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Review Article

Impacts of Climate Change on Vector-Borne Pathogens: Emerging Threats to Livestock Health and Production

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ABSTRACT

Climate change, one of the greatest challenges of the current century, increasingly affects the geographic distribution, seasonal abundance, and transmission capacity of arthropod vectors such as ticks, mosquitoes, and flies. The present study aimed to review the available scientific evidence on the ecological and epidemiological mechanisms by which climate change affects the transmission dynamics of vector-borne diseases in farm animals. Adaptation and risk-reduction strategies, including integrated vector management, vaccine development, climate-based early warning systems, and changes to farm management practices, were reviewed by the present study. These environmental changes have facilitated the emergence and re-emergence of vector-borne diseases in livestock, posing significant threats to animal health, food security, and the global economy. Higher temperatures, milder winters, and changes in precipitation patterns have expanded vector distributions to higher latitudes and elevations and prolonged their periods of activity. Consequently, diseases traditionally endemic to tropical regions, including Rift Valley fever, theileriosis, babesiosis, anaplasmosis, and Crimean-Congo hemorrhagic fever, were observed in temperate regions. Many of these diseases are zoonotic, highlighting the need for a One Health approach. Direct effects on production included weight loss, reduced milk yield, abortion, infertility, and increased mortality, all of which resulted in major economic losses to the livestock industry. Finally, the present study underscored the need to address these emerging threats and sustain livestock production in a changing climate.

1. Introduction

Climate change has become an undeniable reality and one of the biggest dangers to people's health, food security, and the sustainability of ecosystems worldwide[1]. The Earth's temperature is rising at an unprecedented rate, rainfall patterns are changing, floods and droughts are becoming more frequent and severe, and polar glaciers are melting[2]. All signs that the world's environmental conditions are undergoing a fundamental shift. Climate change affects not only human life, but also directly and indirectly the health and productivity of farm animals, which are one of the main sources of protein for mankind[3,4]. In this context, vector-borne diseases are one of the most sensitive indicators of ecosystem responses to climate change[5].

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Vector-borne diseases, including those transmitted by ticks, mosquitoes, flies, and fleas, have consistently been among the principal obstacles to the growth of the livestock sector worldwide, especially in tropical and subtropical areas[6] (Figure 1). In addition to causing livestock mortality, these diseases bring substantial economic losses to farmers as a result of chronic illness, weight loss, decreased milk and meat production, miscarriages, and infertility[7]. At the same time, many vector-borne pathogens are zoonotic and capable of being transmitted from livestock to humans, a fact that elevates them from a veterinary problem to a public health problem[8-10].

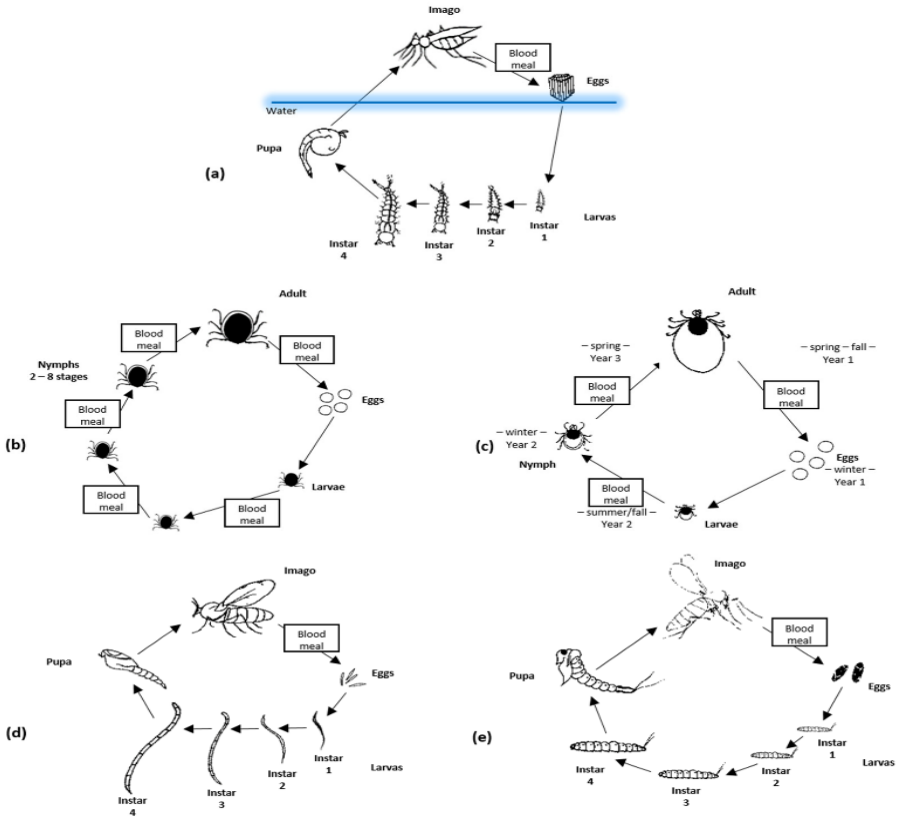


Figure 1. Life cycles of major arthropod vectors. **a**: Mosquitoes, **b**: soft ticks, **c**: hard ticks, **d**: biting midges, and **e**: sandflies. Source: MDPI Copyright, 2022; Socha et al.[6]

Climate change affects vector ecology and disease transmission dynamics in multiple ways. Temperature is an important factor affecting the life cycle of arthropods[11]. Higher temperatures may increase vector growth and reproduction and shorten larval development time, allowing more generations per season[12]. In addition, milder and shorter winters favor the persistence of adult vectors and larvae during the cold season, extending their activity period into early spring and late autumn[13]. Changes in precipitation patterns alter the availability of stagnant water (mosquito breeding sites) and vegetation (tick habitats) and thus could lead to new environments for vectors[14].

