

Factors Influencing the Emergence and Re-emergence of Zoonotic Infectious Diseases in Livestock and Human Populations

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ABSTRACT

The emergence of zoonotic infectious diseases poses a significant threat to human and animal health. Understanding the factors influencing the emergence of these diseases is crucial for effective prevention and control strategies. Livestock populations act as reservoirs for zoonotic pathogens, circulating silently and potentially infecting humans. Disease transmission, pathogenesis, and genetic diversity within and across the livestock and human populations play a significant role in disease susceptibility, thus increasing the risk of disease emergence. These factors also hinder disease surveillance, control measures, and timely interventions, allowing disease to spread among different geographical regions. The deviations in human and animal behavior, habitat, ecology, vector biology, pathogen adaptability, use of antibiotics, livestock farming, production systems, food safety, malnutrition, urbanization, deforestation, and climate contribute to the emergence of highly infectious diseases. In addition, wildlife animals also serve as a reservoir of zoonotic pathogens which cause newly emerging and reemerging zoonotic diseases. Therefore, understanding and addressing these factors is essential for effective prevention and adaptation of control measures to mitigate the high risk of zoonotic disease emergence, re-emergence, transmission, and spreading in livestock and human populations.

Keywords: zoonosis, disease transmission, pathogen adaptation, surveillance, prevention

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ZOONOSIS

1. INTRODUCTION

An emerging zoonosis is one that has recently been identified or evolved in recent past and still prevailing more in terms of its geographic, host, or vector ranges (Alvi et al. 2023a). Over the past 70 years, about 250 zoonoses have been reported as emerging and re-emerging spreading over the globe with more intensity than previous (de Thoisy et al. 2014). The animals being as reservoirs for newly emerging and re-emerging zoonotic diseases transmit to human populations, play a crucial role in the dynamics of disease morphology, pathogenesis, overflow, and amplification (Usmani et al. 2022). There are multiple factors which affect the transmission and occurrence of zoonotic infectious diseases from animal population to human beings. Furthermore, these factors also have significance in disease transmission within livestock (Craddock and Hinchliffe 2015). First, the close contact between humans and livestock, particularly in intensive farming systems, increases the opportunities for disease transmission because livestock populations serve as reservoirs for zoonotic pathogens, even without apparent signs of disease. Second, genetic diversity within livestock populations affects disease susceptibility, with reduced diversity increasing the risk of disease emergence (Fig. 1).

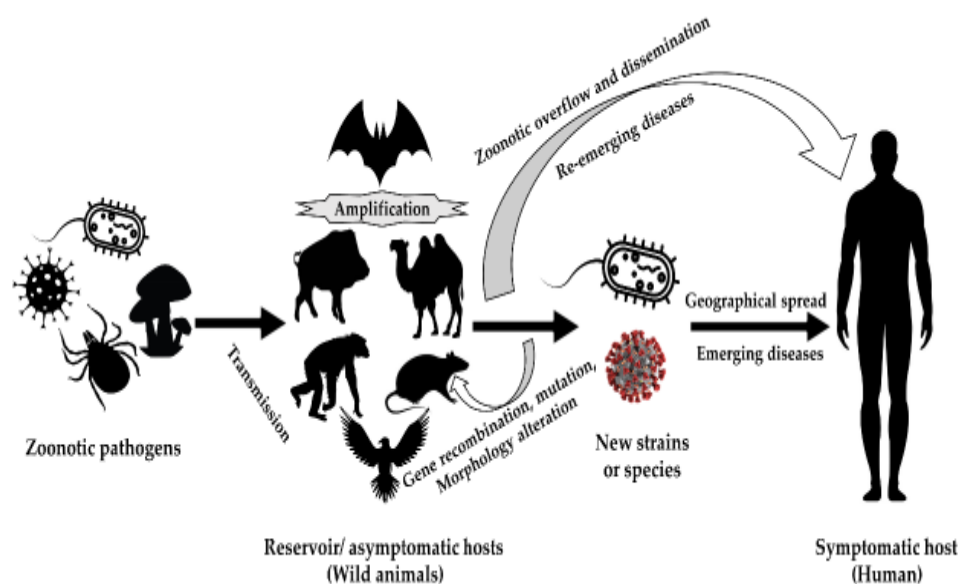


Fig. 1: Transmission of zoonotic pathogens and emergence of infectious diseases in animals and human populations (Rahman et al. 2020)

