



Catalytic Effects of Temperature and Rainfall Variabilities on the Occurrence of Ruminant Livestock Diseases in Some Southern African Countries: A Review

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ABSTRACT

Extreme climatic variations contribute to the increased occurrence of livestock diseases by creating new transmission routes brought about by the survival, adaption and population growth of disease vectors and pathogens. With the growing global concern about climate change, the sustainability of livestock production is threatened. In developing countries, livestock is used to combat the effects of poverty and malnutrition by providing income, manure and food security. The aim of this review is to evaluate the effects of temperature and rainfall variabilities on the occurrence of ruminant diseases. The literature used in this review was sourced from electronic databases such as Google Scholar, ResearchGate, Link springer and Science Direct and covers the period of 2006 to 2022. Literature search revealed that the occurrences of ruminant diseases in Southern African countries were influenced by temperature, rainfall and humidity variations. Climatic factors act as catalysts for the transmission of diseases by weakening the immune system of the host, facilitating the abundance of vectors and pathogens in their habitats and contaminated environments. Information on the impact of climatic conditions on the occurrence and prevalence of diseases is important in bringing disease awareness and developing disease control measures.

Key words: Climatic variations, Habitats, Immune system, Pathogens, Vectors.

Livestock production plays an essential role in the development and growth of economies in African countries (Undi *et al.*, 2006). In developing countries, livestock animals are kept as assets to generate income and provide food security for approximately 60-80% of the rural communities (Smit *et al.*, 2013). Ghil and Lucarini (2020) defined climatic variability as the climatic parameter of an area changing from its long-term mean due to natural internal processes inside the climatic system and from differences in external forces (anthropogenic and natural). Ruminants are severely affected by climatic variabilities, resulting in increased susceptibility to diseases. Ali *et al.* (2020) stated when ruminant animals are exposed to high temperatures, feed intake is reduced while respiration and sweating rates increase. RocklÖv and Dubrow (2020) reported that climatic variabilities affect the re-emergence of vector-borne diseases, the dynamics and rate of transmission and the geographic spread of the diseases through various ways that involve the pathogen, the vector and the animal. Additionally, De *et al.* (2022) reported that climatic variabilities promote habitat patterns, reproduction and spread of vectors such as ticks, flies, midgits and mosquitoes.

Chepkoech *et al.* (2018) reported that in recent years, climate change has resulted in adverse variabilities such as extremely hot or cold temperatures and prolonged periods of drought and floods. According to Office International des Epizootic (2014) the scarcity of water caused by drought spells typically changes the hygiene habits and quality of water and that might increase the occurrence of viral diseases mostly in arid and semi-arid

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areas. Filipe *et al.* (2020) observed that a rise in ambient temperatures typically results in reduced feed intake because the hypothalamic appetite centre of farm animals is affected. Matope *et al.* (2020) added that the occurrence of ruminant diseases and associated mortalities is common in sub-Saharan Africa following extreme droughts and periods of heat stress. Ekine-Dzivenu *et al.* (2020) stated that when lactating animals are subjected to high ambient temperatures and humidity for long periods, their ability to regulate heat that is generated from both the environment and metabolic processes decreases and thus results in decreased milk production. There is a need to determine the extent to which ruminant diseases are influenced by temperature and rainfall variabilities so that the adverse effects of climate change can be reduced by developing control and management practices in accordance to disease prevalence.

The information provided in this review was acquired from the articles that were published from the year 2006 to 2022. Electronic data sources such as Google scholar, Research gate, Link springer and Science direct were accessed to retrieve the articles. The keywords "climatic factors", "occurrence", "ruminant diseases" and "pathogens" were used in the search process.

The effects of temperature and rainfall variabilities on the immune statuses of ruminants

Chauhan *et al.* (2021) pointed out that the role of the immune system is to protect the host from invasive pathogenic organisms through its complex mechanisms however, according to Lacereta (2019), environmental extremities such as heat stress impair immune responses. Chen *et al.* (2018) highlighted that the effects of heat stress can be direct or indirect while severity of the effects depends on the amount of time an animal is exposed to heat and animal factors such as the species, breed, sex and age. According to Ali *et al.* (2020), when the immune system of an animal is affected, unfavourable conditions take place such as an increase in the occurrence of infections and the reduction in production efficiencies. Livernois *et al.* (2021) reported that prolonged exposure to heat stress results in depressed lymphocyte levels and the reduction of vaccination efficacy. Furthermore, high temperatures weaken the functionality of neutrophils, which usually play a major role in protecting mammary glands from infections (Bagath *et al.*, 2019).