One of the most obvious consequences of global warming is the geographical redistribution of vectors to higher latitudes and altitudes[15,16]. Global warming has driven the emergence of diseases formerly endemic to tropical regions, including Rift Valley fever, theileriosis, babesiosis, anaplasmosis, and Crimean-Congo hemorrhagic fever (CCHF), in temperate zones of Europe, Central Asia, and North America[13,17]. This geographic spread renders vulnerable livestock populations susceptible to novel pathogens for which their immune systems have no prior adaptation, and may give rise to severe epidemics and widespread losses[18].

Climate change profoundly affects vector-borne diseases and has significant economic consequences for the global livestock sector[19]. Direct costs include treating diseased animals, vaccination, and vector control measures such as pesticide application[20], whereas indirect costs include reduced production, declining product quality, import restrictions, and international quarantine measures[21]. From a public health perspective, the increasing incidence of vector-borne zoonotic diseases such as CCHF implies an increased risk of transmission to humans and an increased burden on national health systems[22]. This situation underscores the crucial need for a holistic, interdisciplinary approach called One Health, which understands human, animal, and environmental health in an integrated manner[8].

The management of vector-borne diseases is affected in many ways by climate change. Traditional vector-control methods, such as pesticides, are becoming less effective because vectors are increasingly resistant and because of environmental concerns[23,24]. In addition, climate change prevents traditional epidemiological models based on historical data from accurately predicting outbreaks[25,26].

Therefore, dynamic adaptation strategies are needed, such as integrated vector management, early warning systems based on climate models, next-generation vaccines, and modified farm management practices such as altered grazing schedules and selective breeding for increased resistance. The present study aimed to evaluate the impacts of climate change on vector-borne diseases in farm livestock, addressing gaps in researchers' understanding of the complex links between climate change, vector ecology, and livestock disease epidemiology.

2. Search criteria

A narrative and comprehensive search was conducted in reliable international databases, including PubMed/Medline, Scopus, and Web of Science. Google Scholar was also used as an additional source to maximize coverage of gray literature and emerging publications. The search period was from January 2021 to October 2026 to include the most recent scientific evidence in this rapidly developing field. The search was limited to English-language articles, including reviews, original research, and systematic reviews. All identified records were imported into EndNote for systematic duplicate removal and title and abstract screening.

The search strategy was developed following standard narrative review principles and using a Concept Blocks structure[27]. Three core concepts were defined separately, including climate variables, vector-borne diseases, and farm livestock. To enhance search sensitivity, synonymous keywords in each block were connected with the OR operator. The blocks were then combined with the AND operator to increase search precision. For instance, the climate block contained terms such as climate change, global warming, temperature, and precipitation. The vector-borne diseases block included vector-borne diseases, tick-borne, mosquito-borne, and specific diseases such as Rift Valley fever, Bluetongue, Theileriosis, and CCHF. The farm animals block included the words livestock, ruminant, cattle, sheep, and goat. The search strategy was executed in PubMed using MeSH terms.

3. Ecological and climatic mechanisms affecting vectors and pathogens

3.1. Temperature

Temperature constitutes a significant environmental factor governing the ecology of arthropod vectors[28]. As arthropods are poikilothermic (ectothermic), their body temperature is directly regulated by ambient temperature[29]. Vector biological parameters are therefore significantly affected by the rising temperatures associated with climate change. First, higher temperatures increase larval growth and development rates, thereby decreasing the time to reach sexual maturity. Secondly, temperature influences the longevity of adult vectors, with a longer lifespan in the optimal temperature range (generally 20–30°C), but a shorter one at extreme temperature levels[30]. Third, temperature influences the blood-feeding rates and frequency. Increased vector metabolism at higher temperatures increases blood meal requirements, which in turn increases the likelihood of contact with host livestock and subsequent pathogen transmission[30].

3.2. Precipitation patterns and humidity

Additional significant factors affecting vector ecology include precipitation patterns and humidity. Climate change has modified the spatial and temporal distribution of rainfall, such that some areas experience greater torrential rains while others face prolonged periods of drought. Such changes will have differential effects on vector populations[31]. Heavy and torrential rains can create larval habitats for mosquitoes, with eggs being laid and larvae developing in stagnant water that accumulates in puddles, discarded tires, water storage containers, and irrigated fields[32]. Conversely, long-term droughts can reduce river flow and generate more stagnant water bodies, which in turn drives up mosquito populations. High relative humidity is an essential factor for tick survival, given that ticks are sensitive to desiccation[33]. Changes in vegetation as a consequence of altered precipitation patterns affect tick access to intermediate and definitive hosts[34]. In addition, high humidity can also influence the survival of pathogens outside the vector body[35]. Certain viruses and bacteria can survive for longer periods in humid conditions, which elevates the probability of transmission. Accordingly, changes in precipitation and humidity patterns not only influence vector populations but also exert a direct effect on pathogen survival[36].