2. IMPACT ON GLOBAL SOCIO-ECONOMIC AND PUBLIC HEALTH

The emergence and re-emergence of zoonotic diseases has great impact on global socio-economic and public health. A total of 132 diseases have been declared as emerging zoonotic infectious diseases out of 175 recognized emerging diseases (Alvi et al. 2022). The most important emerging zoonotic diseases are avian influenza (AI), bovine spongiform encephalopathy (BSE), Ebola, rotavirus, West Nile (WN) fever, canine leptospirosis, cat scratch disease, MRSA infection, SFTS (severe fever with thrombocytopenia syndrome), MERS (Middle East respiratory syndrome), SARS (severe acute respiratory syndrome), and the most recent COVID-19 (coronavirus disease 2019). These zoonotic diseases account for almost 60.3% of all new diseases and about 71.8% of them are derived from wildlife animals (Mosnier et al. 2020).

On the other hand, many regions of the world have declared rabies, brucellosis, Japanese encephalitis, tuberculosis (TB) special emphasis on *Mycobacterium bovis*, and *Schistosoma japonica* infection as zoonotic (Civitello et al. 2015). Recently, a *bunyavirus* belonging to the *Bunyaviridae* family causes the potentially fatal infection known as SFTS, characterized by abrupt onset of fever, thrombocytopenia, and leukopenia.

ZOONOSIS

The signs and symptoms of this infection are quite similar to hemorrhagic fever. Under extreme circumstances, this infection can lead to a multi-organ failure, which kills almost 6-30% of patients. In May 2007, this disease was first reported in central and northeast China, transferred by Ixodid tick (*Haemaphysalis longicornis*) and mostly affects the people working at and nearby the mountains (Bolatti et al. 2020). The animals in the endemic regions develop antibodies that are antigen specific i.e., against severe fever with thrombocytopenia syndrome (SETS) virus. Typically, this disease spreads horizontally i.e., direct interaction with animals or vectors. Later, SFTS-like clinical indication, similar to bunyavirus-associated disease was reported in the USA, Japan, and South Korea. These findings have led to the disease being classified as an emergent zoonotic infection in several regions of the world (Binetruy et al. 2020). In 2012, Middle East Respiratory Syndrome (MERS) was first reported in Saudi Arabia in camels and is an emerging viral zoonotic infection that affects humans (Chaisiri et al. 2017). The MERS coronavirus (MERS-CoV) is the causative agent of this infection and significantly causes high fatality rates, lowers production performance, and has public health significance. This disease has about 60% morbidity and 7-14% mortality rates in humans, although it has no signs and symptoms in the infected dromedaries. However, the dromedaries which had the infection showed mild respiratory symptoms. There is evidence that MERS-CoV can cause serious infection in the lower respiratory tract of animals (Saldanha et al. 2020).

3. ROLE OF KEY FACTORS IN THE EMERGENCE OF INFECTIOUS ZOONOTIC DISEASES

The emergence of zoonotic diseases in livestock and human populations can be influenced by various factors which can be broadly categorized as biological, ecological, and socio-economic factors. The interaction of human, animal, and environment associated factors in the transmission and spreading of infectious zoonotic diseases in one health perspective has been described in Fig. 2. However, these factors are further classified and the key factors that may contribute significantly to the emergence of zoonotic infectious diseases are discussed below:

4. ECOLOGICAL CHANGES

Human-derived changes such as deforestation, agriculture expansion, and urbanization to ecosystems have led to the alteration of habitats and increased the interactions between wildlife, livestock, and human population (Fong 2017). This interaction created a favorable condition for the transmission of zoonotic diseases, altered the disease transmission dynamics, fragmentation, distribution and behavior of human, livestock, and wildlife populations. These changes brought them into closer contact, facilitated the transmission of pathogens between different species across the different geographical regions (García-Pena et al. 2016).