Description of ruminant vector-borne diseases and their occurrences in relation to climatic variabilities

Ticks are described as hematophagous ectoparasites that infest ruminants and other domesticated animals, wildlife and human beings. Ticks are the vectors of tick-borne diseases which are highly prevalent in tropical and subtropical areas in the world (Twana and Harun, 2022). This makes them a public health and veterinary concern because they are responsible for financial and livestock losses (Boularias *et al.*, 2020). Ticks are categorized into three families known as *Argasidae*, *Ixodidae* and *Nuttalliellidae*. Soft ticks (*Argasidae* ticks) thrive well in hot areas that are very dry and have desert-like conditions. They have the ability to resist desiccation which assist their expansion amid climatic variabilities (Adenubi *et al.*, 2018). Hard ticks (*Ixodidae* ticks) suck the blood of mammals, reptiles, avians and amphibians (Martínez-García *et al.*, 2021). These ticks are known to thrive in warm environments with high humidity. The *Nuttalliellidae* family consists of one tick species (*Nuttalliella Namaqua*) and shares the same characteristics with both the *Ixodidae* and *Argasidae* ticks (Twana and Harun, 2022).

Anaplasmosis (Gall sickness)

Anaplasmosis is a tick-borne disease affecting ruminants and caused by *Anaplasma marginale*, which is a gram-negative obligate intracellular bacterium that parasitizes

erythrocytes (Ashraf *et al.*, 2021). Mubashir *et al.* (2022) reported that cattle anaplasmosis is transmitted by at least twenty tick species, however, the main transmission agent is *Rhipicephalus (Boophilus) microplus* (De Almeida *et al.*, 2022). The occurrence of the disease is dependent on the growth and survival of the tick population. The tick consists of parasitic and non-parasitic phases in the one-host life cycle. The non-parasitic phase begins soon after the feeding stops and engorged females drop off the host so to oviposit in the environment (Yogeshpriya *et al.*, 2022). This phase involves periods of pre-ovipositional and oviposition in engorged females, the incubation and hatching of eggs and larvae seeking a host (Marques *et al.*, 2020). The population growth and survival of *Rhipicephalus microplus* is largely dependent on the environmental temperatures, vegetation habitats and host availability in an area (Leal *et al.*, 2018). Areas with average temperatures above 17°C can cause the population dynamics of the tick to differ from two to five generations in a year. Furthermore, Oshiro *et al.* (2021) reported that oviposition in engorged females' initiates when temperatures are above 28°C and when temperatures are around 4°C oviposition delays.

Babesiosis (Red water)

Bovine babesiosis is a widespread tickborne disease caused by parasites of the genus *Babesia* with the most common species being *B. bovis*, *B. divergens* and *B. bigemina* (Zaman *et al.*, 2022). Hard ticks of the family *Ixodidae* transmit the disease with *Rhipicephalus microplus* as the principal vector of the parasites (Jacob *et al.*, 2022). Clinical signs of babesiosis are high fever, anorexia, anaemia, depression and splenomegaly (Suarez *et al.*, 2019). Gray (2021) stated that the occurrence and prevalence of the disease depends on the abundance of the ticks. Babesiosis is commonly reported during the summer and autumn seasons (Ferreira *et al.*, 2022). Abdullah *et al.* (2019) reported that extreme variations of climatic factors such as temperature and humidity promote the survival, growth and activity of ticks, however, high rainfall patterns were reported to negatively affect the abundance and survival of tick larvae (Ahmad *et al.*, 2023).

