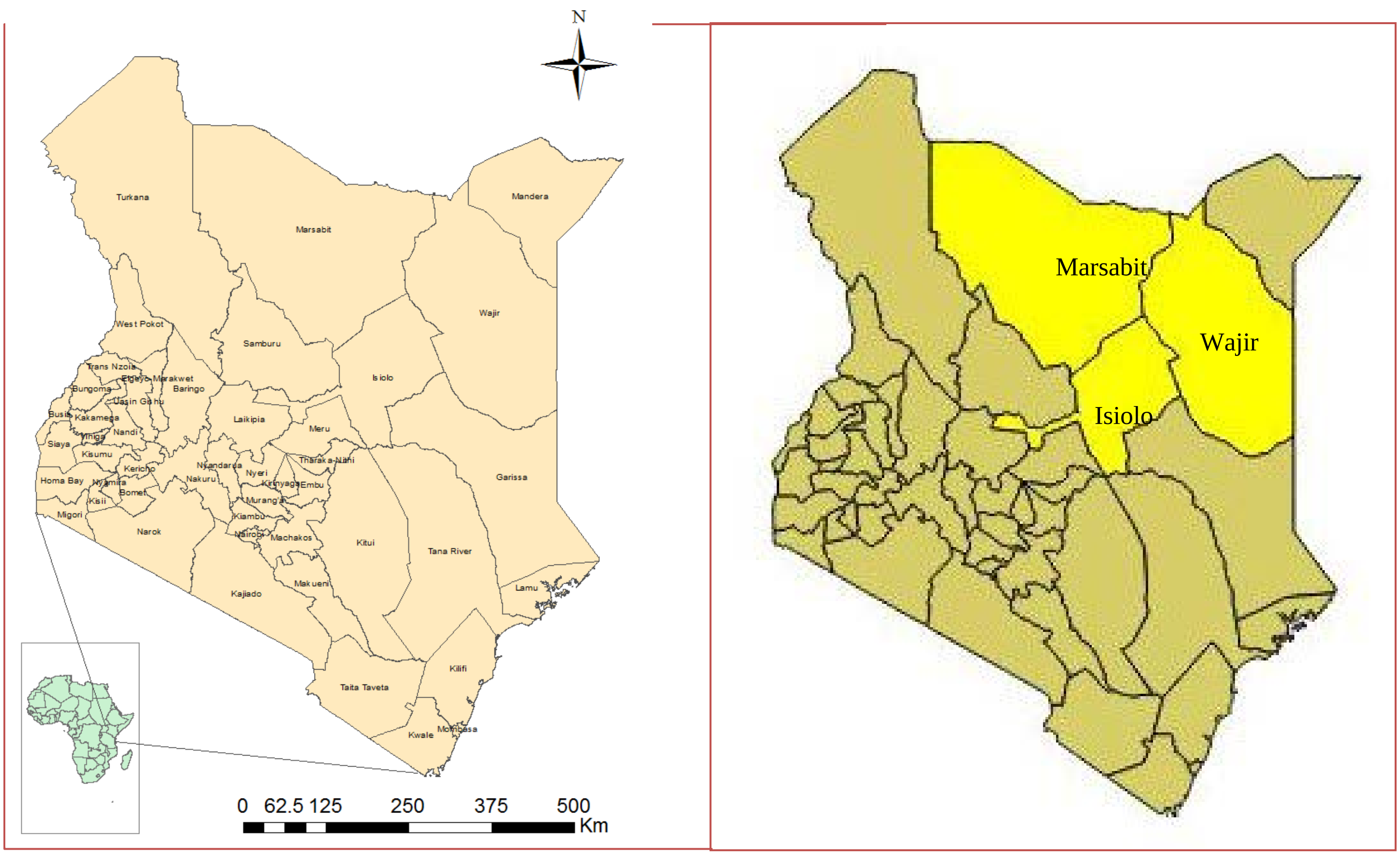

Figure 3.1: Map of Kenya showing the study counties

Kenya has a total area of 580,367 km^2 with a land cover of 569,140km^2; the rest is under water. It lies between latitudes 5°N and 5°S, and longitudes 34°E and 42°E and lies on the equator with the Indian Ocean to the south-east, Tanzania to the South, Uganda to the West, South Sudan to the North- west, Ethiopia to the North and Somalia to the North-East. The Country has 47 administrative regions known as counties. Kenya has seven agro-ecological zones as shown in Fig. 3.2. The three study counties fall under very arid and arid agro-ecological zones. The demographic characteristics of the counties are displayed in Table 3.1.

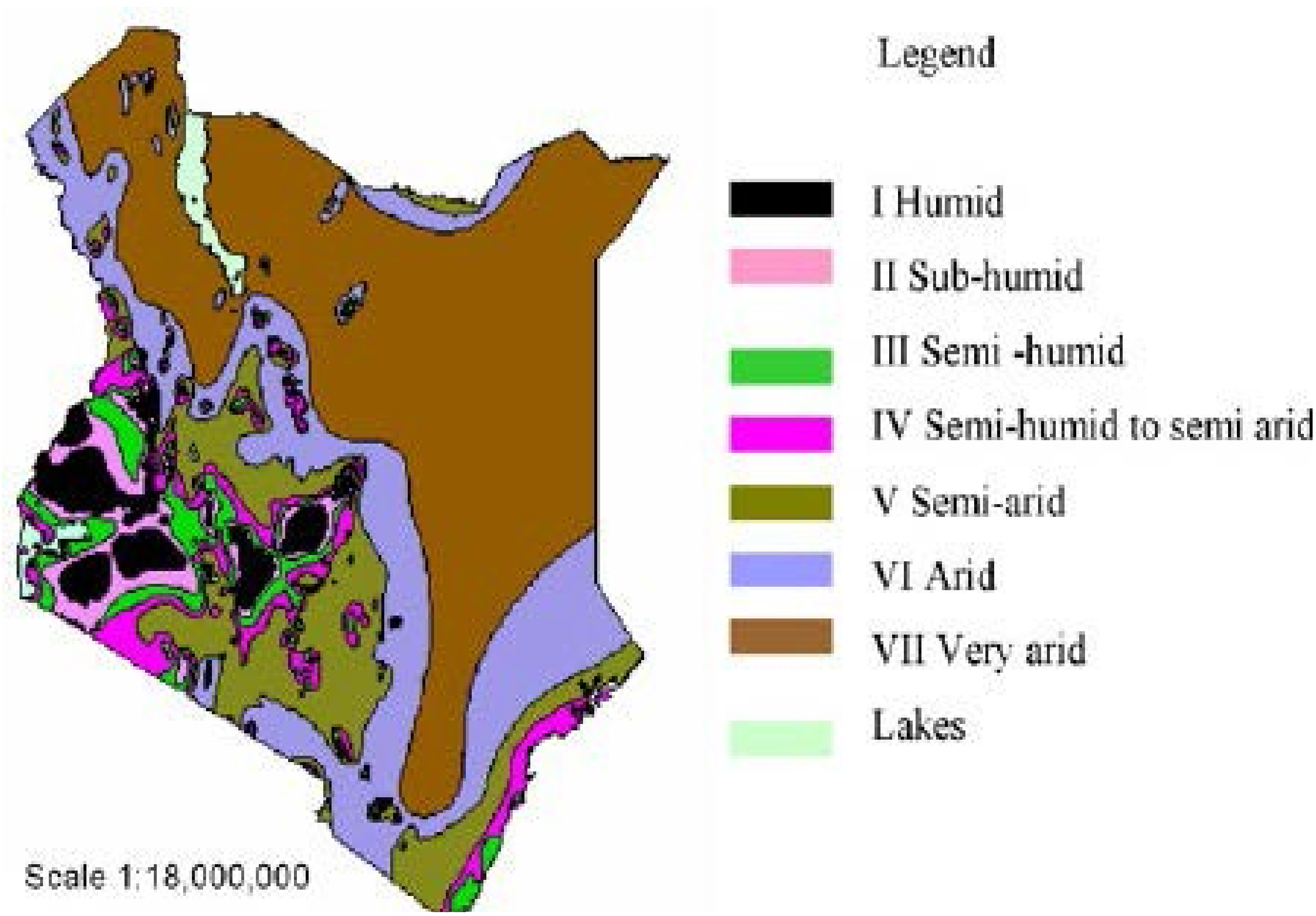

Figure 3.2: Agro-ecological zones of Kenya

Source (Kamoni P. T. *et al*., 2007)

Table 3.1: Demographic Characteristics of Marsabit, Isiolo and Wajir Counties of Kenya, 2017

Parameter	**Marsabit**	**Isiolo**	**Wajir**
Population	291,166	143,294	661,941
Surface area (km²)	70,961	25,336	56,686
Annual Rainfall(mm)	200mm - 1,000mm	400mm - 650mm	250mm - 300mm
Mean temperature	20.1^0C	29^0 C	36^0 C
Poverty rate (%)	83.2	71	84
Total no of Cattle	424,603	198424	794552
Total no of sheep	960,004	361836	1406883
Total no of goats	1,143,480	398903	1866226
Total no of Camel	203,320	39084	533651

Source: (Wajir County integrated Development plans, 2013)
(Isiolo Country Integrated Development Plan, 2013)
(Marsabit County Integrated Development Plan, 2013)

3.2 Study design

The study was a cross-sectional survey which was conducted between September 2016 and July 2017.

3.3 Sample size determination

1. County veterinary departments provided the confirmed areas where anthrax cases occurred in the past (hotspots). Local veterinary extension officers who knew the local languages and the locations were employed to assist in translating the questionnaires and identifying the areas named by the County Veterinary departments. All the reported anthrax hotspots were visited and their coordinates (latitude, longitude and altitude) recorded using a The Global Positioning System) hand receiver. A total of 53 hotspots were identified and recorded for anthrax mapping: 29 from Wajir, 13 from Marsabit and 11 from Isiolo County.