3.3. Seasonal changes and overwintering

Climate change alters seasonal patterns, which in turn affect vector activity and disease transmission[28]. The most noticeable changes are milder winters and a shorter cold season. As a result, adult vectors and larval stages can overwinter and become active earlier in the spring. This phenomenon is called overwintering[37]. The result is a prolonged period of vector activity and a greater number of generations per year[38] (Figure 2). *Ixodes ricinus* ticks, the vectors of Lyme disease and babesiosis, are active in winter in temperate regions of Europe, whereas they were once active only in spring and summer[39]. This seasonal change increases the risk of vector exposure for livestock during previously safe periods[16]. Also, shifts in the timing of migration of birds and other wildlife that act as intermediate hosts can help introduce pathogens to new areas[40].

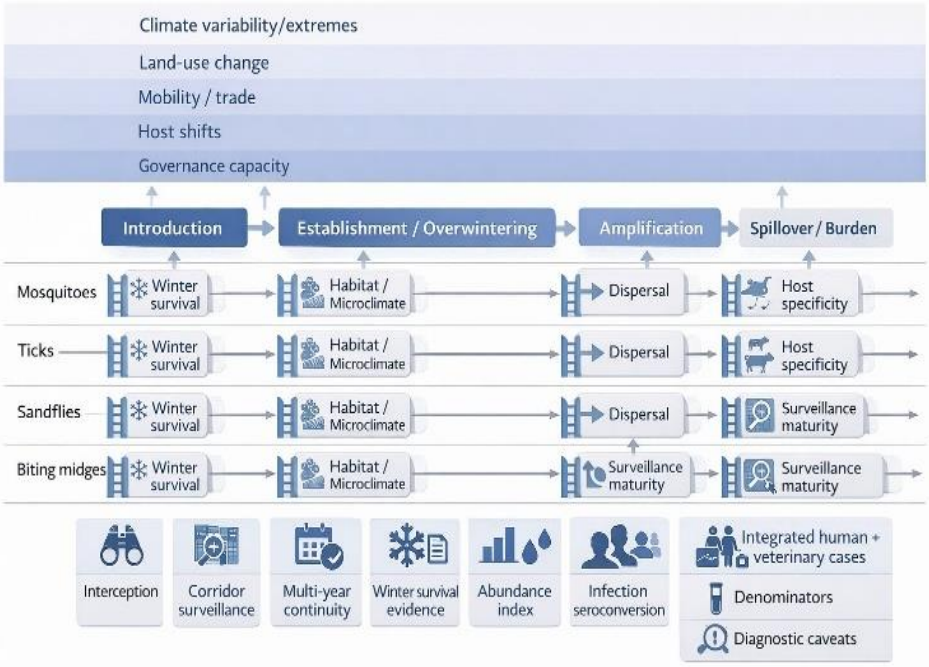


Figure 2. Stages of invasion, establishment, and spillover of vector-borne pathogens including mosquitoes, ticks, sandflies, and biting midges, driven by climatic and environmental changes (Source: MDPI Copyright, 2026; Touati et al.[38])

3.4. Pathogen transmission cycle

Climate change affects not only vectors but also the pathogen transmission cycle directly. One key parameter in this framework is the extrinsic incubation period, which refers to the time required for a pathogen to complete its life cycle in the vector and become capable of transmission to a host[41,42]. The extrinsic incubation period gets shorter as temperatures increase; for instance, the pathogen replicates faster within the vector and can transmit disease more easily[43,44]. This change increases transmission and accelerates disease spread in livestock populations. Increased temperatures can also affect vector competence, the ability of the vector to transmit the pathogen[11,43-46]. Several studies demonstrated that viruses such as Rift Valley fever and bluetongue replicate more rapidly in mosquitoes at higher temperatures, increasing the likelihood of transmission to livestock[8,17,47]. In addition, climate change may affect interactions between pathogens and vectors' immune systems, leading to changes in infection patterns. Figure 3 illustrates the impacts of temperature on vectors' habitats and life cycle.

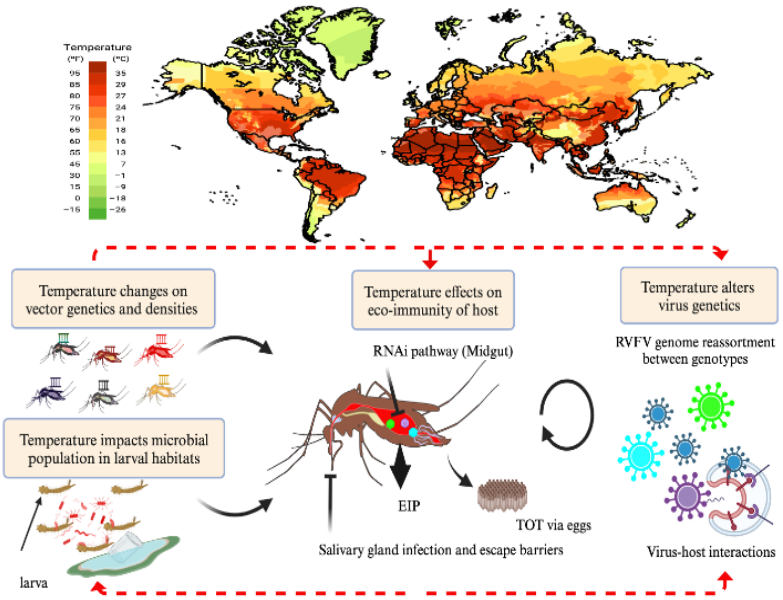


Figure 3. Effects of temperature on the natural habitats of mosquitoes and virus genetics (Source: MDPI Copyright, 2025; Azerigyik et al.[47])

