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EFFECT OF CLIMATE CHANGE ON TRANSMISSION OF LIVESTOCK DISEASES

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ABSTRACT

Livestock production is crucial in meeting global food demands and contributes significantly to nutrition, employment, and economic growth. However, the rapid increase in demand for livestock products is determined by income growth, and urbanization faces critical challenges from climate change. Rising temperatures can alter precipitation patterns and extreme weather events due to a negative impact on livestock productivity and exacerbate zoonotic disease transmission. Climate change affects the spread of zoonotic diseases by altering the distribution of vectors, pathogens, and hosts. Vector-borne diseases such as Rift Valley fever and African horse sickness are sensitive to climate fluctuations and lead to potential outbreaks in new regions. Additionally, livestock diseases like anaplasmosis and babesiosis may be stable in the endemic areas and could spread due to climate-induced shifts. The emergence and re-emergence of zoonotic diseases such as Ebola and influenza are tied to the interaction between livestock and humans. Ecological disturbances and climate changes drive them. As livestock health weakens their heat stress and reduces immunity, the risk of disease transmission increases, posing significant threats to animal and human health. This article reviews the current literature on climate change's effect on zoonotic disease transmission in livestock and explores potential plans for mitigating these risks in vulnerable regions.

Keywords: Zoonotic Disease Transmission, Livestock Health, Vector-borne Diseases, Emerging Pathogens

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1. INTRODUCTION

Human societies contribute significantly to livestock products and services to fulfill their daily food demands (Bett et al. 2017; Latino et al. 2020; Anuoluwa et al. 2024). Globally, livestock accounts for approximately 26% of ice-free land, and one-third of arable land is devoted to feed production. Livestock production contributes 33% of worldwide protein and 17% of global consumption of calories, providing roughly 40% of the global (Alders et al. 2021). However, it creates substantial employment opportunities for rural communities. In developing countries, food, nutritional security, livelihoods, and income are the rewards of the livestock sector (Bisht et al. 2020). Moreover, the demand for livestock products is increasing rapidly due to rising income, urbanization, and population growth. At the same time, the repercussions of climate change, particularly elevated temperatures, unpredictable precipitation patterns, a rise in extreme weather occurrences, and heightened carbon dioxide concentrations, adversely impact cattle output (Ashraf et al. 2017; Soumya et al. 2022).

These changes show adverse effects on livestock productivity throughout several regions. Additionally, livestock significantly contributes to greenhouse gas emissions due to a direct supplier of methane and nitrous oxide and an indirect source via land use and feed production (Cheng et al. 2022). Livestock emissions are estimated to constitute approximately 14.5% of total anthropogenic greenhouse gas emissions. Similarly, livestock productivity is affected by diseases, which also leads to financial losses, environmental harm, negative impressions on human health, and an increase in poverty (Altizer et al. 2013; Veneny 2023). The livestock sector plays a crucial part in the livelihoods of rural communities and the global economy. There is the greatest burden of animal outbreaks in developing countries, and these livestock diseases kill around 20% of ruminants and over 50% of poultry annually (Getachew and Mulatu 2023).

Global climate change contains harsh risks like social instability, population movement, economic challenges, and degradation of the environment. All ecosystems are affected by climate change and global warming is now

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widely accepted and will continue to be if no action is taken (Lal et al. 2015; Abdela and Jilo 2016). Agriculture and livestock are vulnerable in developing countries because poor rural communities face the most severe consequences of climate change (Sivakumar 2021). However, some environmental variation impacts have gained considerable focus, and effects on animals, particularly concerning their health and infectious diseases, have been largely overlooked. Climate change influences the emergence and dissemination of disease hosts, vectors, and infections by altering distribution patterns and host-parasite relationships in new regions (Wells and Flynn 2023). Climate change, including global warming, significantly affects animal health by both direct and indirect patterns. Climate-direct effects cause vector-borne, soil-associated, waterborne, rodent-related, or temperature- and humidity-sensitive diseases (Husen et al. 2022). Similarly, animals' attempts to adapt to new thermal environments, changes in microbial communities, the prevalence of vector-borne illnesses, host resistance to pathogens, and issues like feed and water absences or foodborne illnesses are occurring due to their indirect effects (Dietrich et al. 2023). Climate change can influence livestock health by factors such as vector abundance, wildlife reservoirs, and viruses' ability to survive in the environment. Furthermore, rising heat may accelerate the growth of some parasites or diseases that go through steps in their life cycle outside of their host animals (Magiri et al. 2020). This can promote lower generation durations and potentially increase the strength of pathogen or parasite generations per year ultimately resulting in larger population sizes. The geographic range and the intensity of pests and diseases can expand with the increase in temperature because it affects livestock productivity or even causes livestock deaths in extreme cases (Baylis and Risley 2023; Iqbal et al. 2024).