Theileriosis (East Coast fever)

Chen *et al.* (2021) defined theileriosis as a disease transmitted by ticks and caused by an obligate intracellular protozoan parasite called *Theileria*. Globally, *Theileria annulata* and *Theileria parva* have been reported to be the major species causing the disease (Dhaygude *et al.*, 2021). *Ixodid* ticks are responsible for the transmission of the disease and have a complex life cycle in vertebrates (Dadhick *et al.*, 2017). Symptoms of the disease include fever, anaemia, reduction in milk production, weakness and lethargy (Agina *et al.*, 2020). According to Khawale *et al.* (2019), extreme variations in temperature and humidity create an ideal environment for the abundance of ticks and thus the occurrence rate of the disease is higher during summer months.

Table 1: The occurrence of vector-borne diseases in relation to climatic variabilities in some Southern African countries.

Disease	Geographical location/country	Animal species	Time period	Findings	Authors
Anaplasmosis	South Africa	Cattle	2013 to 2018	The highest prevalence of the disease and its causing pathogens were observed during the autumn season and were associated with the dry conditions and gradually rising temperature.	(Jaja and Wanga- Ungeviwa, 2022)
	Zambia	Cattle	2010	<i>Anaplasma marginale</i> seroprevalence rate of 25.7% reported during the change of season from winter to spring (July-September). These findings were attributed to the dry conditions and gradually rising temperatures during the sampling period.	(Tembo et al., 2018)
Ovine anaplasmosis	Malawi	Sheep and goats	-	<i>Anaplasma marginale</i> seroprevalence rate of 65% was reported. These findings were attributed to the warm and dry conditions that were prevailing during the season of sampling.	(Chatanga et al., 2021)
	Botswana	Goats	2016	<i>Anaplasma marginale</i> seroprevalence rate of 88% reported during the spring season. These findings were attributed to the prevailing dry conditions during the sampling period.	(Berthelsson et al., 2020)
Redwater (Bovine babesiosis)	Angola	Cattle	2012	An overall prevalence rate of 1% was reported despite the heavy rainfall and warm temperatures that were prevailing during the period of reporting.	(Kubelová et al., 2012)
	South Africa	Cattle	2011	<i>Babesia bovis</i> seroprevalence rate of 35% reported while 30 % seroprevalence rate was reported for <i>Babesia bigemina</i> . These findings were attributed to the warm temperatures and heavy rainfall during the sampling period.	(Terkawi et al., 2011)
	Namibia	Cattle	2018	<i>Babesia bovis</i> seroprevalence rate of 17% reported while 37% was reported for <i>Babesia bigemina</i> . These findings were attributed to the high temperatures and heavy rainfall that occurred during the sampling period.	(Matheus et al., 2019)
	Mozambique	Cattle	2011	<i>Babesia bovis</i> seroprevalence rate of 76% reported while 79% was reported for <i>Babesia bigemina</i> . These findings were attributed to the warm and wet conditions that were prevailing during the sampling period.	(Tembue et al., 2011)
Heartwater (<i>Ehrlichia</i> spp.)	South Africa	Cattle	2012 to 2014	<i>Amblyomma hebraeum</i> prevalence of 42% reported. These findings were attributed to hot and wet conditions (December to February) and hot and dry conditions (September to November) during the sampling periods.	(Mapholi et al., 2022)

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Botswana	Goats	2013 to 2014	Disease prevalence was reported to be 17%. The <i>Amblyomma hebraeum</i> tick was reported to be present throughout the year with high activities observed during the summer and winter seasons.	(Jongejan et al., 2020)
	Cattle	1987 to 2007	A high occurrence rate was reported in most parts of the country. These findings were attributed to the low rainfall and high temperatures of the region.	(Batisani et al., 2012)
	Cattle	2014	<i>Ehrlichia ruminantium</i> seroprevalence rate of 15% reported during the winter season (June and July). These findings were attributed to the low temperatures and dry conditions that were prevailing during the sampling period.	(Matos et al., 2019)

Ehrlichiosis (Heart water)

Ehrlichiosis also known as cowdriosis or heartwater is an infectious and acute tick-borne disease caused by a gram-negative obligate intracytoplasmic bacterium called *Ehrlichia ruminantium* which belongs to the *Rickettsiales* order (Basit et al., 2022). Ticks responsible for the transmission of the bacterium belong to the genus *Amblyomma*, specifically the species *Amblyomma hebraeum* and *Amblyomma variegatum*. Garcia et al. (2022) reported that after disease transmission, cattle display clinical signs such as muscle twitching, walking difficulties, anaemia, high fever and disorientation. Ghafar et al. (2020) reported that just like other tickborne diseases, the occurrence of ehrlichiosis is high during the summer seasons mainly because of favourable conditions created by high average temperatures and high humidity.