2. The sample size for assessing the Knowledge, Attitudes and Practices (KAPS) of anthrax was calculated using Yamane's (1967) formula with standard error of 5% and confidence interval of 95%. When there is a finite population and if the population size is known. In a finite population, when the original sample collected is more than 5% of the population size, the corrected sample size is determined by using the Yamane's formula.

$$n = \frac{N}{1 + Ne^2}$$

Where:

n is the sample size

N is the population size

e is the level of precision (or error limit)

The population of the three Counties was 1,096,401 people. The average household size of the study area was approximately seven individuals, so after dividing the population of the study area with seven, the total number of the households was 156,629. Inserting these parameters in the formula, the sample size was;

$$\frac{156,629}{1+(156,629*0.05^2)}$$

$$= 399$$

400 households

3.4 Data collection procedures

3.4.1 Data collection for mapping

All the areas where anthrax outbreaks had occurred before were visited and their coordinates were recorded using Garmin® Global Positioning System (GPS) hand receiver to obtain the GPS readings (Easting, Northing and Altitude) in Universal Transverse Mercator (UTM) units. A total number of 53 anthrax hotspots were recorded from Wajir, Isiolo and Marsabit counties of Kenya.

Environmental data were downloaded from online databases; Kenya county map, elevation and soil pH data was downloaded from ILRI GIS database. Slope data was downloaded from FAO soil data base (http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/). The 19 bioclimatic parameters were downloaded from world bioclim database and shown in Appendix 1.

3.4.2 Data collection for Knowledge, Attitude and Practices (KAPS) on anthrax

A total number of 400 questionnaires were administered to 400 farmers who dwell in the areas within which anthrax outbreaks were confirmed. Farmers were selected using systematic sampling with an interval of 5 households. The household head were selected for the questionnaires. Questionnaires were printed using english language (Appendix II), and were translated to the different local languages with the help of local veterinary extension officers. Information regarding demographic characteristics, knowledge about anthrax, symptoms of anthrax in livestock, symptoms of anthrax in human and sources of anthrax outbreaks was obtained. Information about attitudes and practices on anthrax, how they perceive anthrax, how to handle animals with anthrax, slaughtering of dead animals, slaughtering animals dead that died for anthrax, skinning of animals dead with anthrax, were collected.

3.5 Data analysis

3.5.1 Questionnaire data

The data collected in the questionnaire surveys was recorded and analyzed with STATA (Version 11). Descriptive statistics were generated and the results displayed in graphs and tables. The answers of the questions about knowledge and practices of anthrax were ordered as poor, moderate and good. The correct answer was coded as 1 and the wrong answer coded 0, it was then summed up. The total responses of anthrax knowledge were ordered as 0 to 2=poor, 3= medium, and 4 to 5= good knowledge. The total responses on anthrax practices were ordered as 0 to 2=poor, 3 to 4=medium, 5 to 6=good.

3.5.2 Ecological data

The spatial mapping was done using ecological niche modelling (ENM). This model establishes the risk mapping of anthrax. To obtain a crude risk map for anthrax in Wajir, Marsabit and Isiolo, an ecological niche model was fitted to the data collected from the three counties and ecological parameters mentioned in Section 3.4.1. The data collected from the three counties were 53 points and an optimal analysis of at least 40 points is required. Pseudo-absence data were obtained by generating random points across the county, with the County's shape file used to guide this process. The analysis was implemented in two successive stages. First, all the variables were fitted to the model. In the second stage, the most significant variables were used. Mapping of the anthrax spatial distribution was developed and the ecological parameters which affect anthrax occurrences were identified using QGIS software (V. 2.16) and R statistics

(V. 3.3.1).

Species distribution models require data on both species presence and the available environmental conditions (known as background or pseudo-absence data) in the area. However, there is still no consensus on how and where to sample these pseudo-absences and how many. The model randomly produce the pseudo-absence points. The output of the predicted map has a probability scale.

3.5.3 Model evaluation

The predictive accuracy of the model was estimated by plotting the area under the curve (AUC). The area under the curve ranges from 0 to 1 and is a measure of rank-correlation. In unbiased data, a high AUC indicates that sites with high predicted suitability values tend to be areas of known presence and locations with lower model prediction values tend to be areas where the species is not known to be present.

3.6 Ethical consideration

The study participants had voluntarily participated in this study for the purposes of collecting data and each of the respondents were required to sign a consent form (appendix 1II). The outcome of this research will be shared with the relevant authority as a document for diseases control, elimination and training the pastoralists.

CHAPTER FOUR: RESULTS

4.1 Demographic characteristics of the surveyed population

Almost two-thirds (67%; 266/400) of the surveyed population were males (Table 4.1). Majority of the study population were in age-group of 45-58 years indicating that livestock ownership was mostly by the aged. Education was very low with three quarters (75.3%) of the population having no formal education. Only 1.5% of the 400 of the surveyed population had University education (Table 4.1).

Table 4.1 Demographic characteristics of the surveyed population of Marsabit, Isiolo and Wajir Counties, Kenya, 2016-2017.

Variable	**Level**	**Number**	**Proportion (%)**
Sex	Male	266	66.5
	Female	134	33.5
Total		**400**	
Age-group (years)	18-30	75	19
	31-44	108	27
	45-58	111	28
	>58	106	26
Total		**400**	
Education	None	301	75.2
	Elementary	38	9.5
	Intermediate	31	7.8
	Secondary	24	6
	University	6	1.5
Total		**400**	

A variety of livestock species were found in the surveyed households including sheep, goats, cattle, Camels and chicken (Table 4.2). Goats, Sheep and Cattle were the most commonly kept species. Camel and donkeys were also popular but at lower frequencies. These latter species are very handy for ferrying household items when the pastoralists move to new areas in search of water and pasture for their livestock.

Table 4.2: Livestock ownership in the surveyed households, 2016-2017

County	Sheep	Goats	Cattle	Camel	Donkey	Chicken	Total
Wajir	144 (38%)	142 (37%	81 (32%)	74 (52%)	37 (25%	10 (17%	488
Isiolo	139 (36%	139 (36%	94 (37%	25 (18%	46 (32%	49 (80%	492
Marsabit	99 (26%)	102 (27%)	81 (32%)	42 (30%)	62 (43%)	2 (3%)	388
Total	**382**	**383**	**256**	**141**	**145**	**61**	**1368**

4.2 Knowledge on Anthrax

Anthrax was well known in the three counties considering the local names of the disease (Table 4.3). Most of the local names of the disease relate to the cutaneous form of anthrax. One ethnic group, the Gabra related anthrax to the soil (Table 4.3).

Table 4.3: Traditional names of anthrax

Ethnic	**Local names of anthrax**
Gabra	*Chilmale*, *Wuni Awara* (disease of the soil)
Somali	*Kud* (Cutaneous ulcers on the skin)
Daasanach	*Gamudich*
Boran	*Lockshum* (nodules on the skin)
Turkana	*Enomokore*
Samburu	*Lockshum* (Cutaneous ulcers on the skin)
Rendille	*Sugeri hara*

Table 4.4 summarizes the level of anthrax knowledge in Wajir, Marsabit and Isiolo. The percentage of good anthrax knowledge was 57.7% for Wajir, 69.8% for Marsabit and 46.9% for Isiolo.

Table 4.4: Level of anthrax knowledge in Wajir, Marsabit and Isiolo Counties

Level of anthrax knowledge	**Wajir**	**Marsabit**	**Isiolo**
Poor	15 (10.1%)	1(0.9%)	21(14.5%)
Moderate	48 (32.2%)	31(29.3%)	56(38.6%)
Good	86 (57.7%)	74(69.8%)	68(46.9%)
Total households	**149**	**106**	**145**

Pastoralists reported anthrax as a zoonotic disease together with rabies, brucellosis and Rift Valley Fever (Fig 4.1). This was an indication that pastoralists have a wealth of indigenous knowledge on livestock diseases.