5. CLIMATE CHANGE

Global climate change influenced the distribution of disease, especially the prevalence of vector-borne diseases and their biological and mechanical vectors i.e., mosquitoes, ticks, and flies. It also led to changes in the distribution and behavior of human, wildlife, and livestock populations, increasing the likelihood of disease transmission (Barry et al. 2018). This climate change badly altered the distribution and behavior of zoonotic pathogens, their hosts i.e., animals and insects such as mosquitoes and ticks. These hosts and vectors' geographic ranges increased and shifted towards warm and humid temperate regions exposing them to new populations of humans and animals (Alvi et al. 2020). This increase in temperature favors the circumstances for disease-carrying vector reproduction and survival. For instance, the rise in temperature favors mosquitoes to spread diseases such as malaria, dengue fever, and the Zika virus (ZIKV) and alters

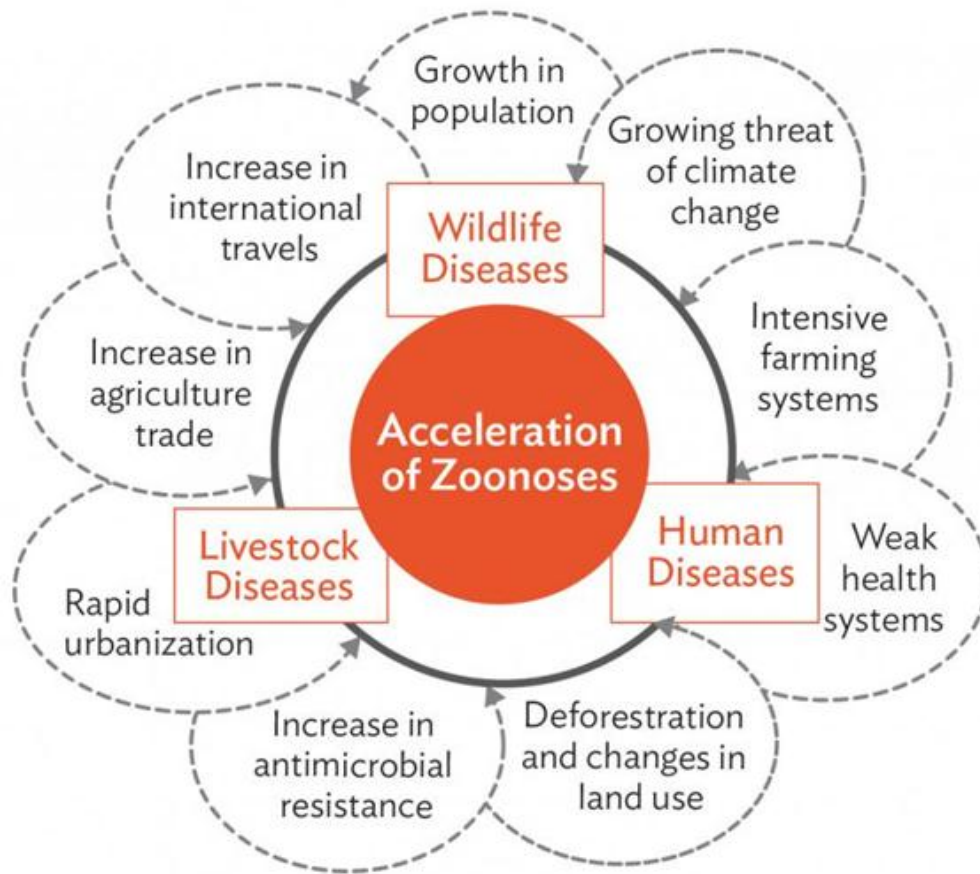


Fig. 2: Interaction of human, animal, and environment associated factors in the acceleration of infectious zoonotic diseases in One health perspective (Messenger et al. 2014).

the dynamics of zoonotic pathogen transmission (Imran et al. 2023). At high temperature, shorter incubation periods and quicker transmission can result in disease outbreaks more quickly at higher intensity. This may lead to disease transmission at higher magnitude and perhaps even more severe outbreaks. Both host's and pathogens' physiological and behavioral characteristics can be altered by climate change. This may alter the host and pathogen interaction, thereby altering the prevalence, severity, and patterns of disease transmission (Petersen et al. 2016).