Zoonotic diseases are contagious illnesses that can spread from domestic or wild animals to people. These illnesses, which mostly have natural zoonotic origins, are especially important in light of the rise in infectious diseases that affect humans (Simpson et al. 2018; Singh et al. 2019; Rahman et al. 2020). A thorough analysis of Cleaveland et al. found that 1,415 types of infectious organisms can infect humans, including 217 viruses and prions, 538 bacteria and rickettsia, 307 fungi, 66 protozoa and 287 helminths. Of these, 175 pathogenic species were connected to newly emerging diseases; 132 (75%) of the 175 emerging pathogens were zoonotic (Kharate et al. 2022). Of these, 868 (61%) were categorized as zoonotic. The word "zoonosis" is used to describe a wide variety of epidemiological circumstances. Some pathogens, like rabies, West Nile, anthrax, and Nipah/Hendra viruses, are mostly limited to animal reservoirs and are uncommon or represent dead-end human infections (Marrana 2022). Others, like salmonellosis and TB in cattle, are well-established in both humans and animals. Certain infections, such as the viruses that cause monkeypox, Hanta, Lassa, and Ebola, fall into an intermediate category where animals serve as the primary hosts for diseases that sporadically affect people and create transmission chains that ultimately end (Vourc'h et al. 2022). For example, several zoonotic agents are now readily transmissible between humans because they have progressively evolved to human-to-human transmission. The unexpected development of certain animal-origin viruses, including influenza type A, HIV, and possibly severe acute respiratory syndrome (SARS), has impacted human populations recently (Recht et al. 2020).

To be considered a classic zoonotic disease, an emerging zoonosis must meet the criteria of "a zoonosis that is newly recognized and is showing increased incidence or increasing in geographic, host, or vector range." Certain illnesses might develop further to the point where they can spread from person to person. As a result, a newly discovered zoonosis spreads to new areas and may be an old infection that resurfaces (Braam 2023). Numerous illnesses, such as zoonotic diseases, which were previously under control worldwide but are now beginning to resurface, include malaria, dengue fever, cholera, tuberculosis, and yellow fever. Whether it comes to diseases like the flu, measles, smallpox, diphtheria, or HIV/AIDS, zoonotic illnesses have a less direct effect on human health (Yadav and Upadhyay 2023; Ali et al. 2024). But it's becoming more and more clear that zoonotic agents first spread a lot of these illnesses. Pandemics in the 20th century provided evidence supporting the theory that many newly emerging human diseases came directly from animal reservoirs rather than progressively developing from pre-existing zoonotic agents (Tomori and Oluwayelu 2023). HIV viruses did not appear to be approaching equilibrium, even though they might exist for several years before becoming a pandemic. Instead, the distinctive structure of the host contact network, initially confined to isolated rural villages, may have played a role in delaying the early phases of HIV development (Gangopadhayya and Bhukya 2023). Moreover, the key source of potential epidemics and the emergence of novel pathogens is increasing due to interaction between animals and humans. According to an estimation, 60% of emerging human pathogens are zoonotic. In short, the emergence and spread of zoonotic diseases are attributed to a combination of factors related to pathogens, hosts, vectors, and ecology (Tazerji et al. 2022). This review explores the current literature on the impact of climate change, human activities, and natural factors on zoonotic in developing countries. Thus, this paper aims to provide an overview of the effects of climate change on livestock health.

2. EFFECTS OF CLIMATE CHANGE ON LIVESTOCK HEALTH

The spread and distribution of livestock diseases are highly influenced by climate change (Tazerji et al. 2022).

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However, the incidence of diseases transmitted by insects, such as Rift Valley fever, African horse sickness, and bluetongue, is closely linked to seasonal and long-term climate changes (Gebremichael et al., 2023). Changes in climate influence infectious diseases in various ways, including the development of pathogens, changes in the distribution of diseases that impact vulnerable animal populations, and alterations in the distribution and abundance of disease vectors (Semenza et al. 2022). Additionally, changes in transmission rates are evident in climatic shifts between hosts (Thongsripong et al. 2021). Although a warmer climate will necessarily lead to more diseases not supported universally, other factors, including complex market chains and intensified production systems, may contribute to rising disease risks (Gomes et al. 2024; Ulllah et al. 2024).