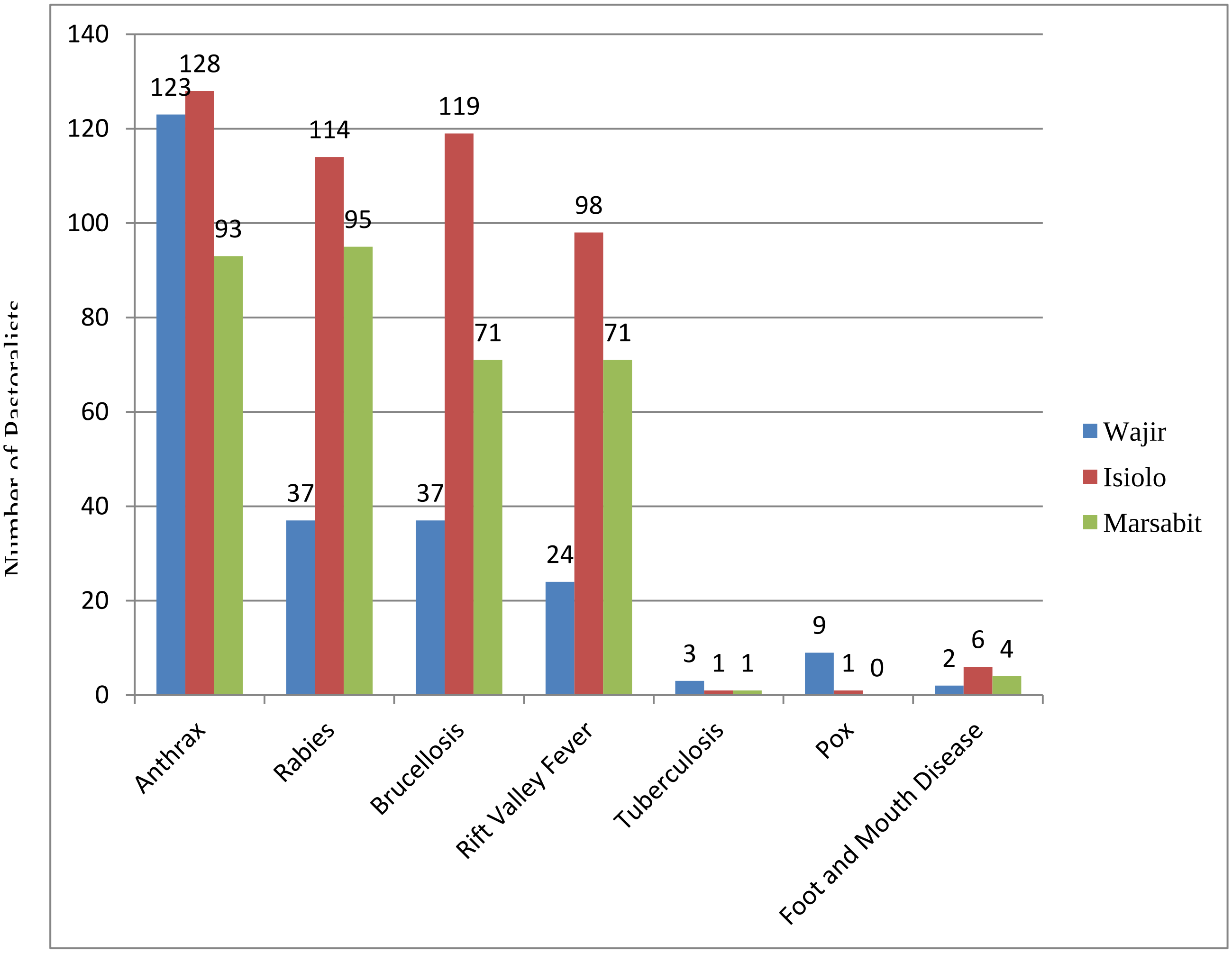

Figure 4.1: Diseases perceived as zoonosis by the surveyed households of Wajir, Isiolo and Marsabit.

As far as getting information on anthrax was concerned, the vast majority (78.5%; 314/400) of the respondents reportedly acquired that information from fellow pastoralists. Other Sources of information reported were veterinarians (15.3%; 61/400), medical doctors (1.5%; 6/400), electronic media (1.5%; 6/400), and other sources (3.2%; 13/400) as shown in Table 4.5.

Table 4.5: Sources of anthrax information by pastoralists of Wajir, Isiolo and Marsabit Counties

	Source of Information					
County	**Farmer**	**Vet officer**	**Medical doctor**	**Media**	**Others**	**Total**
Wajir	102 (69 %)	40 (27%)	2 (1%)	5 (3%)	0 (0%)	**149**
Isiolo	109 (75%)	19 (13%)	3 (2%)	1 (1%)	13(9)	**145**
Marsabit	103 (97%)	2 (2%)	1 (1%)	0 (0%)	0 (0%)	**106**
						400

Various signs of anthrax in livestock were reported by pastoralists from the three counties. These included sudden death, bleeding from natural orifices, and skin nodules (Fig 4.2). Sudden death was reported equally in the three counties while bleeding from orifices were reported by more pastoralists from Wajir and Marsabit Counties (Fig 4.2). Sudden death, skin nodules and bleeding from body orifices were reported as signs of anthrax in humans.

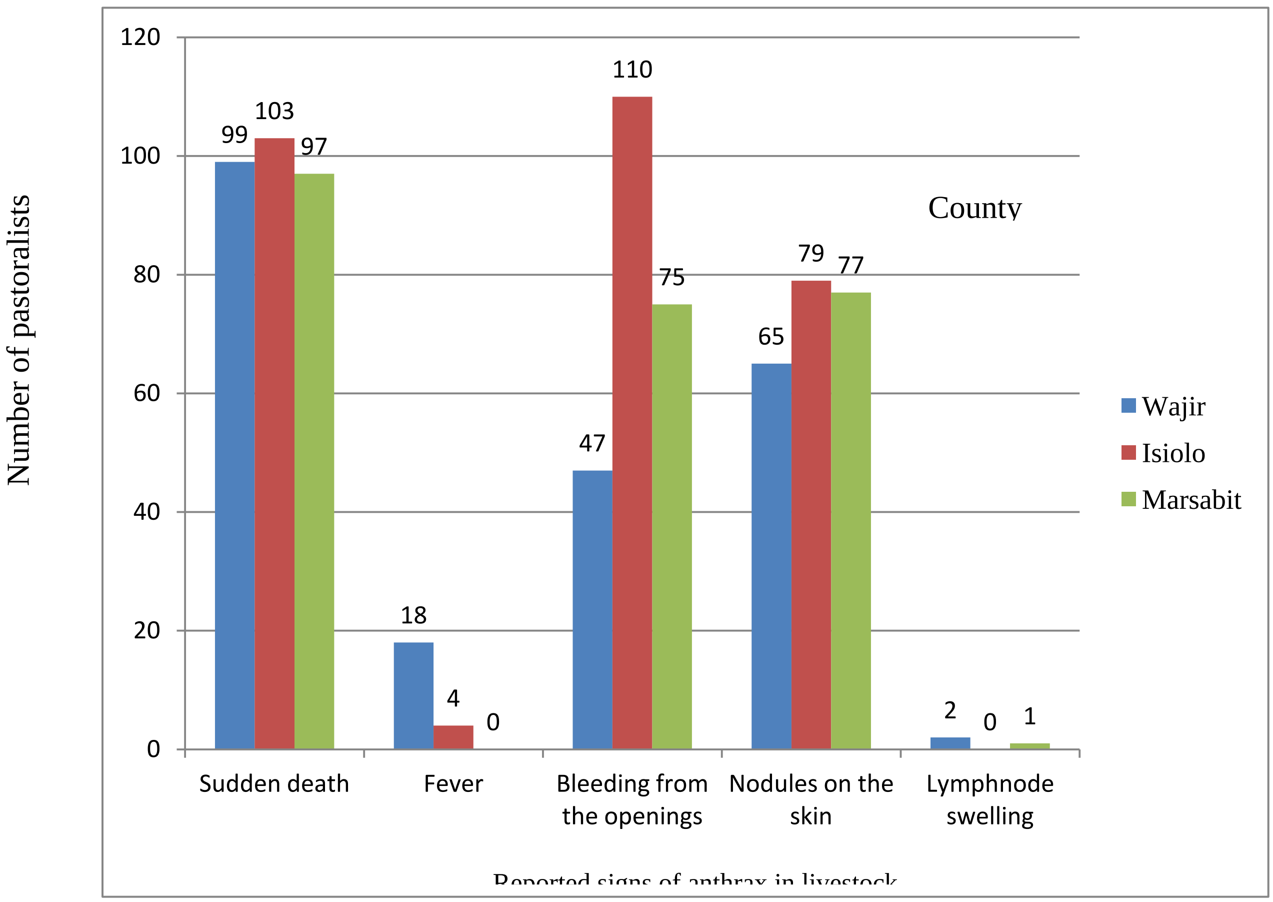

Figure 4.2: Reported signs of anthrax in livestock by surveyed pastoralists of Wajir, Isiolo and Marsabit Counties, Kenya.

The sources of anthrax infection reported included domestic and wild animals as well as the soil (Fig. 4.3). These were reported more by pastoralists from Marsabit than those from Isiolo and Wajir.