Rift valley fever

Rift valley fever is a disease that affects both humans and ruminant animals and caused by an arbovirus of the genus *Phlebovirus*, family *Bunyaviridae* (Javelle et al., 2020). Disease transmission in animals takes place following the bite of an infected mosquito and in humans it takes place following contact with infected animals and animal products (Petrova et al., 2020). Rift valley fever is usually associated with abortions. Rift valley fever is typically associated with occasional epidemics caused by an increase in the emergence of floodwater mosquitoes after an area experiences heavy rainfall. Table 1 presents an overview of the occurrence of vector-borne diseases in relation to climatic variabilities in some southern African countries.

Description of infectious, non-vectorized diseases of ruminants and their occurrences in relation to climatic variabilities in some southern African countries

Anthrax

Anthrax is primarily a disease of domestic and wild ruminants and is caused by *Bacillus anthracis*, a Gram-positive and spore forming bacterium (Islam et al., 2021). Constable et al. (2022) reported that environmental temperatures between the ranges of 12-42°C promote rapid sporulation of the bacterium. Similarly, higher occurrence rates have been reported in areas that experience heavy rainfall following prolonged drought conditions, dry summer months or after prolonged dry seasons with warm climates (Alam et al., 2022). *Bacillus anthracis* spores are usually present in the top layers of alkaline soils with high compositions of organic matter and calcium. The spores remain dormant in the soil during unfavourable climatic and environmental conditions for prolonged periods until the conditions become favourable and sporulation takes place (Pittiglio et al., 2022). The disease is transmitted when grazing animals ingest contaminated forage and inhale spores. Dead animals transmit the vegetative bacilli through their discharges

Table 2: The occurrence of infectious, non-vectorised diseases of ruminants in relation to climatic variabilities in some southern African countries.

Disease	Geographical location/Country	Animal species	Time period	Findings	Authors
Anthrax	Zambia	Cattle	1995 to 2018	<i>Bacillus anthracis</i> average seropositive rate of 24.9% reported during the summer seasons. Findings were attributed to the average temperatures (23°C) and average humidity (73%) during the study period.	(Simbotwe et al., 2019)
	Zambia	Cattle	1999 to 2007	A high disease occurrence rate was reported (1 216 cases) with a large number of cases occurring during the dry seasons (June to November) as compared to the wet seasons.	(Munang'andu et al., 2012)
	South Africa	-	2018	The occurrence of the disease was reported to be high during the dry periods (from late winter) with the disease trend showing a decrease as soon as the first rains occur.	(Steenkamp et al., 2018)
Foot and Mouth	Zambia	Cattle	2015 to 2020	Thirty-two percent of the primary outbreaks with an associated seropositivity rate of 77% were reported during extremely dry environmental conditions in the year 2019 (November to March). Outbreaks of foot and mouth disease are usually reported during the warm and dry periods. Although mortality rates are often low (<1%) morbidity rates are often high>75%)	(Banda et al., 2021)
Mastitis	South Africa	Cattle, Sheep and Goats	1996 to 2018	An average of 40% occurrence rate reported for 13 different staphylococcus species in milk samples that were collected across all seasons. Temperatures ranged from 28 - 30°C while rainfall ranged from 23 - 100 mm during the study period.	(Calkins and Scasta, 2020)
	Namibia	Cattle	1991 to 2000	An average occurrence rate of 3% reported with the occurrence being higher during the rainy seasons (January to March) as compared to the dry cool seasons (July to September).	(Monday and Yiseyon, 2022)
	Botswana	Goats	-	An average occurrence rate of 17, 8% reported for both clinical and subclinical mastitis in does under varying humidity levels.	(Undi et al., 2006)
Lumpy skin diseases	Namibia	Cattle	2017	Thirty-two primary outbreaks of the disease were reported during summer and winter seasons (January to July). These findings were attributed to the prevailing climatic conditions during the study period.	(Mugabe et al., 2017)
	Zimbabwe	Cattle	2013 to 2014	A total of 10 038 cases of the disease were reported with the highest incidence taking place during the wet autumn season (March and April).	(Molini et al., 2018)
					(Mafirakureva et al., 2017)

thereby contaminating the surrounding soil and water sources (Bakhteeva and Timofeev, 2022).