4. Geographic distribution of vector-borne diseases

4.1. Tick-borne diseases

Ticks are the most important arthropod vectors affecting farm livestock and transmit numerous diseases that have significant economic impacts. Epidemiological evidence indicates that climate change has led to the substantial spread of these diseases such as Theileriosis, Anaplasmosis, CCHF, and Babesiosis into temperate regions and higher latitudes. Theileriosis is caused by the protozoa *Theileria annulata* and *Theileria parva* and transmitted by ticks of the genera *Hyalomma* and *Rhipicephalus*[47-49]. The life cycle of *Theileria* spp. Is depicted in Figure 4. Recent studies demonstrated the disease was spreading into areas of Northern Europe and Central Asia that have been free of theileriosis[50]. For instance, bovine theileriosis has been reported in Kazakhstan and Southern Russia, where cold temperatures previously prevented vector tick survival[51]. Additionally, the expansion of vector-borne diseases is associated with rising average summer temperatures and milder winters.

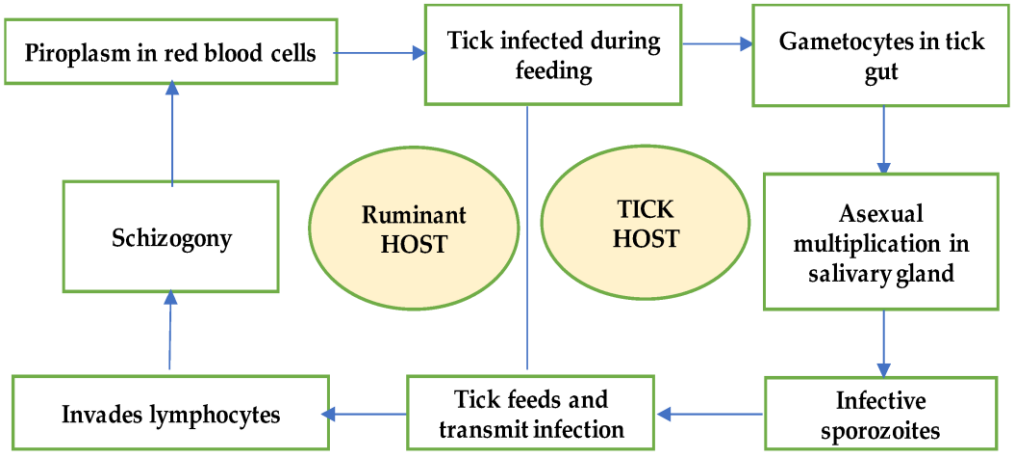


Figure 4. Life cycle of *Theileria* showing different stages in ruminants and tick hosts (Source: MDPI Copyright, 2022; Zeb et al.[52]).

Babesiosis is caused by *Babesia bovis* and *Babesia bigemina*, transmitted by ticks of the genus *Rhipicephalus*[53] (Figure 5). Bovine babesiosis has been detected in Europe in countries such as Germany, Poland, and the Baltic states[53,54]. This proliferation was linked to higher winter temperatures and longer periods of tick activity.

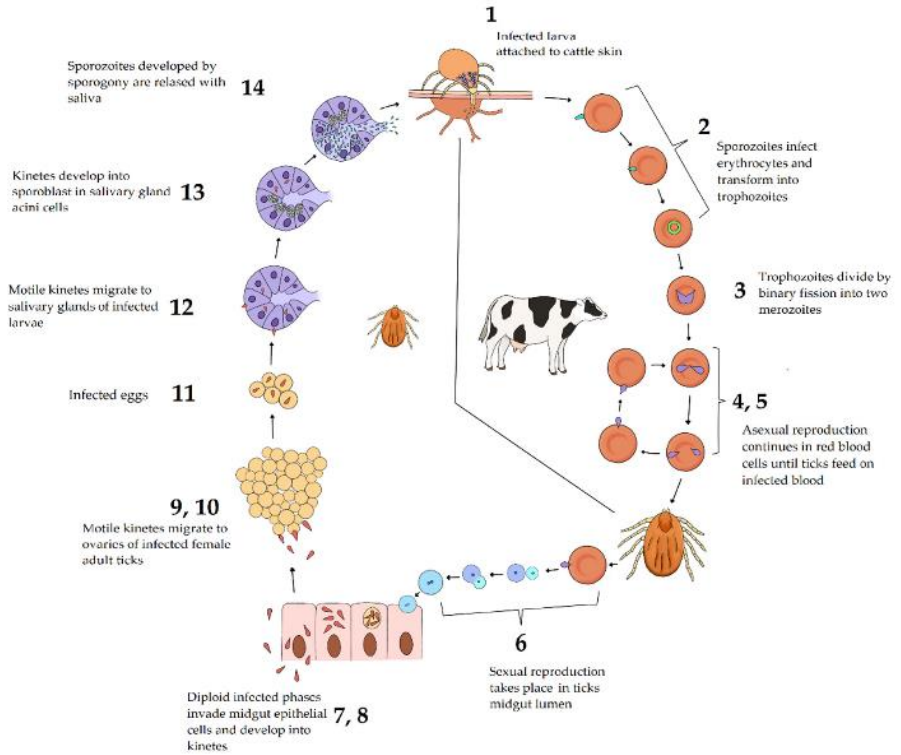


Figure 5. *Babesia bovis* life cycle (Source: MDPI Copyright, 2021; Hildebrandt et al.[53])

Anaplasmosis is caused by *Anaplasma marginale* and is transmitted by ticks of the genera *Rhipicephalus* and *Dermacentor*[55]. The spread of anaplasmosis in the temperate regions was demonstrated by epidemiological studies[56,57]. Anaplasmosis in cattle has been reported in previously disease-free western Canadian provinces of North America[55]. This spread was associated with rising temperatures and changes in precipitation patterns. Crimean Congo hemorrhagic fever is a zoonotic viral disease transmitted by ticks of the genus *Hyalomma*[58]. The Transmission cycle of CCHF is illustrated in Figure 6. Crimean Congo hemorrhagic fever is endemic in large areas of Africa, Asia, the Middle East, and Southeast Europe[59]. Recent studies indicated that CCHF was expanding across Europe, with reported cases in Spain, Portugal, and Greece[60,61]. This expansion was linked to rising summer temperatures and milder winters, which allowed vector ticks to survive.