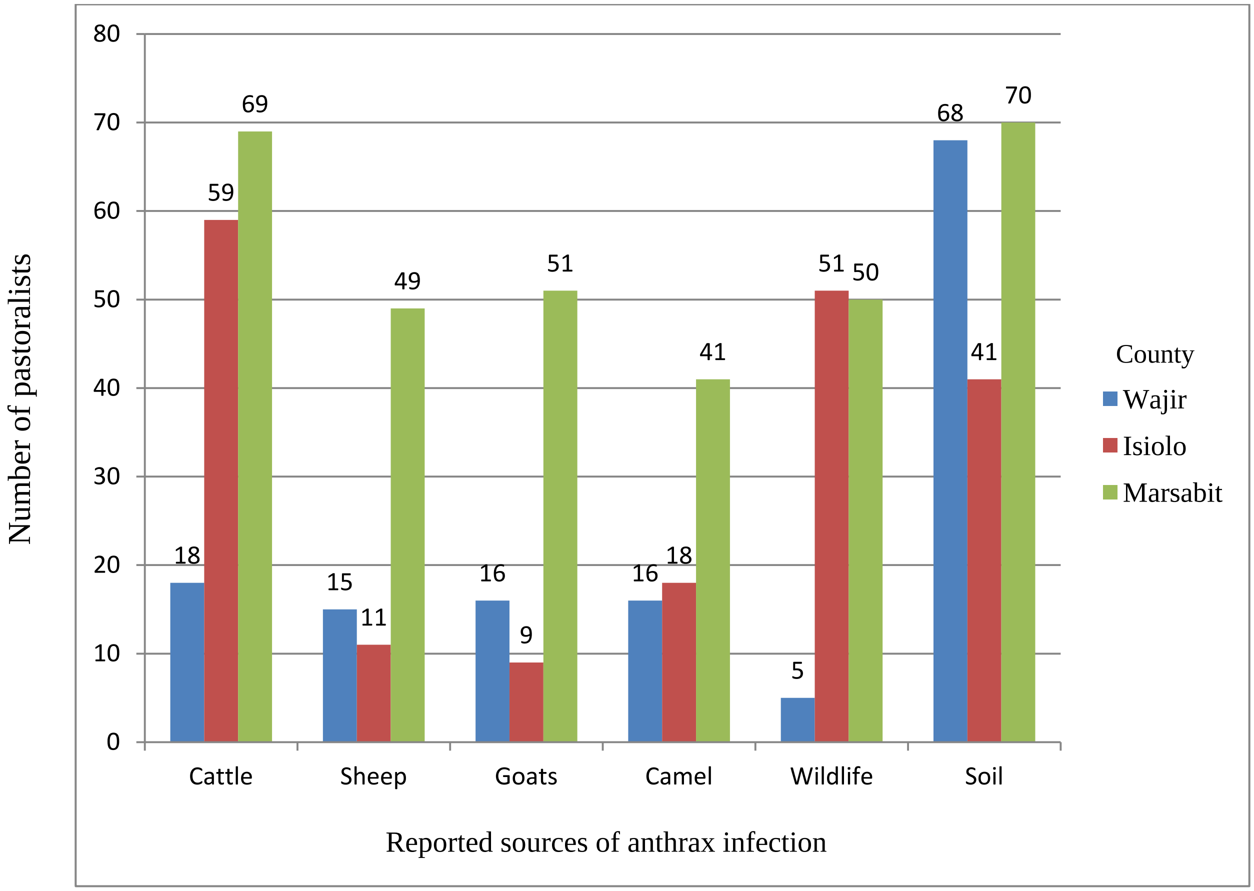

Figure 4.3: Reported sources of infection of anthrax by pastoralists of Isiolo, Wajir and Marsabit Counties, Kenya

Modes of anthrax transmission to human are displayed in Table 4.6. However, some of the transmission modes were reported at higher frequencies than others including consumption of infected animal products (320 respondents, 34%)), contact with infected livestock (199 responds, 21%) and handling infected carcasses (259 respondents, 28%) (Table 4.6). Infected aerosols, an important mode of transmission for pulmonary form of anthrax, was reported by 59 respondents (6%).

Table 4.6: Modes of anthrax transmission to humans reported by pastoralists from Marsabit, Wajir and Isiolo

	Modes of Transmission					
County	**Contact with infected livestock**	**Consumption of infected products**	**Contact with wild animals**	**Inhalation of infected aerosols**	**Handling of infected carcass**	**Skin of infected animals**
Wajir	24 (12%)	87 (27%)	4 (5%)	6 (10%)	81 (31%)	14 (78%)
Isiolo	95 (48%)	128 (40%)	26 (32%)	16 (27%)	80 ((31%)	0 (0%)
Marsabit	80 (40%)	105 (33%)	52 (63%)	37 (63%)	98 (38%)	4 (22%)
Total	**199**	**320**	**82**	**59**	**259**	**18**

4.3 Attitude of anthrax by the pastoralists

Wajir, Isiolo and Marsabit pastoralists had negative attitudes towards anthrax. They believed that anthrax was a very dangerous disease and affect both human and animals. Some of them believed that they should not talk about anthrax since this is a very serious disease. However, some pastoralists from Marsabit and Isiolo eat meat from animals that died of anthrax. They believed that cooking and throwing the intestines, soup and bones would protect them from getting anthrax infection.

Most farmers had negative attitude about anthrax vaccines. They believed that vaccines would not help their animals from the diseases but they later believed that anthrax vaccines reduced the occurrences of anthrax in Wajir, Isiolo and Marsabit Counties. Slightly over a third (34.5%) of the pastoralists reported that they self-treated their animals against anthrax while 7.3% choose the wait and see attitude (Table 4.7)

4.4 Practices of anthrax by pastoralists in Wajir, Isiolo and Marsabit Counties, Kenya

Of the 400 responds, 196 (49%) said they would report suspected cases of anthrax to the relevant veterinary authorities.

Table 4.7: Handling animals infected with anthrax

County	Treatment	Report to the relevant authority	Wait and see	Others	Total
Wajir	64 (46%)	67 (34%)	7 (24%)	11 (30%)	149
Isiolo	23 (17%)	95 (49%)	1 (4%)	26 (70%)	145
Marsabit	51 (37%)	34 (17%)	21 (72%)	0 (0%)	106
Total	**138**	**196**	**29**	**37**	**400**

On the handling of animal carcasses, respondents from Marsabit and Isiolo Counties said they would skin the dead animals, eat the carcass or eat the carcass known to have died from anthrax (Table 4.8). None of the respondents from Wajir County responded to have engaged in these dangerous practices.

Table 4.8: Practices of pastoralists on dead animals and those who died specifically of anthrax

County	**Skinning dead animals** n (%)		**Eating carcass from dead animal** n (%)		**Eating cadaver dead for anthrax** n (%)	
	Yes	No	Yes	No	Yes	No
Wajir	0 (0%)	149 (100%)	0 (0%)	149 (100%)	0 (0%)	149 (100%)
Isiolo	92 (63.4%)	53 (36.6%)	88 (60.7%)	57 (39.3%)	9 (6.2%)	136 (93.8%)
Marsabit	105 (99.1%)	1(0.9%)	105 (99.1%)	1 (0.9%)	73 (68.9%)	33 (31.1%)
Total	**400**		**400**		**400**	

Regarding the disposal of suspect anthrax cases, a variety of methods were reported including burning (147 respondents, 37%), burying and burning (81 respondents, 20%), burying (60 respondents, 15%) and simply throwing away the carcass in the bush (55 respondents, 14%). Despite these dangerous practices, majority of the respondents from Isiolo and Marsabit were confident on their knowledge of anthrax and thus did not need any training on the disease with regard to it's recognition and avoidance of infection. However, most of the respondents (n=139) from Wajir identified the need of training.

Table 4.9: Disposal of suspected carcass cases

County	Throw it away	Burying	Burning	Burying and burning	Skin and eat the meat	Total
Wajir	17 (30%)	12 (20%)	93 (63%)	27 (33%)	0 (0%)	149
Isiolo	18 (31%)	45 (75%)	27 (18.5%)	50 (62%)	5 (9%)	145
Marsabit	22 (39%)	3 (5%)	27 (18.5%)	4 (5%)	50 (91%)	106
Total	**57**	**60**	**147**	**81**	**55**	**400**

The percentage of good anthrax practice was 96.6% for Wajir, 0.9% for Marsabit and 35.9% for Isiolo.

Table 4.10: Level of anthrax practices in Wajir, Marsabit and Isiolo Counties

Level of anthrax Practice	**Wajir**	**Marsabit**	**Isiolo**
Poor	0 (0%)	72 (67.9%)	5 (3.4%)
Moderate	5 (3.4%)	33 (31.2%)	88 (60.7%)
Good	144 (96.6%)	1 (0.9%)	52 (35.9%)
Total	**149**	**106**	**145**

4.5 Anthrax mapping

4.5.1 Anthrax occurrence points

Fig. 4.4 shows the map of Kenya, the study areas (Marsabit, Wajir and Isiolo) and anthrax occurrence points. These occurrence points are the areas where confirmed cases of anthrax had occurred persistently. The occurrence points were 53; 29 from Wajir, 13 from Marsabit and 11 from Isiolo County. As shown in Figure 4.4, most anthrax outbreaks reportedly occurred in Wajir Couny and the least in Isiolo County.