6. GENETIC DIVERSITY

The microbes, especially viruses and bacteria evolved through mutation and recombination, resulting in the development of new and more virulent strains. These new virulent strains infect multiple hosts which include humans and animals more severely than previous (Bhatt et al. 2013). This genetic variation within livestock populations can also influence disease susceptibility. Reduction in genetic diversity results from selective breeding for specific traits can make animals more susceptible to certain diseases. This also increases the likelihood of disease occurrence and spread within livestock populations (de Thoisy et al. 2014). A population's genetic homogeneity, though, may also make some diseases more contagious in animals. In a population with low genetic variety, a single virus can quickly spread throughout the community, raising the danger of zoonotic transmission (Ioos et al. 2014).

7. PATHOGEN RESERVOIRS

Livestock populations act as reservoirs for various pathogens that can cause zoonotic infectious diseases. These pathogens may circulate silently within animal populations without causing apparent disease in the animals, but they can still be transmitted to humans and cause infections (Alvi et al. 2023b). Animals in close proximity to one another, shedding and spreading pathogenic organisms in the environment are greater sources of infections to humans and their feces due to intensive farming techniques. As a result, there is a greater chance that viruses will be released into the environment and might infect people who come into touch with polluted surfaces, water, or air (Binetruy et al. 2020). More than a billion people are suffering from zoonotic infectious diseases, and more than 60% fatalities are being reported in humans and domestic or wild animals each year. According to estimates, zoonoses account for 75% of newly emerging infectious diseases. There is a large variety of terrestrial and aquatic vertebrate animals that can spread a wide range of microbial infections to people either directly or indirectly (Usmani et al. 2022). A wide variety of microorganisms, including rickettsiae and mycobacteria, viruses, fungi, parasites (including protozoa, metazoans, and helminths), and prions are included in the vast range of infectious agents. Animals can spread infectious diseases to people through a number of different routes, including the fecal-oral route with foodborne zoonoses, accidentally contaminated drinking water, unwashed hands, direct contact with or without bites or scratches, indirectly through a variety of vectors [mosquitoes, sandflies, fleas, and ticks], and incidentally by environmental contamination with animal pathogens, such as aerosol of dried infected animal excrement (Imran et al. 2023).

8. ANTIMICROBIAL RESISTANCE

The overuse and misuse of antimicrobials in both human and animal medicine contributes to the development of resistant pathogens, which can be more difficult to treat and control. The overuse of antibiotics in livestock farming can contribute to the emergence of drug-resistant pathogens. To slow down the emergence of antibiotic resistance, safe and judicious use of antibiotics must be implemented in veterinary and human medical procedures. Regular monitoring of antibiotic-resistant bacteria in humans and animals can help to identify the growing patterns of resistance and developing effective control measures (Plowright et al. 2017; Mosnier et al. 2020). In addition, the One Health strategy also collaborates the human, animal, and environment and playing positively in identifying and managing the development of antibiotic resistance microbes (AMR) at the human-animal-environment interface (Blaizot et al. 2020). This one-health is also making possible to lessen the selection pressure for antibiotics by promoting the use of organic and sustainable therapeutic agents that will definitely decrease the overuse of antibiotics which will ultimately slow down the spread of AMR and improve the humans and animals' health status (Mosnier et al. 2020).