2.1. Climate Change Effects on Disease Vectors and Pathogens

Arthropod vectors are vulnerable to climate change and are ectothermic. Variables like temperature, precipitation, and humidity play a critical role in their survival, reproduction, and behavior. Moreover, the vector factors, including distribution, abundance activity patterns, and biting rates, are affected by climate directly (Skendžic et al. 2021). Climate change may influence disease vectors through temperature and moisture changes often defining their geographical range (Caminade et al. 2019). Previously, in colder regions unsuitable for vectors, warming temperatures may allow these vectors to thrive in the hotter region and may become more or less suitable depending on moisture levels (Yadav and Upadhyay 2023). Consequently, climate change alters the life cycles and distribution of vectors and pathogens, and livestock will face exposure to new parasites and diseases. For example, shifts in the tsetse fly's African distribution are predicted and observed that may threaten livestock survival and productivity. Research in India has linked meteorological parameters such as temperature and humidity, to seasonal variations in diseases like Foot and Mouth Disease (FMD) and tick infestations in cattle. High temperatures accelerate the feeding frequency in arthropod vectors (McCown 2022).

Blood-feeding vectors often utilize two feedings for disease transmission that may be classified as the time to become infected and once to spread it. Warmer conditions can shorten the interval between feeds and increased transmission potential (Thongsripong et al. 2021). Higher humidity and rising temperatures often accelerate the growth of parasites and pathogens that have life cycle stages outside their hosts. Wind patterns may affect pathogen spread, while extreme weather events such as floods create conditions favorable for waterborne pathogens (Haikerwal and Saxena 2020). Additionally, climate change may extend the active season for warm-associated diseases and cold-associated diseases could reduce the number of infection cycles. Moreover, certain pathogens and vectors can survive more successfully in the warmer winter and overwinter. Flooding, which often follows extreme climate events, can spread pathogens, including Cryptosporidium and Escherichia coli, through agricultural runoff to pose zoonotic risks to livestock and humans (Libera et al. 2022).

2.2. Impact of Climate Change on Hosts

Climate change can alter the distribution of pathogens and vectors in livestock that may encounter new diseases, potentially leading to severe outbreaks in previously unaffected populations (Ogden et al. 2021). Climate stress, like heat and inadequate food and water, can weaken host immunity and make animals more susceptible to disease (Thongsripong et al. 2021). Previously, diseases that were stable in endemic areas may shift due to climate changes by affecting non-immune populations (Semenza et al. 2022). For instance, livestock diseases often exhibit endemic stability, whereas younger animals experience milder infections, and lifelong immunity follows (Batista et al. 2020). Climate change could disrupt this stability by leading to severe disease outbreaks in new regions (Gangopadhayya and Bhukya 2023). Their heightened exposure to ultraviolet B (UV-B) radiation causes ozone depletion. It can suppress cellular immunity in mammals making them more vulnerable to pathogens like viruses and bacteria (Kett et al. 2020).

3. CLIMATE CHANGE AND DISEASES EPIDEMIOLOGY

Climate change influences disease transfer between hosts to affect the survival of pathogens and vectors. For example, in 1990, a series of droughts in East Africa led pastoral communities to move cattle into wildlife areas where infected cattle spread rinderpest to susceptible wildlife. They resulted in devastating disease outbreaks (Lelenguyah 2023). Climate change can also alter the host's distribution, and predators, parasites, and competitors of disease vectors are also affected by climate change, creating new disease patterns (Filion et al. 2020). Ecological disturbances, including agricultural expansion, overgrazing, deforestation, and biodiversity loss, may lead to the emergence of new pathogens and vectors. These disturbances can mix different species and strains to expose hosts to novel diseases. In general, many diseases are transmitted by vectors such as ticks, mites, mosquitoes and flies susceptible to temperature and humidity (Njeru 2021). The distribution and abundance of

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these disease vectors may change due to rainfall and temperatures while extreme weather events can exacerbate disease transmission.