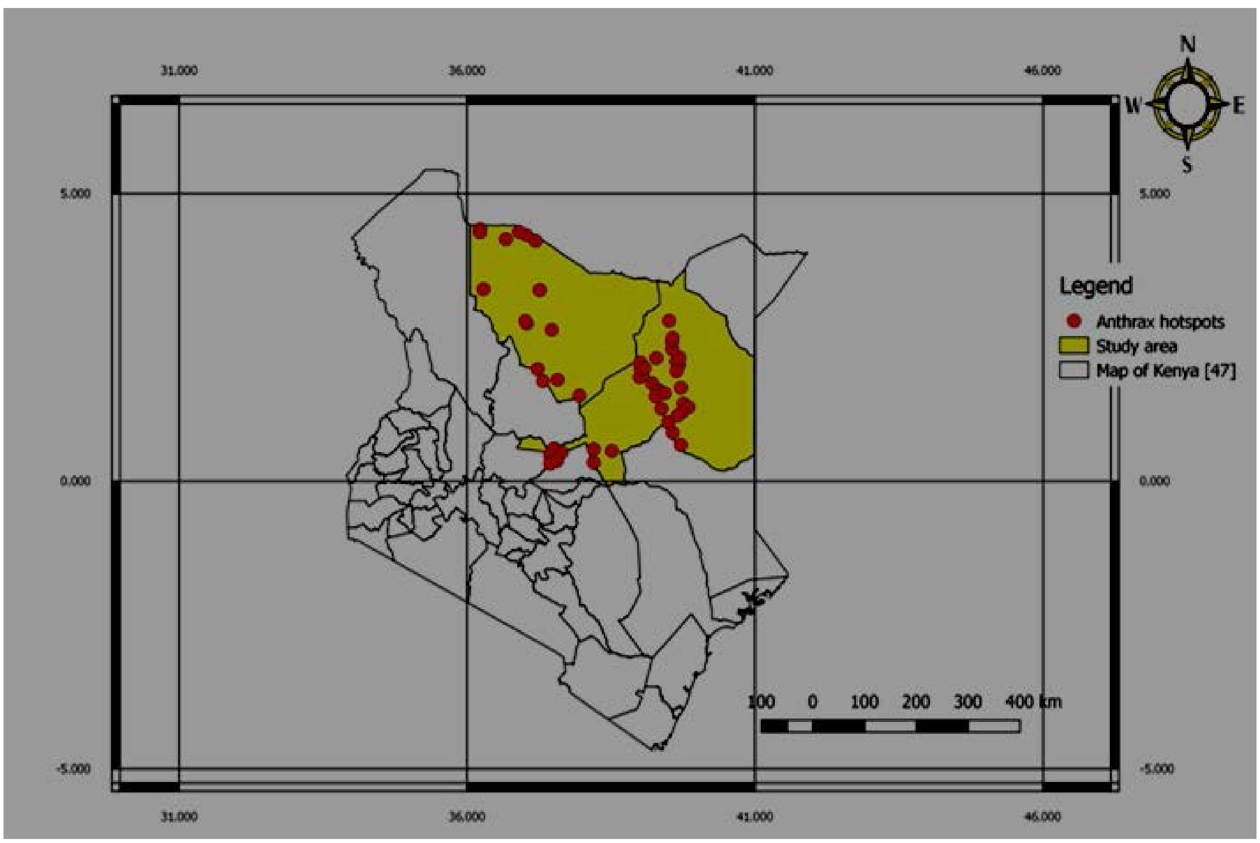

Figure 4.4: Anthrax occurrence points in Wajir, Isiolo and Marsabit Counties

4.5.2 Anthrax predictive map

Fig 4.5 shows the predicted map of anthrax in Isiolo, Wajir and Marsabit Counties of Kenya. The red dots show the occurrence points of anthrax as confirmed. The likelihood of future anthrax occurrence increases in Fig 4.5. -6 is a weak likelihood while 2 is a strong likelihood and thus green areas are likely to have anthrax cases in the future. The model predicts that future outbreak of anthrax would occur in the immediate neighborhood of previous outbreaks.

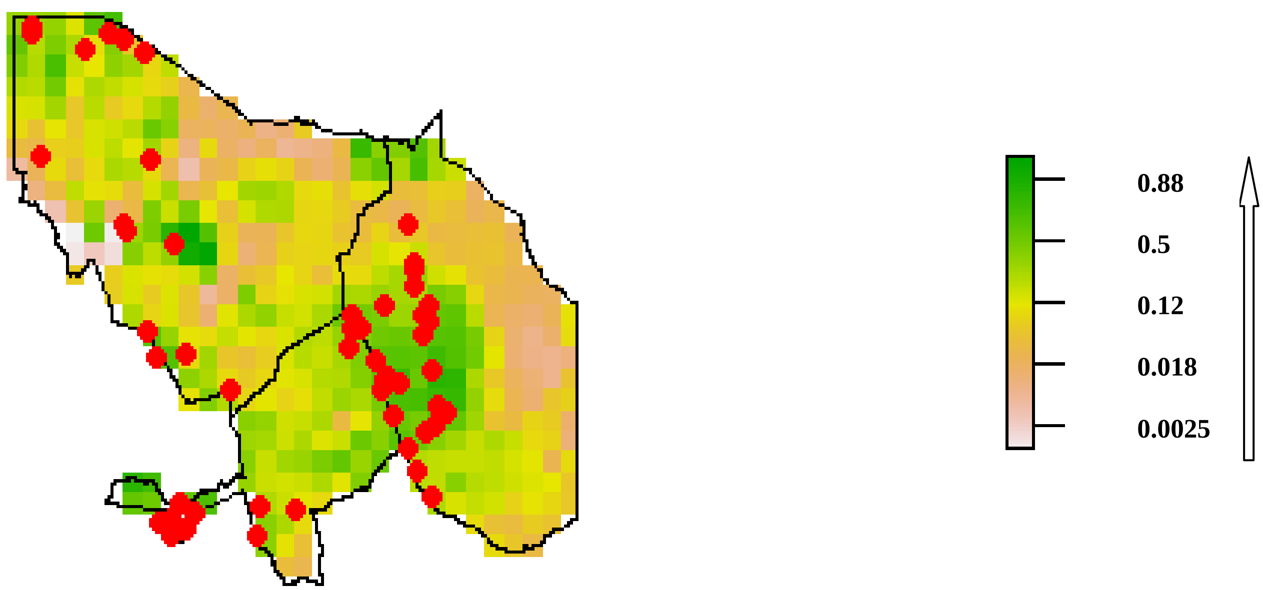

Figure 4.5: Predicted map of anthrax by an ecological Niche Model

4.5.3 Ecological parameters which influence the occurrences of anthrax

In this model, twenty two ecological parameters were examined for their influence on anthrax occurrences including Isothermality, temperature seasonality, mean temperature of warmest quarter, precipitation of the wettest month, elevation and soil ph (Fig 4.6-4.10). The red dots are the anthrax occurrence points and the blue dots pseudo-absence points of anthrax

4.5.3.1 Isothermality

Isothermality is the third bioclimatic parameter and is calculated by dividing the mean diurnal temperature (^{0}C) with the annual temperature (^{0}C). Isothermality was found to have an influence on the occurrence of anthrax ($p<0.05$). Areas with low Isothermality were likely to have an anthrax case in the future. The model predicted more outbreaks of anthrax in Wajir county than in Isiolo and Marsabit counties.

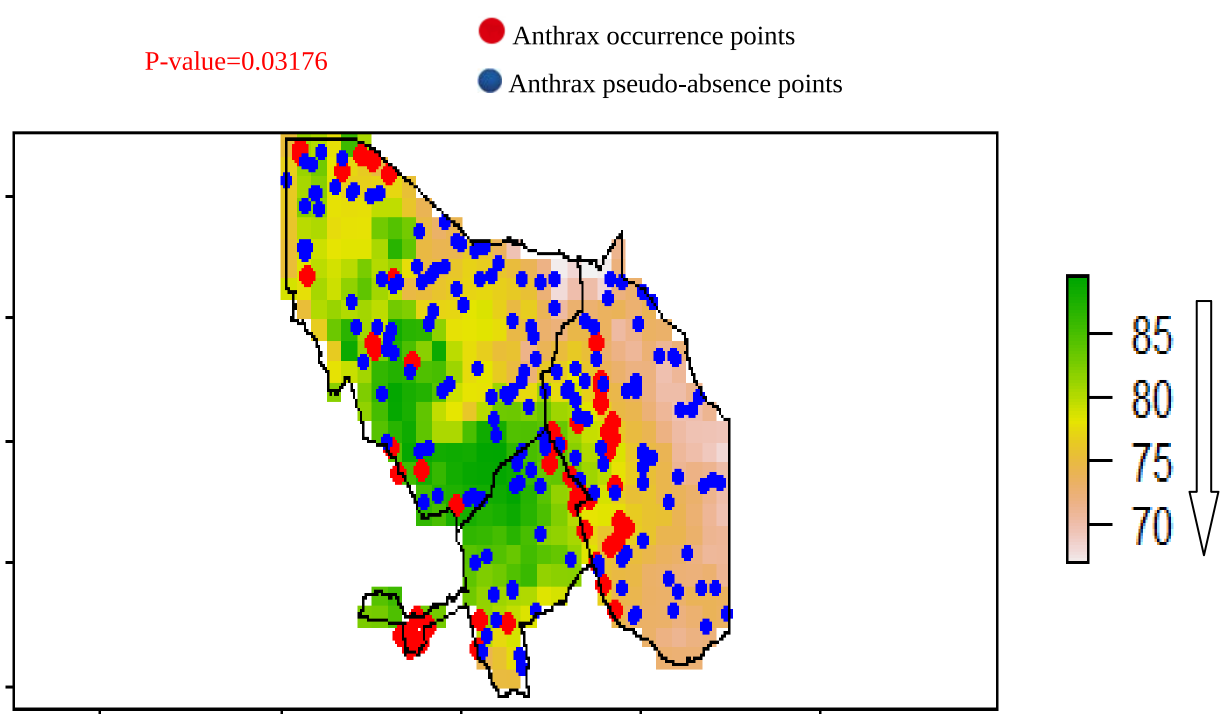

Figure 4.6: Isothermality (unit less)

4.5.3.2 Temperature Seasonality

Temperature seasonality (Fig. 4.7) was found to be among the parameters that influenced the occurrence of anthrax ($p<0.05$). Areas having low temperature seasonality were predicted to be suitable for anthrax outbreaks. Using this parameter, the model generated more pseudo-absent anthrax points in Wajir county, and less so in Marsabit and Isiolo counties.