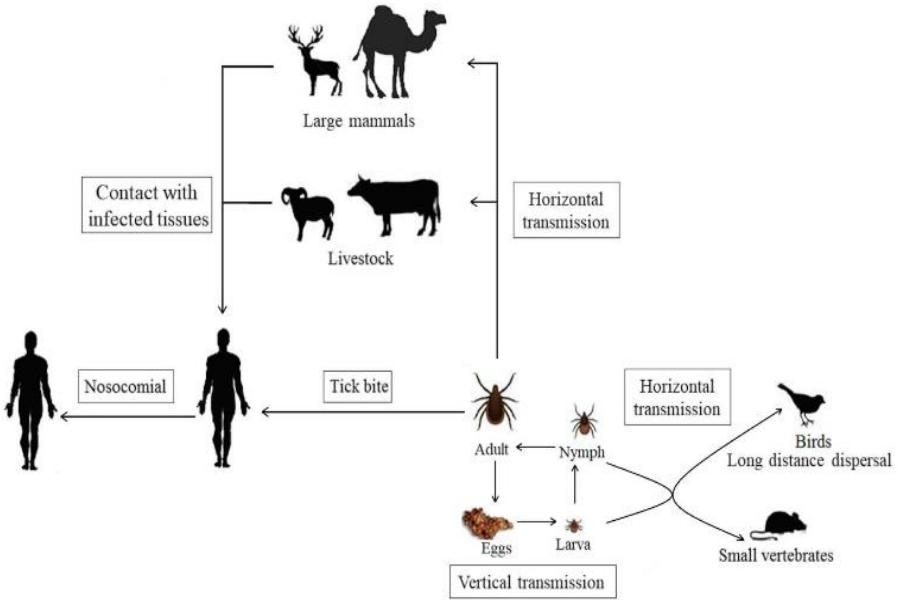


Figure 6. Transmission cycle and routes of Crimean-Congo hemorrhagic fever (Source: MDPI Copyright, 2021; Shahhosseini et al.[62])

4.2. Mosquito-borne diseases

Mosquitoes are important vectors of viruses that cause disease in farm animals, and climate change has significantly increased the spread of these diseases. Rift Valley fever is a viral disease of ruminants transmitted by mosquitoes of the genus *Aedes* and *Culex*, resulting in abortion and high mortality rates[63,64] (Figure 7). Rift Valley fever is indigenous to Africa and the Arabian Peninsula. Recent studies indicated that Rift Valley fever is moving to new areas in North Africa and the Middle East. Cases have been reported in Egypt, Tunisia, and Saudi Arabia[63,65,66]. The spread of Rift Valley fever was associated with increased torrential rainfall, which created breeding sites for mosquito larvae.

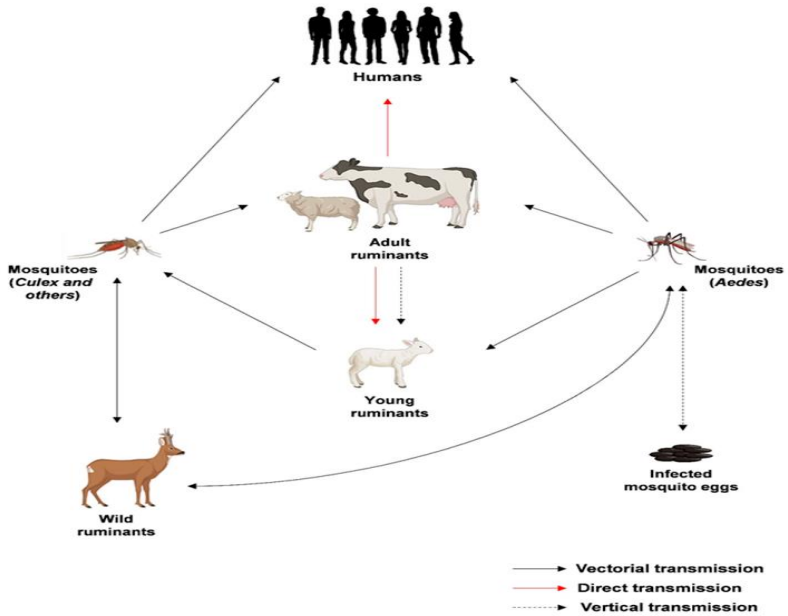


Figure 7. Epidemiological transmission cycles of Rift Valley fever (Source: MDPI Copyright, 2024; Lapa et al.[64])

Bluetongue is a viral disease of sheep and cattle, transmitted by *Culicoides*, that causes fever, oral lesions, and mortality. Bluetongue is an endemic disease of tropical and subtropical zones[67,68]. Recent evidence suggested that bluetongue was entering temperate regions of Europe, and there have been recent reports of cases from countries such as Germany, the Netherlands, Belgium, and the United Kingdom[69,70]. This increase in bluetongue distribution was associated with increasing summer temperatures and the longer activity period of the vector midges. Figure 8 depicts the environmental factors that are associated with bluetongue disease outbreaks.