9. INTENSIVE LIVESTOCK FARMING PRACTICES

Basically, a high-density and monoculture livestock farming practice can facilitate the rapid spread of infectious diseases among animals. Such kind of systems often have poor biosecurity measures and high-stress levels for animals, which can compromise their immune systems and production performance as well as making them more susceptible to infections. Specific breeds of animals with desired productivity traits are frequently preferred in intensive farming, and they are frequently stuffed together in small quarters of intensive husbandry (Cascio et al. 2011). Such conditions i.e., over-crowding, stress, poor biosafety, and unhygienic environment weaken the immune system of animal, leaving them more prone

ZOONOSIS

to disease. Under these circumstances, there is a higher chance of spreading and proliferation of zoonotic pathogens from animals to human beings. Moreover, when animals are fed on animal and plants byproducts, this may also expose them to various toxins present in these products. This could spread zoonotic infections and introduce new microbial pathogens to the community of humans and animals (Craddock and Hinchliffe 2015).

10. INADEQUATE DISEASE SURVEILLANCE AND MONITORING SYSTEM

Lacking rapid and accurate tools for the detection and reporting of emerging infectious diseases can delay the proper identification and effective prophylactic measures against zoonotic disease outbreaks, allowing them to spread quickly and widely (Usmani et al. 2022). Early and accurate detection of pathogens is essential to limit the spread of outbreaks in a wide geographical region. Due to limited diagnostic facilities, unavailability of skilled personnel and poor healthcare infrastructure, zoonotic diseases may go unreported or get the wrong diagnosis. Lack of precise data on disease prevalence and distribution, the effective control initiatives are also being hampered regularly (Cascio et al. 2011).

11. SOCIOECONOMIC FACTORS

Socioeconomic factors, such as poverty, limited access to healthcare, and inadequate veterinary services, can impact disease emergence and spread. These factors can hinder disease surveillance, control measures, and timely interventions, allowing disease outbreaks. Among these factors, the alterations in human and animal behavior, habitat, ecology, vector biology, pathogen adaptability, farming practices, livestock production systems, food safety, urbanization, deforestation, and global warming facilitating the emergence and transmission of zoonotic diseases (Cipolla et al. 2015). Additionally, certain behaviors and cultural practices i.e., consumption or use of animals in traditional medicine, can increase the risk of exposure to zoonotic pathogens. Poor sanitation and hygiene practices in both human and animal population can facilitate the transmission and persistence of zoonotic infectious pathogens. Moreover, poverty, malnutrition, and poor healthcare infrastructure can also exacerbate the emergence and spread of zoonotic diseases by limiting the access to healthcare, disrupting disease control efforts, and increasing vulnerability to infections (Cassadou et al. 2014; Wood et al. 2016).

12. GLOBAL TRADE AND TRAVEL

Increased movement of humans, animals, and animal products across borders can introduce new pathogens to previously unexposed populations. The live animal trade, in particular, can facilitate the spread of zoonotic diseases. The movement of livestock, either within a country or across international borders, can contribute to the spread of diseases. Trade in live animals, animal products, and the movement of people associated with livestock farming can introduce pathogens into new areas and increase the risk of disease transmission (de Thoisy et al. 2010; Hoen et al. 2018).

13. CHANGES IN LAND USE AND AGRICULTURE PRACTICES

Alterations in land use, such as the expansion of agricultural land or changes in farming practices, can affect the interaction between livestock, wildlife, and humans (Wangdi et al. 2015). Encroachment into wildlife habitats or the conversion of forests into agricultural land can bring livestock and humans into closer contact with wildlife, increasing the chances of exposure to new pathogens. Livestock animals often live in close proximity to humans, increasing the opportunities for disease transmission. Intensive farming

practices, such as factory farming, can lead to high population densities of animals, making it easier for diseases to spread within and between herds (Civitello et al. 2015).