The IPCC (2013) reported that the projected rise in surface temperature is primarily attributed to increasing global atmospheric temperatures and greenhouse gases like carbon dioxide (CO_2). These changes and variations in precipitation have significant implications for livestock. Temperature affects rainfall patterns, forage availability, reproduction, and livestock health (Soumya et al. 2022). Therefore, higher temperatures, elevated CO2 levels, and changes in precipitation influence forage production. However, temperature increases and precipitation variability can also affect livestock health. The factors affecting livestock health are complex and involve environmental, ecological, social, and economic elements and individual and community behaviors (Tamboli et al. 2023). Climate change's direct and indirect effects on livestock are also mentioned in Fig. 1. Direct impacts are temperature-related diseases and increased mortality. Indirect impacts are more intricate and involve changes in pathogen density, vector populations, and the spread of vector-borne, soil-borne, and water-borne diseases (Başaran 2023).

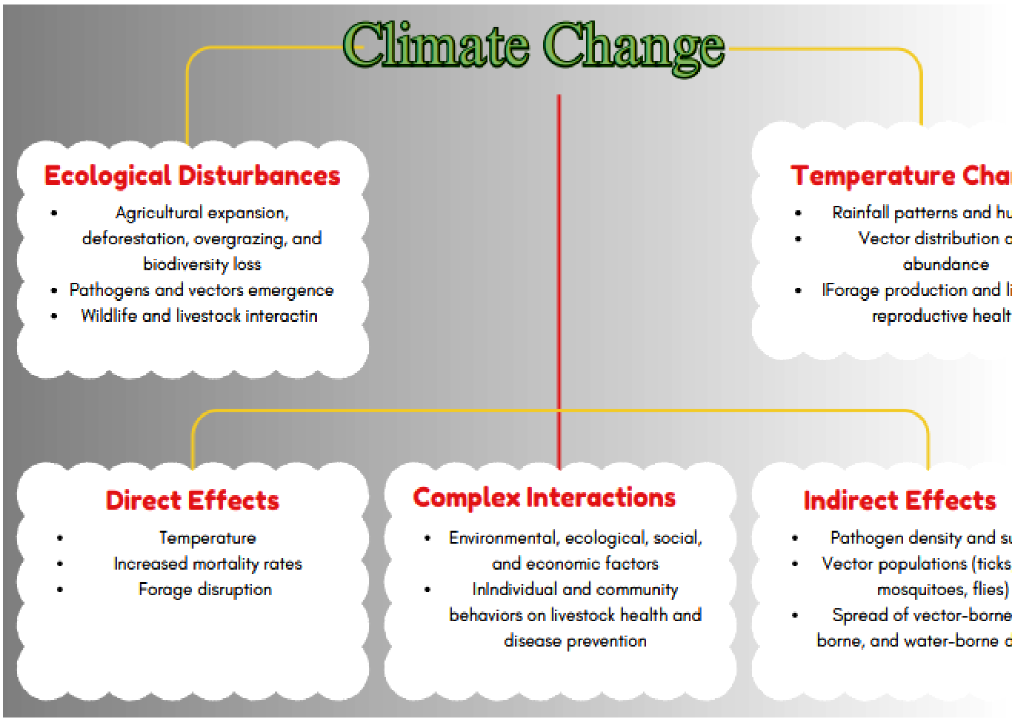

Fig. 1: Various effects of climate change on livestock (Cialdini and Jacobson 2021).

4. HEAT STRESS IN LIVESTOCK DISRUPTS MANY METABOLIC PROCESSES

Livestock poses homeothermic and adapts to high temperatures through increasing heat loss and reducing internal heat production. Moreover, this is achieved by boosting respiratory and sweating rates due to a decreased feed intake (Rashamol et al. 2020; Jafari et al. 2024). However, metabolic disorders may be led by these physiological adjustments. Some metabolic diseases are discussed below:

4.1. Lameness

Heat stress (HS) contributes to lameness in farm animals with ruminal acidosis or increased bicarbonate output (Burhans et al. 2022). Ruminal acidosis occurs because animals eat less during hotter periods but overeat during cooler times which can cause laminitis (McCown 2022). Prolonged standing due to HS may worsen claw conditions and can contribute to lameness (Webster 2020).

4.2. Ketosis

This metabolic disorder is marked by elevated levels of ketone bodies and a decrease in blood glucose (Skendžic et al., 2021). It is resulting from a negative energy balance and fat mobilization (Guliński 2021). HS exacerbates ketosis by reducing feed intake and increasing energy demands which can lead to weight loss and decreased milk production (Hubner et al. 2022).