Foot and mouth disease

Foot and mouth disease is a highly contagious disease affecting cloven hoofed animals. The disease is caused by a virus of the genus *Aphthovirus* from the family *Picornaviridae* (Baro *et al.*, 2019). Foot and mouth disease is transmitted when an animal has direct contact with a contaminated environment and when virus particles are inhaled following direct contact between infected and non-infected animals (Paton *et al.*, 2009). The survival and occurrence of the virus is highly influenced by the environmental and climatic factors of an area. Naganayak *et al.* (2022) reported that foot and mouth disease virus is genetically unstable and that results in its genome evolution being largely influenced by the mutation pressure. Climatic and environmental conditions have a substantial effect on the mutation pressure. The virus can survive for longer periods in areas where the relative humidity is above 55% and temperatures are below 50°C (Colenutt *et al.*, 2020).

Mastitis

Mastitis is an infectious disease affecting udder tissue and results in inflammation of mammary glands. The disease is caused by various classes of microorganisms with bacteria such as *Staphylococcus aureus*, *Escherichia coli* and *Streptococcus uberis* being the commonly isolated pathogens (Cobirka *et al.*, 2020). Fukushima *et al.* (2020) reported that mastitis is characterised by an increase in the somatic cell count of the tissues of the udder and milk. Clinical signs of the disease include a swollen, red, painful and hot udder, permanent blockage of milk ducts and reduced milk production (Abdalhamed *et al.*, 2018). Factors that collectively influence the occurrence of mastitis in cattle herds include biosecurity measures, lactation stage, parity and the season (Smit *et al.*, 2013). Chen *et al.* (2022) reported high occurrences of mastitis high during the summer rainfall seasons. According to Dado-Senn *et al.* (2018), mastitis occurs because of the immune systems' response to the invasion of bacteria in the teat canal which is common during the summer seasons.

Lumpy skin disease

Lumpy skin is caused by a brick shaped enveloped virus belonging to the family Poxviridae (Gumbe, 2018). The disease is transmitted through the bite of arthropod vectors namely flies, ticks and mosquitoes. Another transmission route takes place when calves suckle milk from infected dams and when animals share feeding and watering points that are contaminated by saliva and nasal secretions (Issimov *et al.*, 2022). According to Choudhari *et al.* (2020) clinical signs of the disease include nasal discharges, salivation; fever of 40-41°C, lacrimation and lameness. In severe cases, the disease causes infertility in both males and females. Lumpy skin disease has been reported in difference countries around the world. Das *et al.* (2021) reported that the disease is more prevalent in areas with humid and

warm climates since these environmental conditions create ideal conditions for the growth and development of ticks, mosquitoes and flies hence the disease usually occurs in wet seasons. Table 2 presents an overview of the occurrence of infectious, non-vectored diseases in relation to climatic variabilities in some southern African countries.

CONCLUSION

Temperature and rainfall variabilities have an effect on the occurrence of ruminant diseases in the study area. Climatic variabilities compromise the overall health of the animal by creating conditions that facilitate the life cycle of disease-causing pathogens and vectors. Considering the adverse effects of climatic variations on livestock production, research should focus on ways of promoting farmer awareness to common livestock diseases and promote the adoption of management practices that will reduce the adversities of climatic conditions on animals and reduce the transmission and contamination rate of ruminant diseases.

Sources of data

Data used in this review were gathered from recently published articles in different journals. Databases were accessed using electronic data sources such as Science Direct, Google scholar, JURN, Directory of Open Access Journals and Research gate. In addition, the citations included in articles from the databases were used to search for other relevant articles. In the search process, the keywords were "climatic factors", "occurrence", "ruminant diseases" and "pathogens".

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All the authors listed in this manuscript give consent for publication.

Conflict of interest

All the authors have no conflict of interest to declare.

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