14. WILD ANIMALS AND RE-EMERGING ZOOSES

The disruption of the ecological interactions among the one-health components due to globalization, habitat degradation, climatic change, species extinction, and biodiversity loss eventually results in the formation of zoonotic infections and alterations in how they are transmitted. Mammals, reptiles, birds, fish, amphibians, and other wild animals are reservoirs for zoonotic illnesses that can be transmitted to humans or other animal hosts (Roux et al. 2013). It is concerning that wild animals are involved in the epidemiology and spread of zoonotic illnesses. The type of pathogen implicated and environmental factors like temperature, humidity, and rainfall affect the patterns of transmission of wildlife zoonoses (Chaisiri et al. 2017). These viruses' patterns of transmission among wild animals, domestic animals, and people determine when and if they first appear and reappear.

The following factors have an impact on these processes: (1) the rapid increase in the human population; (2) the consumption of wild meat (such as bush meat); (3) the increased exposure of humans to animals and animal products; (4) the careless handling and transportation of wildlife carcasses; (5) wildlife farming; (6) the ease of domestic and international travel; and (7) variations in agricultural methods. There is significant human-to-wild animal pathogen transfer in developing and reemerging diseases. The majority of human diseases are contracted from wild animals either directly or with the use of a vector, as in the cases of lyssaviruses, hantaviruses, the Nipah virus, the West Nile (WN) virus, and the agents that cause leptospirosis and ehrlichiosis. Human-to-human transmission is a major factor in the spread of illnesses such as the coronavirus, Ebola virus, and HIV (Bolatti et al. 2020).

15. ROLE OF POPULATION MOVEMENTS IN ZOOBOTIC DISEASES EMERGENCE AND TRANSMISSION

The BAM concept's M component, which refers to population mobility, international travel, and trade globalization, also points to these factors as important factors for the rapid spread of viruses (Bhatt et al. 2013). The probability of new epidemics is clearly influenced by climate change and environmental destruction. They have moved people, animals, insects, food, plants, and vectors that are ever more linked to the transcontinental persistence of germs (Stanaway et al. 2016). When it comes to microbial infections, examples of rapid worldwide growth were historically uncommon, but as more people and money have moved around the world, barricades between the species and ecosystems have gradually crumbled, cumulative the prevalence, geographic spread, and host ranges of numerous new communicable illnesses (loos et al. 2014).

Local population shifts brought on by migratory patterns, the cross-border pendulum, or periodic mobility (Saldanha et al. 2020) may also have amplification effects on these emerging diseases, or at the very least make it more difficult to contain and eradicate them. Along with this immigration, informal living has grown significantly, which encourages the direct and/or indirect communication of many dangerous illnesses (Wangdi et al. 2015). In addition to the challenging economic situation i.e., 45% of the total population lives below the poverty level, 20% lack adequate access to drinking water, and the number of unemployed individuals is over 22%, these features all contribute to the high rate of immigration (Stanaway et al. 2016). Examples of illnesses that infected visitors can bring into geographically vulnerable locations where capable mosquitoes or arthropod vectors are present include vector-borne infections. Through the occurrence of epidemics, dengue fever, zika, chikungunya and yellow fever (YF) illnesses, whose distribution has increased in risk areas, have demonstrated different impacts to this vibrant process in recent decades (Epelboin et al. 2016; Mosnier et al. 2020).

The most substantial virus spread by mosquitoes to people is believed to be dengue fever. Due to the significant public health burden associated with these outbreaks, surveillance mechanisms have been strengthened, allowing us to clearly show that a serotype's resurgence was caused by imported human cases (Cassadou et al. 2014). For example, during the 2012–2013 DENV-2 pandemic, the detection of cases with scientific verification rapidly decreased to sporadic levels before disappearing completely after September 2016. In January 2019, two epidemiologically unrelated dengue fever cases were discovered, one of which was introduced from the French West Indies (Petersen et al. 2016). Late in April, the epidemiological investigation conducted in Kourou revealed the finding of a second DENV-2 case, this one imported from South America; the examination also showed a secondary case, the first local case found in the area since 2016. A few weeks later, an outbreak started, most likely in response to the discovery of a DENV-1 case in Cayenne that had been brought in from the French West Indies. Between January 2019 and April 2020, the region experienced over 1000 cases in two separate epidemic outbreaks linked to these two serotypes, providing insight into the spread of viral circulation (Hoen et al. 2018).