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4.3. Oxidative Stress

Research into oxidative stress caused by HS has recently gained momentum (Balducci et al. 2023). This condition occurs through an imbalance between oxidant and antioxidant molecules resulting in increased reactive oxygen species (ROS) which damage cells through lipid peroxidation and enzyme inactivation (Ogden et al. 2021). The ROS are highly reactive molecules that can inflict the cellular damage through lipid peroxidation which disrupts the cell membrane as well as cause inactivation of biological enzymes resulting into impairment of metabolic processes (Pasha et al. 2024). During summer antioxidant levels like Vitamin E to decline and further aggravate oxidative stress in livestock (Costantini 2024). Reactive oxygen species cause heat stress in livestock species and it has become necessary for improving animal stress and productivity. Dietary interventions including supplementation with antioxidants like vitamin E, Vitamin C and selenium lessen the oxidative damage in livestock (Penev et al. 2021). During summer antioxidant levels such as Vitamin E tends to decline it reduces the ability of animals to neutralize excess ROS. This imbalance further exaggeration of Oxidative stress that can lead to inflammation, compromised immunity, reduced the fertility and lowers the milk and meat production (Cialdini and Jacobson 2021).

4.4. Immunosuppression

Heat stress weakens animal's immune systems by making them more susceptible to infections. In poultry, chronic HS is linked to reduced immune response (Penev et al. 2021). Dairy cows experience decreasing levels of colostrum immunoglobulins due to the effect of calf immunity (Cartwright et al. 2023). HS also hampers neutrophil function, which can increase infection risk and potentially lead to antimicrobial resistance (AMR), which is a growing global concern (Balducci et al. 2023). HS significantly hampers the function of neutrophils, essential immune cells responsible for combating infections. Impaired neutrophil activity increases the risk of bacterial and fungal infections in livestock, which leads to prolonged disease stress (Cartwright et al. 2023; Rashid et al. 2024). This immune dysfunction can also contribute to antimicrobial resistance, a global health concern. When this infection becomes severe, then it will become harder to treat, and the heavy potency of antibiotics is required for its treatment (Balducci et al. 2023). To rescue the animals suffering from immune suppression during heat stress, the livestock managers should improve their practices, enhance the doses of nutritional supplements, and prefer the breeds that are heat tolerant (Penev et al. 2021).

4.5. Reproductive Effects

Climate change adversely influences both males and females because the reproductive functions of livestock are highly vulnerable to climate change. Heat stress reduces reproductive performance in animals. Thermal stress disrupts reproductive processes through elevated temperatures and intense radiant heat, directly affecting the reproductive cycle through the hypothalamic-pituitary-ovarian axis (Penev et al. 2021). However, cows under heat stress often exhibit poor estrus expression due to reduced estradiol secretion from the dominant follicle that develops in a low LH environment.

During summer, conception rates in dairy cows can drop by 20–27% because heat stress negatively impacts ovarian function and embryonic development. Moreover, this can lead to lower conception rates and compromised embryo quality. In buffaloes, low estradiol levels during the summer result in poor estrus expression called silent heat. This is why during the summer; lower estrus expression and conception rates are recorded in crossbred cattle and buffaloes (Krishnan et al. 2017). Heat stress has negative impacts on reproduction by altering blood flow and hormone production. However, 20-30% conception rates in ruminants drop, and anestrus becomes more common in summer (Pasha et al. 2024). For example, the incidence of post-partum anestrus in cattle during summer reaches up to 14.43% in Bangladesh. Moreover, semen quality, estrus cycles, and embryo development are influenced by heat stress and further complicate livestock reproduction (Ali et al. 2020).