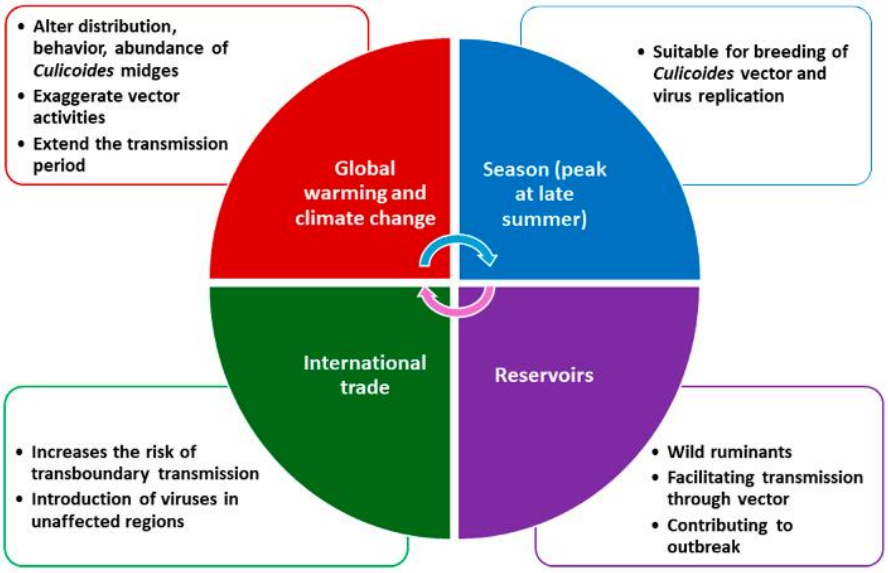


Figure 8. Factors influencing the risk of bluetongue and epizootic hemorrhagic disease virus outbreaks (Source: MDPI Copyright, 2024; Barua et al.[68])

West Nile fever is a mosquito-borne disease transmitted by *Culex* mosquitoes and can cause encephalitis in horses and humans[71,72] (Figure 9). Recent studies found that West Nile fever was spreading across Europe and North America[72-74]. Cases in horses have been recorded in countries such as France, Italy, and Greece.

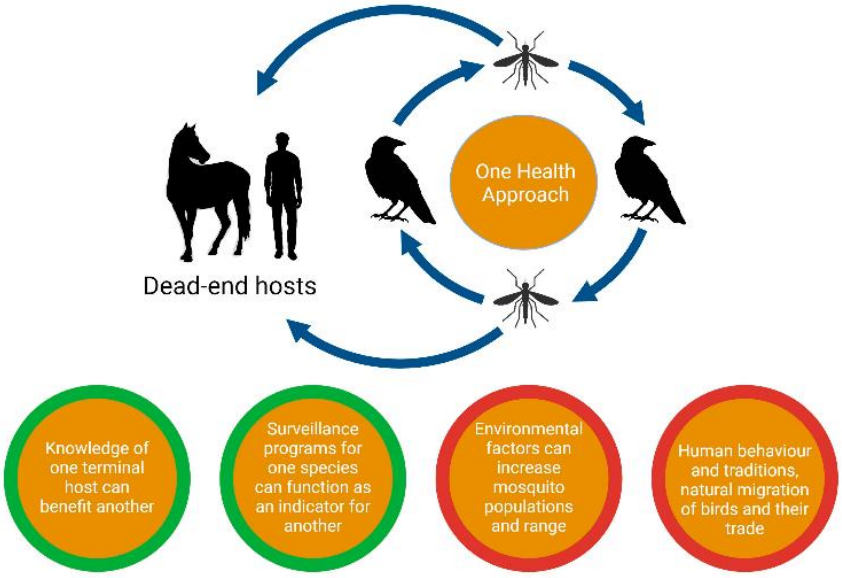


Figure 9. West Nile Virus transmission cycle and surveillance indicators. Green circles indicate public health opportunities, red circles indicate risk factors that drive the virus (Source: MDPI Copyright, 2024; Naveed et al.[71])

4.3. Fly-borne diseases

Flies are also important vectors of livestock diseases. Climate change has affected the distribution of flies. Trypanosomiasis is caused by *Trypanosoma* spp., transmitted by the tsetse fly (*Glossina* spp.), and causes Nagana disease in livestock[75-77]. Trypanosomiasis is endemic to Africa (Figure 10); however, recent studies indicated that climate change could modify the distribution of the tsetse fly, thereby placing previously unaffected areas at risk, and these shifts were associated with changes in temperature and humidity[78,79].