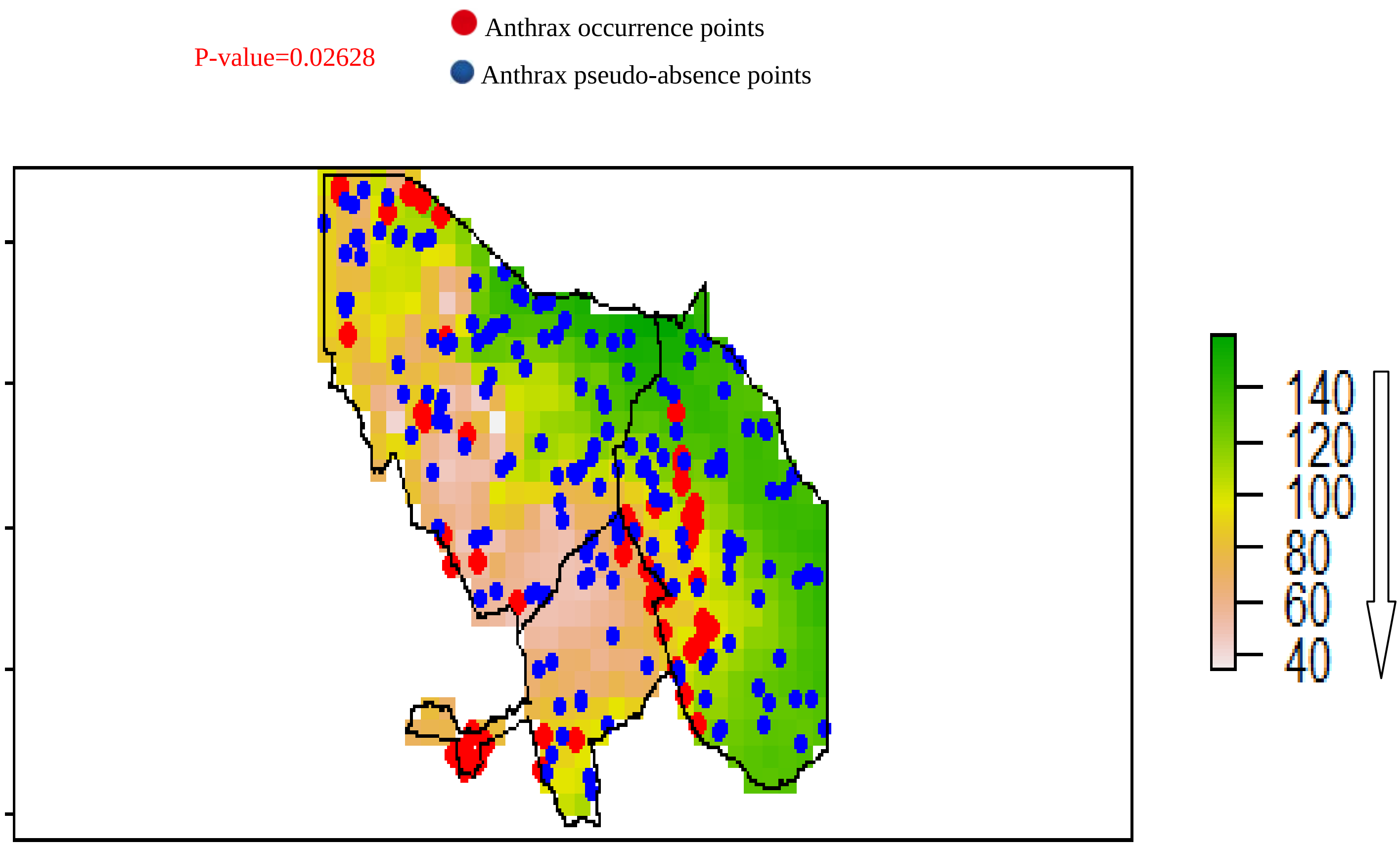

Figure 4.7: Temperature Seasonality (^{0}C)

4.5.3.3 Precipitation of the Wettest Month of the year

Precipitation of the wettest month of the year also had an influence for the occurrence of anthrax (P<0.05). Areas with high precipitation of the wettest month were predicted to be suitable for anthrax occurrences (Fig. 4.8).

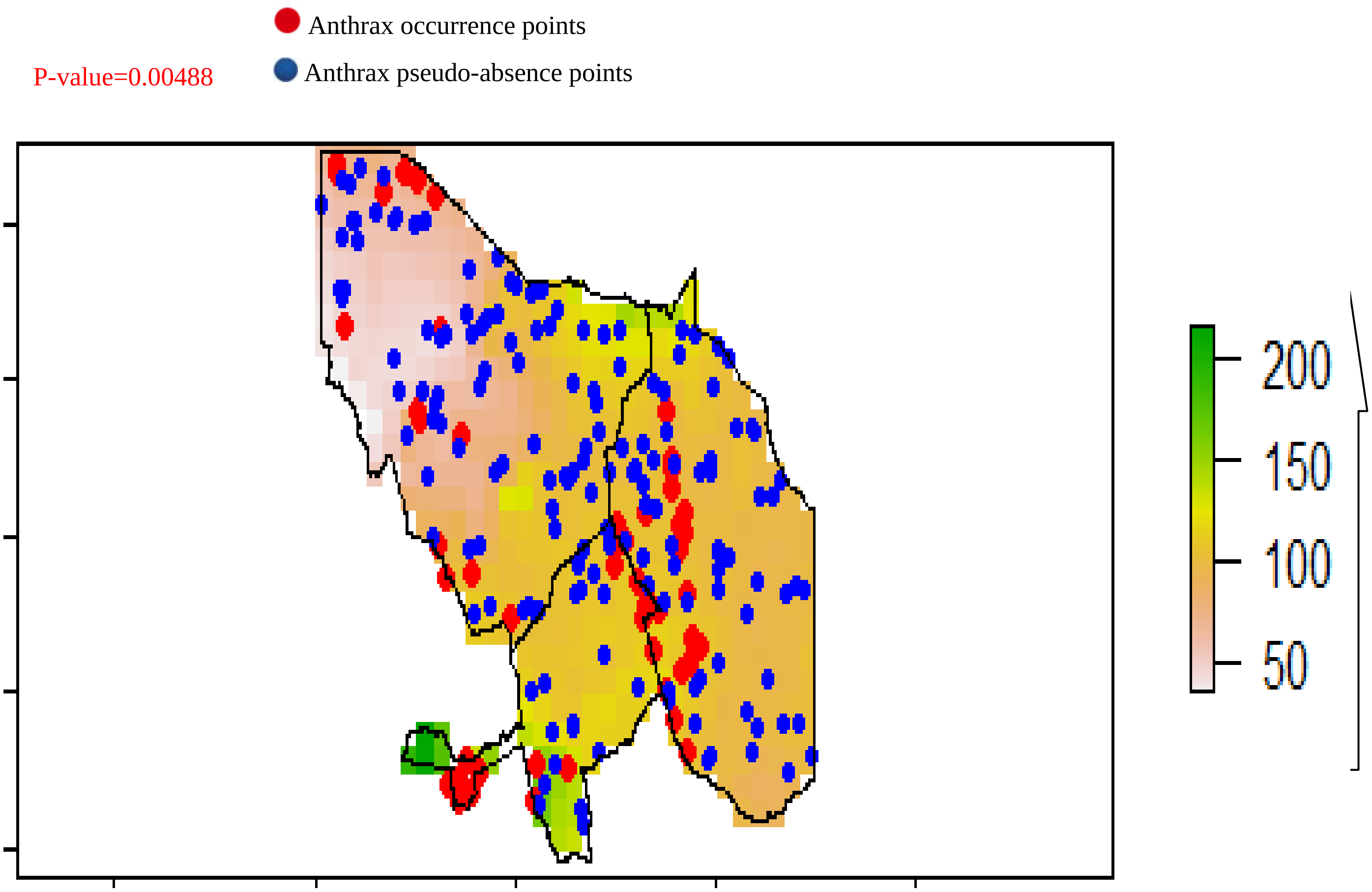

Figure 4.8: Precipitation of the Wettest Month (mm) of the year

4.5.3.4 Elevation

Elevation was another parameter found to have an influence on the occurrence of anthrax (P<0.05). Areas with high elevation were found to have higher risk of having anthrax cases in the future (Fig. 4.9). This prediction was uniform in all the counties.

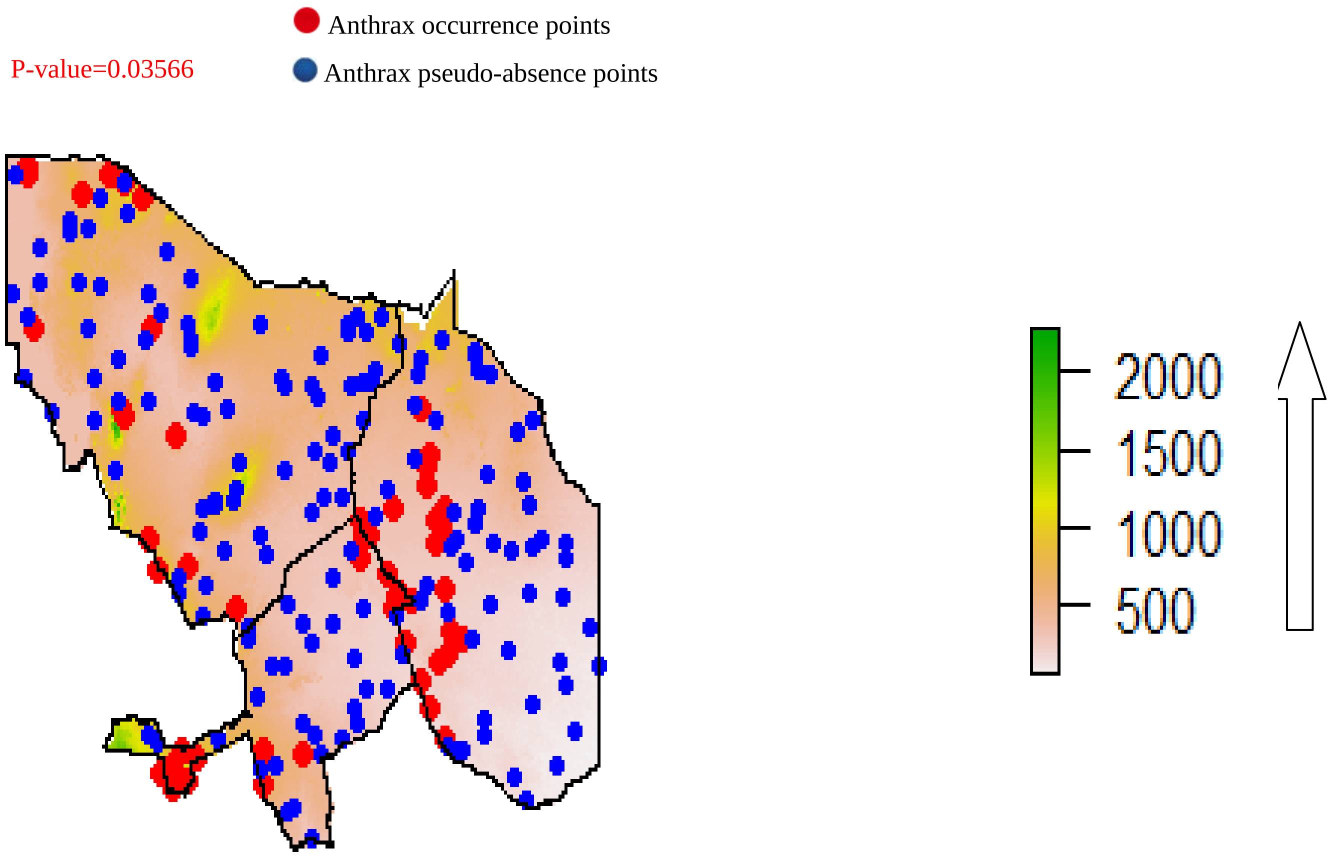

Figure 4.9: Elevation (meters)