5. MITIGATING ZOONOTIC RISKS IN LIVESTOCK DEVELOPMENT POLICIES

The economic and human consequences of zoonotic disease epidemics in intensive livestock systems can be substantial. Disease epidemics are more likely to occur when livestock intensification is pushed without adequate risk mitigation and regulatory frameworks (Gwenzi et al. 2022). One noteworthy instance is the 2004 outbreak of highly virulent avian influenza that affected the Thai poultry industry. This outbreak was reported to have cost $3 billion and resulted in the death or culling of 62 million hens. It also caused 17 human cases and 12 deaths. Before this, Thailand was an annual exporter of more than 300,000 tons of chicken, and it had a market until importing nations closed their borders in response to World Trade Organization Sanitary and Phytosanitary (SPS) regulations. Later, it was found that the proximity of intensive and extensive poultry operations contributed to the spread of the disease (Sanwisate 2021). Dense populations of domestic and wild birds are mostly linked to the emergence of novel influenza by other species that can also be involved. Land-use changes primarily drive the disease spillover

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from wildlife to livestock. However, intensive livestock systems are amplifying zoonotic disease risks. Livestock often act as intermediate hosts to facilitate the evolution and transmission of pathogens to humans due to increased human-animal interactions compared to extensive systems (Goldstein et al. 2022). Moreover, dense populations and interconnected livestock operations with trade and transport create ideal conditions for disease transmission. Recently, outbreaks such as avian influenza have highlighted the importance of focusing risk mitigation efforts on surveillance and biosecurity to prevent disease spread. For example, research indicates that South and Southeast Asia and China are high-risk regions for zoonotic disease emergence due to environmental, agricultural, economic, and demographic factors. As these factors evolve, the new areas may also become hotspots for zoonotic outbreaks (Kang et al. 2024). Consequently, an opportunity to enhance surveillance and data analytics in low- and middle-income countries (LMIC's) is provided to identify emerging risks and implement preemptive measures (Pasha et al. 2024). The institutions responsible for surveillance and enforcement have often evolved in response to food safety crises and changes in consumer concerns about animal health and welfare in the region with the more established intensive system (Magnusson et al. 2022). National governments and multilateral organizations are launching various programs to address challenges though the sustainability of these efforts remains a concern. Similar to antimicrobial use (AMU) management, cultural and technical challenges in sustainable funding are critical to the long-term success of these programs (Coque et al. 2023). Fig. 2 shows the direct and indirect impact of climate change on livestock diseases.

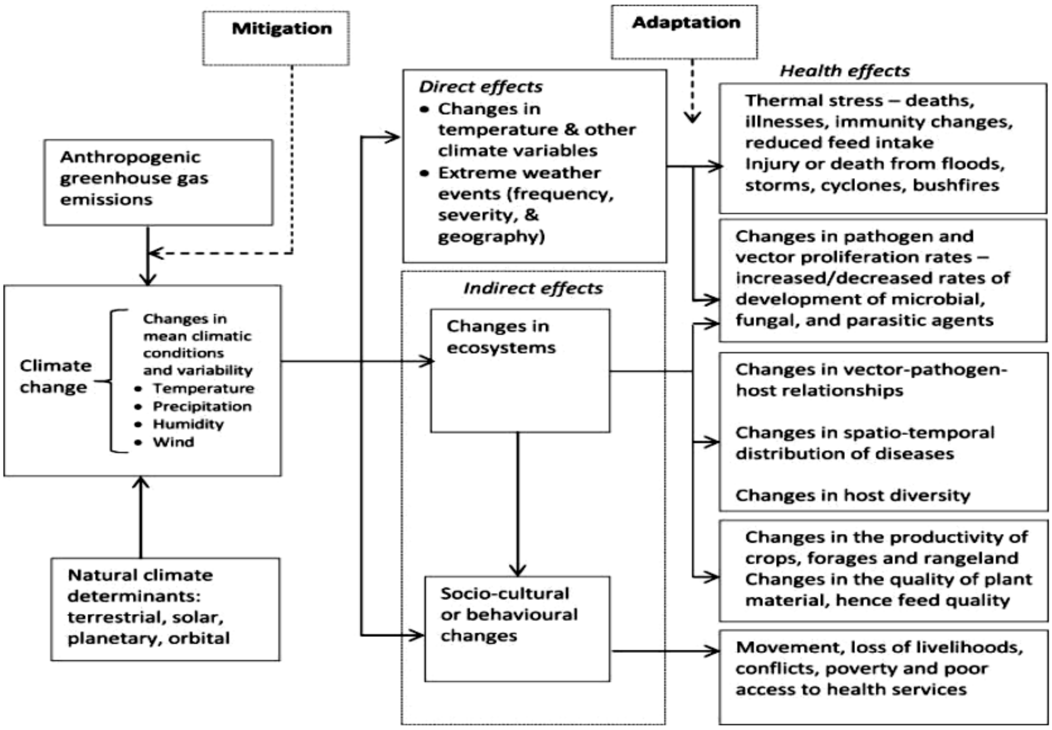

Fig. 2: An example of how livestock diseases are impacted by climate change both directly and indirectly (Haile 2020).