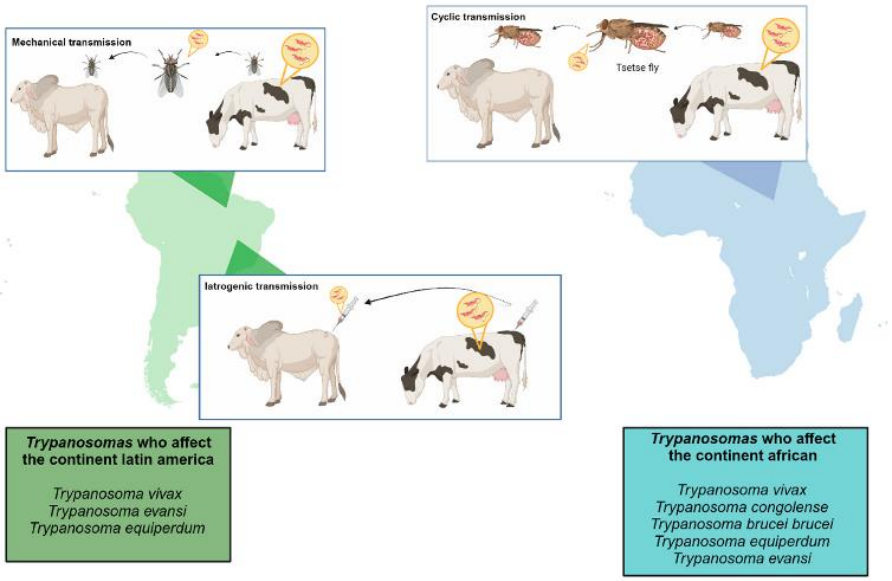


Figure 10. Transmission mechanism between trypanosomes on the African and Latin American continents (Source: MDPI Copyright, 2024; Pereira et al.[77])

Leishmaniasis is caused by *Leishmania* spp. and transmitted by sandflies (*Phlebotomus* spp.), and it is endemic to tropical and subtropical areas[80-82]. Recent studies indicated that leishmaniasis is emerging in temperate Europe, as countries including Spain, Italy, and France have reported cases in dogs and humans[83-88]. The life cycle of leishmaniasis is depicted in Figure 11.

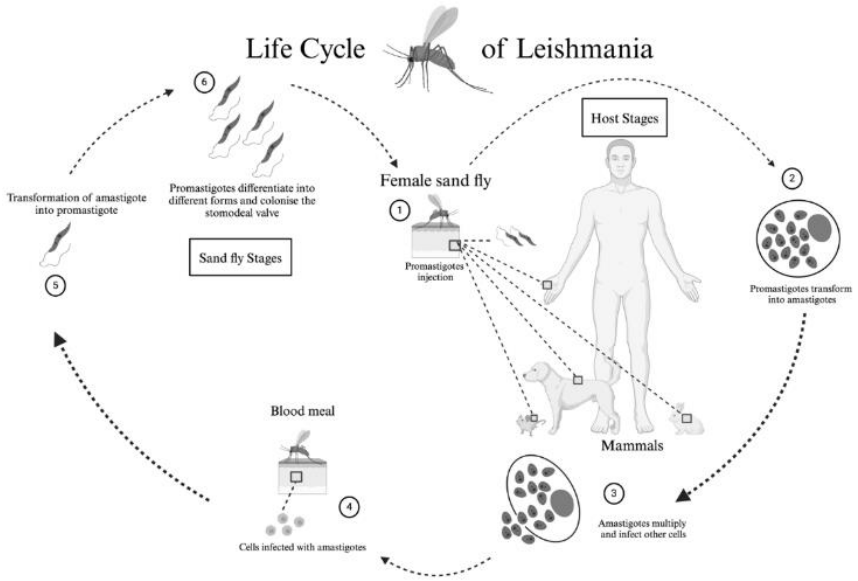


Figure 11. Life cycle of the *Leishmania* protozoan parasite (Source: MDPI Copyright, 2024; Cosma et al.[89])

5. Clinical, economic, and public health consequences in the livestock industry

5.1. Clinical impacts

Vector-borne diseases in farm animals have a wide range of clinical signs from mild subclinical infections to acute fatal diseases[90]. The severity of signs depends on several factors, including pathogen species, immune status, age, sex, and the animal's nutritional condition. Vector-borne diseases can generally be of acute, subacute, or chronic form and negatively affect the animal's health and welfare[91-93]. Animals affected by the acute form of the disease may present with high fever, anorexia, depression, general weakness, lameness, oral and skin lesions, diarrhea, anemia, and jaundice. In acute theileriosis, for instance, infected cattle develop high fever (up to 41°C), swollen lymph nodes, and severe anemia and may die within a few days in the absence of treatment[94]. In acute babesiosis, signs include fever, hemoglobinuria, anemia, and jaundice, all of which arise from parasite-induced destruction of red blood cells[95,96]. The chronic form may manifest with less severe but persistent signs, such as gradual weight loss, decreased milk production, infertility, recurrent abortion, and immunodeficiency[97,98]. Livestock owners often overlook

this chronic form because the signs are nonspecific; nevertheless, its impact on farm productivity and economics is considerable. In chronic anaplasmosis, for example, affected cattle suffer weight loss and reduced milk production, which translates into economic losses[55,99]. Vector-borne diseases can predispose livestock to common secondary bacterial and viral infections. The primary infection impairs the immune system, and opportunistic pathogens can take advantage of this, potentially increasing disease severity and mortality[100]. More importantly, some vector-borne diseases can lead to permanent complications like infertility, recurrent abortion, and damage to internal organs that considerably reduce the economic value of the livestock.

5.2. Direct and indirect economic losses

The global livestock industry suffers significant economic losses due to vector-borne diseases. These losses can be classified as direct or indirect. Direct losses include the costs associated with treating sick animals, using antiparasitic medicines, antibiotics, and fluid therapy, vaccination, spraying and vector control, quarantining infected animals, and disposing of dead livestock[101]. Treating a single cow with acute theileriosis may cost several hundred dollars, imposing a substantial financial burden on small-scale livestock farmers. In addition, the costs of vector control, including routine spraying and the procurement of pesticides and equipment, constitute considerable annual expenditures[102].