3.5.3.5 Soil Ph

Soil Ph also was found to have an influence on the occurrence of anthrax (Fig. 4.11) ($P<0.05$). Areas with high soil Ph were found to have a higher risk of having future anthrax occurrences. There were more pseudo-absence points of anthrax in Wajir than Marsabit and Isiolo Counties.

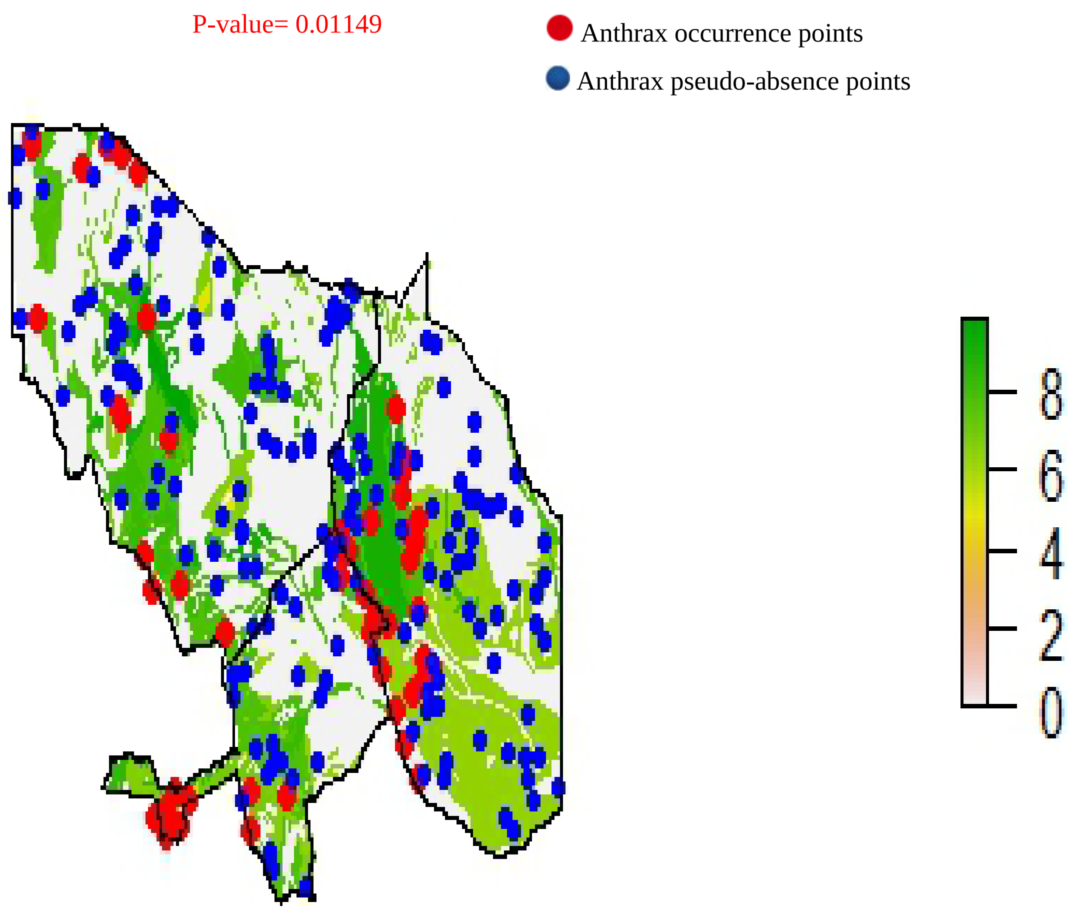

Figure 4.10: Soil pH

3.5.3.6 Outputs of the logistic regression

Table 11: Logistic regression table

	Estimate	**Standard error**	**Z value**	**Pr (>z)**
Intercept	-4.702913	19.067244	-0.247	0.80518
Isothermality	-0.321595	0.149758	-2.147	0.03176
Temperature seasonality	-0.234296	0.105443	-2.222	0.02628
Precipitation of the Wettest Month of the year	0.040473	0.014378	2.815	0.00488
Elevation	0.006441	0.003066	2.101	0.03566
Soil pH	0.227792	0.090130	2.527	0.01149

CHAPTER FIVE: DISCUSSION

The present study provides preliminary baseline data regarding the knowledge, attitude and practices of anthrax by pastoralists, as well as a predictive map of the future occurrences of this disease. This opens the door for future contributions, research, surveillance, and control efforts of anthrax.

The level of education of the surveyed pastoralists was low. This was not surprising because pastoralists live in very remote areas where schools are non-existent and where present, they are few and far apart. These results are in agreement with the report of Kenya National Bureau of Statistics (KNBS) and Society for International Development (SID), (2013) which documented similar poor education in Wajir and Marsabit Counties. The report shows that education level is slightly lower pastoralists in the neighboring Turkana County. However for those pastoralists adopting a sedentary lifestyle, like in Kajiado County, education levels are higher at the report says. Mochobo (2002) and Lotira (2004) also reported similar education levels of pastoralists in neighboring Turkana County. In Turkana, just like in the study counties, pastoralists practice nomadic pastoralism where they move over vast areas in search of water and pasture for their livestock. Thus it becomes difficult for the government to build permanent schools for their children.

The study revealed that anthrax was well known in the three study counties. Indeed, the pastoralists had local names for the disease mostly describing the manifestations of the disease (cutanious, pulmonary and gastro-intestinal) or the source of the bacteria (soil). These results are consistent with those of Dharani *et al.*, (2015) who described an array of names given to anthrax by some pastoralists in Ethiopia, Uganda, Tanzania and Kenya. It has been shown that pastoral communities have a wealth of indigenous knowledge of diseases affecting their livestock. Some of that knowledge was documents by catley *et al.*, (2002). However despite the indigenous knowledge, the training of pastoralists on anthrax awareness by the Accelerated Value Chain Development project conducted by ILRI in the study counties may have played a part. In the purely agricultural county of Muranga, anthrax was well known just within the pastoral areas (Kioko, 2012). This may indicate that perhaps anthrax is known in many communities living in Kenya.

Despite the high levels of knowledge of anthrax by the study communities, they still engaged in dangerous practices that would put them at risk of exposure to the anthrax bacterium. These practices included skinning and opening suspect anthrax cases, consumption of meat from dead animals, and even throwing carcasses in to the bush. In Kenya, outbreaks of anthrax are brought to the attention of the authorities when people get sick and others die following the consumption of uninspected meat. It is conceivable that the 53 reported outbreaks came in to the attention of the authorities in this manner. The practice of boiling meat of suspect anthrax cases and throwing the soup is also practiced by the Turkana pastoral community (Kitala personal communication, 2017). Whether this method of preparing suspect anthrax meat is effective is in preventing infection with anthrax is a subject for further research.

The practice of throwing away instead of burning anthrax suspect cases in to the bush is indeed dangerous. This leads to the contamination of the environment with anthrax spores which are aggravated by scavengers like vultures, hyenas, jackals. Once these spores are in the environment, they are known to remain viable for long periods of time, even up to 90 years (Radostitis O.M., *et al*., 2007) and therefore provide a source of future outbreaks. It was thus not surprising that the ecological niche model predicted future outbreaks in the immediate vicinity of the primary outbreaks. There is a need to educate the pastoralists of the three study counties on the proper handling of anthrax/suspect cases of anthrax in livestock especially the need to bury them 6 feet in the ground and importantly not to open such carcasses and consume the meat.

A total of five variables were found to influence the future occurrence of anthrax using the ecological niche model. These results are in agreement with the study by Blacburn *et al*., (2007) who also identified measures of temperature, precipitation and soil pH as determinants of anthrax future occurrences. Such data are important for veterinary authorities to map out potential areas of anthrax outbreaks and institute control measures such as vaccination of livestock.

The ecological niche model predicted that isothermality, temperature seasonality, precipitation of wettest month, elevation and soil pH as determinants of anthrax outbreaks. This concurs with the findings of Dragon and Dragon, D. C (1995) who found the parameters to be responsible for anthrax spore survival, and sporulation respectively. Thus when all or some are at optimal conditions, anthrax outbreaks would occur.