6. FUTURE PERSPECTIVE

Several factors, including evolving livestock management practices, environmental changes, advancements in animal genetics, and scientific innovations, will likely influence the future of infectious diseases in livestock (Ahmad et al. 2024). However, the impact of these factors remains difficult to predict. Climate change has a particular influence on the occurrence of livestock disease. Furthermore, 58% of animal diseases are susceptible to climate variations of 65 major. Livestock are susceptible to several nematode worm infections with climatic conditions, including temperature, to influence their development (Bautista-Garfias et al. 2022). The relationship between climate change and livestock disease is vital for effectively managing animal health. However, current knowledge on this relationship is limited in various countries, and the economic importance of livestock agriculture in the region (Hosain et al. 2021). Table 1 highlights the zoonotic threats in a changing climate, knowledge gaps and the recommended actions to be taken.

The dual challenge is responding to climate change to meet the growing demand for livestock production makes it difficult to simultaneously increase output and reduce the environmental footprint with greenhouse gas

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emissions. A deep understanding of how climate change affects livestock production and how adaptation and mitigation strategies can help to tackle these challenges (Menghistu et al. 2021). Therefore, the impacts of climate change on livestock production, associated emissions and potential adaptation and mitigation strategies are discussed in this review. Pathogens that undergo a brief, possibly barely noticeable zoonotic phase characterized by sporadic outbreaks and may go unrecognized by local health authorities continuously require a special look (Boguslavsky et al. 2022).

Table 1: Addressing Zoonotic Threats in a changing climate: Knowledge gaps, recommended actions, and technological needs

Pathogen	Knowledge Gaps	Recommended Actions	Technological Needs	References
Brucella	Unknown baseline levels in humans and wildlife	Conduct seroprevalence studies	Species-specific antibody assays for Brucella	Yagupsky et al. (2019)
	Role of marine Brucella unclear	Evaluate existing surveillance systems	Standardized diagnostics for different species	
			Field filter paper blood collection systems	
Toxoplasma	Unknown infection rates in humans and wildlife	Conduct seroprevalence studies	Field filter paper blood collection systems	Zeng et al. (2020)
	Predator-prey cycle role unclear in Arctic regions	Evaluate surveillance systems	Validate diagnostics and surveillance tools	
Trichinella	Lack of infection data in humans and wildlife	Conduct seroprevalence studies	Animal-specific antibody assays	Hegedus et al. (2023)
		Evaluate surveillance systems	Field filter paper blood collection systems	
Giardia/Cryptosporidium	Underreported infection levels	Improve surveillance systems	- Develop serological tests	Bergwerff and Debast (2021)
	Impact of molecular strain variations on disease		Strain-specific molecular diagnostic tools	
Echinococcus	Unknown infection status in humans and wildlife	Assess dog treatment programs	Species-specific diagnostic tests	Schurer et al. (2019)
		Improve surveillance	Molecular variation studies for better strain identification	
Rabies	Prevalence in wildlife reservoirs not well understood	Establish systematic surveillance in fox populations	Enhance Direct Immunohistochemical Test (DRIT)	Singh et al. (2017)
Tularemia	Lack of baseline infection data in humans and wildlife	Conduct surveillance system evaluations	Improve diagnostic accuracy	Kendall et al. (2018)
Other Agents	Inconsistent disease awareness and response to climate change	- Increase education, outreach, and collaboration efforts	Convene expert working groups to monitor progress and actions	Mauser et al. (2013)

7. CONCLUSION

Climate change poses a profound threat to livestock health in terms of zoonotic disease transmission. Globally, temperatures are rising, and vectors and pathogens are adapting to new environments to increase the likelihood of outbreaks in previously unaffected regions. Heat stress, other climate-induced factors, and weakened livestock immunity further amplify the risk of zoonotic disease transmission. This interplay between climate change and disease emergence highlights the need for urgent interventions like enhanced surveillance, biosecurity measures, and adaptive livestock management practices. Without action, the effects of climate change on zoonotic diseases could worsen and pose significant risks to global public health and food security. These challenges may be addressed by requiring a multifaceted approach that includes climate adaptation strategies and a deeper understanding of how environmental shifts impact disease dynamics in livestock.

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