Indirect losses are often greater and less visible than direct losses. Indirect losses include reduced production (milk, meat, wool), reduced quality of products, weight loss, infertility and abortion, increased mortality, and trade restrictions or international quarantines[101]. In a Rift Valley fever outbreak, abortions in cattle and sheep can reach 100% of the herd, with irreparable economic loss to farmers[102,103,104]. Restrictions on exporting livestock and livestock products from infected areas can cost national economies millions of dollars.

5.3. Food security and farmers' health

Vector-borne diseases affect animal health, the economics of the livestock industry, and the food security and livelihoods of communities dependent on livestock. Billions of people around the world depend on farm animals for the majority of their animal protein, meat, milk and eggs. Reduced production and increased livestock mortality from vector-borne diseases limit access to these protein sources[103] (Figure 12). Such declines can lead to malnutrition and food insecurity in low-income and rural areas where livestock are a primary source of nutrition and income. For instance, in Africa, trypanosomiasis (nagana) kills millions of cattle every year, threatening the food security of millions of people[104].

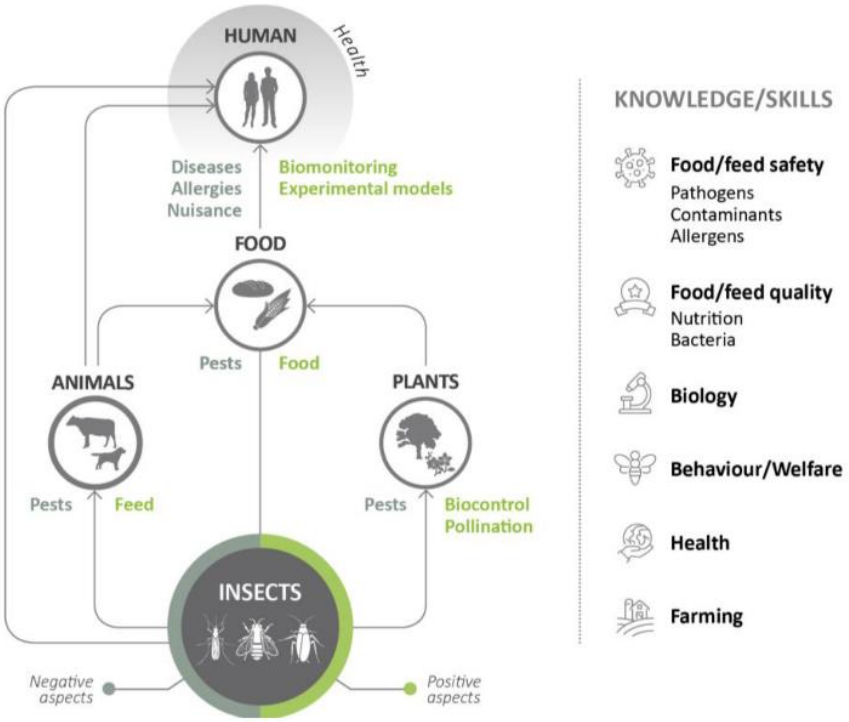


Figure 12. Positive (green) and negative (grey) relationships between insects with respect to contexts with public health implications (Source: MDPI Copyright, 2023; Belluco et al.[105])

Vector-borne diseases pose the greatest threat to the livelihoods of livestock farmers, particularly smallholders. Reduced yields, elevated treatment costs, and livestock mortality can drive their incomes far below the poverty line[103]. Trade barriers and international quarantines can also keep farmers from accessing export markets and earning foreign currency. Small-scale farmers in many developing countries may sell their livestock at low prices

or even give up livestock farming because they cannot afford to absorb such losses. Vector-borne diseases threaten the social and economic fabric of rural communities, resulting in migration to cities and greater urban marginalization, which creates new socio-economic challenges for governments[104].

6. Conclusion

Climate change is a significant factor that affects the epidemiology of vector-borne livestock diseases. Rising temperatures, changing precipitation patterns, milder winters, and shorter pathogen incubation periods are contributing to the spread of diseases such as theileriosis, babesiosis, anaplasmosis, CCHF, Rift Valley fever, and bluetongue. Geographic expansion carries significant clinical, economic, and public health consequences, including reduced production, increased mortality, billions of dollars in losses, threats to food security, and heightened zoonotic risks to humans. Addressing this issue requires an integrated, evidence-based approach that considers animal, human, and environmental health collectively. Future studies should prioritize developing artificial intelligence- and satellite-based early warning systems, paired with cross-border data sharing, so outbreaks can be detected in real time before they spread into newly at-risk regions.

Declarations

Authors' contributions

Ali Heydari and Ali Sarani conceptualized the study and designed the narative review protocol. Saeed Ramezani Nejad and Saeed Jafarian conducted the literature search and performed initial screening of titles and abstracts. Yasamin Golezardi and Zhino Kohzadi independently performed full-text review, data extraction, and quality assessment of the included studies. Mohammad Khaligh and Reza Baeelashaki contributed to data curation and assisted with resolving discrepancies during the screening process. Ali Heydari drafted the initial manuscript, while Ali Sarani and Saeed Ramezani Nejad critically revised the manuscript for important intellectual content. All authors read and approved the final edition of the manuscript.

Availability of data and materials

The manuscript contains all datasets generated and/or analyzed in the current study.

Competing interests

The authors declare that they have no competing interests.

Ethical considerations

The authors checked the manuscript for plagiarism, duplication, and fabrication, and the study is submitted for the first time. No AI tools were used to conduct this study. The authors accept full responsibility for the study's originality before submission and publication.

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