In conclusion, this study shows that anthrax occurs in the study counties of Wajir, Isiolo and Marsabit and that it is well known. However pastoral community engages practices that expose them to infection and further spread of anthrax spores. The hotspots for anthrax occurrences were identified and thus control efforts should be an ongoing process, needless to say education of the community especially on the proper handling of anthrax carcasses would be paramount.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The following conclusions can be drawn from the study:

i. A total of 53 hotspots where anthrax had previously occurred were identified. There were more hotspots in Wajir county than Marsabit and Isiolo counties. Thus anthrax occurred in the three counties.

ii. Several parameters were identified by the ecological niche model that influenced the occurrence of anthrax outbreaks, including soil pH, elevation, isothermality, temperature seasonality and precipitation of the wettest month. These parameters favoured the survival of anthrax spores in the environment, and/or sporulation.

iii. Anthrax was well known in the study community, however there were practices that were likely to cause infection or encourage the spread of anthrax spores in the environment such as eating of uninspected meat, opening of anthrax suspect carcasses, and throwing of anthrax carcass in to the bush.

6.2 Recommendations

i. Although anthrax is well known disease in the study area, the pastoralists engaged in practices that put them at high risk of exposure. Thus there is a need to educate the public on he proper handling of animals especially those that die suddenly.

ii. Anthrax was found to be endemic in Marsabit, Isiolo and Wajir counties. Thus control efforts should be continuous through the vaccination of livestock.

iii. The risk map produced in this study was found useful showing areas where anthrax outbreaks were likely to occur. It should be extended to cover the whole of Kenya for surveillance and control.

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APPENDIX 1

Bioclamatic variables

Bioclimatic variable	Definition
1. BIO1 = Annual Mean Temperature.	The mean of all the weekly mean temperatures. Each weekly mean temperature is the mean of that week's maximum and minimum temperature
2. BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))	The mean of all the weekly diurnal temperature ranges. Each weekly diurnal range is the difference between that week's maximum and minimum temperature
3. BIO3 = Isothermality (BIO2/BIO7) (* 100)	The mean diurnal range (parameter 2) divided by the Annual Temperature Range (parameter 7)
4. BIO4 = Temperature Seasonality (standard deviation *100)	ANUCLIM (cov=TRUE) returns the temperature Coefficient of Variation (C of V) as the standard deviation of the weekly mean temperatures expressed as a percentage of the mean of those temperatures (i.e. the annual mean). For this calculation, the mean in degrees, Kelvin is used. This avoids the possibility of having to divide by zero, but does mean that the values are usually quite small
5. BIO5 = Max Temperature of Warmest Month	The highest temperature of any weekly maximum temperature
6. BIO6 = Min Temperature of Coldest Month	The lowest temperature of any weekly minimum temperature
7. BIO7 = Temperature Annual Range (BIO5- BIO6)	The difference between the Max Temperature of Warmest Period and the Min Temperature of the Coldest Period
8. BIO8 = Mean Temperature of Wettest Quarter	The wettest quarter of the year is determined (to the nearest week), and the mean temperature of this period is calculated
9. BIO9 = Mean Temperature of Driest Quarter	The driest quarter of the year is determined (to the nearest week), and the mean temperature of this period is calculated

10. BIO10 = Mean Temperature of Warmest Quarter	The warmest quarter of the year is determined (to the nearest week), and the mean temperature of this period is calculated
11. BIO11 = Mean Temperature of Coldest Quarter	The coldest quarter of the year is determined (to the nearest week), and the mean temperature of this period is calculated
12. BIO12 = Annual Precipitation	The sum of all the monthly precipitation estimates
13. BIO13 = Precipitation of Wettest Month	The precipitation of the wettest week or month, depending on the time step
14. BIO14 = Precipitation of Driest Month	The precipitation of the driest week or month, depending on the time step
15. BIO15 = Precipitation Seasonality (Coefficient of Variation)	The Coefficient of Variation (C of V) is the standard deviation of the weekly precipitation estimates expressed as a percentage of the mean of those estimates (i.e. the annual mean)
16. BIO16 = Precipitation of Wettest Quarter	The wettest quarter of the year is determined (to the nearest week), and the total precipitation over this period is calculated
17. BIO17 = Precipitation of Driest Quarter	The driest quarter of the year is determined (to the nearest week), and the total precipitation over this period is calculated
18. BIO18 = Precipitation of Warmest Quarter	The warmest quarter of the year is determined (to the nearest week), and the total precipitation over this period is calculated
19. BIO19 = Precipitation of Coldest Quarter	The warmest quarter of the year is determined (to the nearest week), and the total precipitation over this period is calculated

APPENDIX 11

Questionnaires

Assigned livestock owner's number[]

Mapping the spatial distribution and assessment of knowledge and Practices of Anthrax in Wajir, Isiolo and Marsabit counties of Kenya

ID1. Date of interview (dd/mm/yy)	___ ___/______/ 2017
ID2. Place of interview	____________________
ID3. Name of interviewer	____________________
ID4. Contact address for interviewer	Tel.No ____________________ Email address____________________
ID5. Name of respondent	
ID6. Gender of respondent	[ ] (code)
ID7. Residential area of respondent	
ID8. GPS coordinates Latitude: Longitude:- Altitude	
ID9. Filled questionnaire checked by?	

Codes

Gender of respondent 1=Male

2=Female

A. Personal profile of livestock owners

A.1 Information about household members

Parameter	
Age	
Number of Children	
Level of formal education	
Ethnic community	

Codes

Level of formal education
1= None

2= Elementary

3= Intermediate

4= Secondary Graduate

5= University

6=Others

Ethnic group

1= Somali

2= Gabra

3= Boran

4= Rendille

5= Sanburu

6=Turkana

7=Daasanach

A.2 Which livestock species do you keep?

Animal species
1= Sheep 2= Goats 3= Cattle 4= Camel 5=Donkey 6=Poultry 5= Others

(specify) ____________________

A3. Years of experience on keeping livestock sheep/goats/cattle/camel [____](years)

B. Knowledge about Anthrax

1. What zoonotic diseases are you aware of? {___},{___},{___},{___},{___} (enter code(s)) (NB: Please explain to the respondent what you mean by zoonotic diseases) If anthrax is mentioned please go to question 3

Codes

Type of zoonotic diseases

1=Rift valley fever
2=Anthrax
3=Brucellosis
4=Rabies
5=Pox
6= Others (specify)__________________________

2. Are you aware of a zoonotic disease called anthrax? {___} Y=1,N=2

3. If yes, what is the traditional and it's meaning?________________________________

4. How do you call it in your language?____________________, please explain the name you provided____

5. How did you learn about anthrax? {___} {___} {___} {___} {___} (enter code(s))

Codes

How did you learn about Anthrax

1=Another farmer/livestock keeper

2=A vet officer

3=Medical doctor

4=Mass media

5=Others (specify)_______________________________________

4 What are the symptoms of anthrax in livestock? {___} {___} {___} {___} (enter code(s))

Codes

symptoms of Anthrax in livestock

1=Death

2=Bleeding from all openings

3=Ulcers on the skin

4=Others (specify) ___________________________________

5. What are the symptoms of anthrax in humans? {___} { _} {___} {___} (enter code(s))

Codes

symptoms of Anthrax in humans
1=Death
2=Bleeding from all openings
3=Ulcers on the skin
4=Others (specify)

____

5 What do you think are the sources of anthrax outbreaks? { _}{___}{___}{___}{___}{___}{___} (enter code(s))

Codes Species of livestock that can act as a source of anthrax for human
1=Cattle 2=Sheep 3=Goats 4=Camels 5=Wild life 6=Soil in some areas 7=others (specify) ___________________________________

6 How do you think people get infected with anthrax? {___} {___}{___}{___}{___} (enter code(s))

Codes
1=Contact with infected livestock 2=Consumption of products from an infected animal 3=Contact with wild animals 4=Inhalation of infection aerosols 5= Slaughtering an infected carcass Others (specify) ______________________

7. Have you had anthrax outbreaks before in this village? { }
1=Yes, 2= No
If yes,

7. How many times have it occurred?________

C. Practices

C1. Do your livestock mix with wild animals?

1=Yes, 2= No

C2. How do you manage sick animals suspected to have anthrax? {___},{___},{___},{___}

1=Treat with antibiotic 2= Report to the closest veterinary unit 3= Wait and see 4=Others (specify) ____

C3. Do you skin dead animals? 1=Yes, 2=No

C4. Do you eat carcasses from dead animals? 1=Yes, 2=N0

C5. Do you eat carcasses from animals that dead from anthrax? 1=Yes, 2=N0

C6. If yes, how do you treat it before you consume?

____

____

____

____

C7. How do you handle animals dead due to anthrax suspect? { ___,___,___,___}

1=Throw them away 2=Burying 3=Burning 4=Burning and burying 5=Other ______________________________ (specify)

C8. How do you manage anthrax outbreaks? {__________,___,___,___}

1=None 2=Inform the relevant authority 3=Disinfect the infected areas 4=Other (specify) ____

C9. Are you happy about what you know about anthrax? { _} Y=1, N=2 If no, what other additional information would you like to have?

____

THANK YOU

APPENDIX 111

Sample Consent Form

Invitation to participate in the study

Dear sir/madam,

I am Abdirahim Mohamed Ahmed, a student at the University of Nairobi, pursuing a Master's degree in Veterinary Public Health with a thesis titled "The spatial distribution of anthrax and assessment of knowledge, attitude and practices of pastoralists of the disease in Wajir, Isiolo and Marsabit Counties of Kenya". You are kindly requested to answer the following questions by ticking the right option and filling the right information in the blank spaces. The information you provide is purposely for academic purposes and will be kept confidential. Therefore feel free to answer all questions if you can.

I ………………………………………………………………………………… agree to participate in this study and the information provided to you is the truth.

Date ……………………………………………………………………………………….

Thank you

APPENDIX IV

Anthrax occurrence record sheet

Date	County	Sub-country	Ward	Location	GPS coordinates		
					Latitude	Longitude	Attitude (m)