CHIKV has caused numerous significant outbreaks in Asia, Africa, and the Pacific Islands since it was originally discovered in Tanzania in the early 1950s. The discovery of autochthonous cases in Saint Martin, a French overseas territory, in December 2013 sparked the first known case of CHIKV transmission in the Americas. Within nine months, CHIKV had spread rapidly throughout the Caribbean, the Americas, including French Guiana (Cassadou et al. 2014). Particularly, a small number of nearby acquired CHIKV infections were recorded in February 2014. Prior to a significant epidemic in Yap, Federated States of Micronesia, in 2007, and a subsequent one in French Polynesia in 2013, ZIKV was regarded as an emerging virus with few rare cases identified in Africa and Asia (Ioos et al. 2014). ZIKV then carried on disseminating across the Pacific region until making an early 2015 appearance in South America. Due to the virus' quick spread over 50 other countries and territories in the Americas after its first discovery in Brazil in May 2015, it attracted interest from around the world (Hoen et al. 2018; Petersen et al. 2016).

16. IMPACT OF ANIMAL SPECIES COMMUNITIES AND VECTOR-BORNE ZOONOTIC DISEASES

How animal species involved in the disease cycle respond to environmental changes is one crucial consideration. The expansion of more generalist host and vector species may be aided by changes in the distribution of natural resources, the extinction or loss of more specialized, weaker host and vector species, and the simplification of ecological niches. Many illnesses depend on a small number of efficient reservoir and vector species, even though many other species may act as hosts, especially under conditions of ecological disequilibrium (Wangdi et al. 2015). To conceptualize the potential impacts of biodiversity, change on the transmission of zoonotic illnesses, the "dilution effect hypothesis" was utilized. Because the existence of unfit hosts serves as an epidemiological dead end or delays the disease agent cycle, more biodiversity should normally prevent the spread of infectious illnesses. This concept attracted a lot of interest, but it also drew critiques that the relationship between biodiversity and disease was peculiar because alternative mechanisms might instead cause disease transmission to become amplified with greater biodiversity (Epelboin et al. 2016; Mosnier et al. 2020).

Understanding these factors and implementing appropriate preventive measures, such as improved biosecurity, surveillance, and responsible antibiotic use, are essential for mitigating the risk of zoonotic disease emergence in livestock populations. It's critical to understand that interactions between people, animals, and the environment play a role in the genesis of zoonotic illnesses, which is a complicated and multifaceted process. The likelihood of zoonotic disease onset in cattle populations can be reduced by being aware of these factors and putting the right preventive measures in place, such as enhanced biosecurity, surveillance, and responsible antibiotic use. We must better

ZOONOSIS

understand the local contexts and factors that may contribute to disease onset and spread, even though our local societies are now dealing with significant global changes. Only then can we prioritize local resilience in future national and international agendas. Knowledge gaps suggest that future efforts are needed in the following areas:

17. INCREASE IN ACTIVE GLOBAL DISEASE SURVEILLANCE

Commenting on whether disease incidence is changing as a function of environmental circumstances is challenging due to the absence of exact understanding of present disease incidence rates. To give epidemiological research a baseline, incidence statistics are required. Additionally, these data will be helpful for confirming forecasting models. Since these data are challenging to collect, especially in remote areas, a centralized computer database must be established to make it easier for researchers to share these data.

18. CONTINUATION OF EPIDEMIOLOGICAL RESEARCH INTO ASSOCIATIONS BETWEEN CLIMATIC FACTORS AND INFECTIOUS DISEASES

Research is required to demonstrate persistent trends across many populations and geographical locations in order to make a causal connection between patterns of infectious disease and climate change. The most effective way to do this is to use robust study designs that sufficiently account for social and environmental variables. In order to increase the depth of knowledge, multidisciplinary collaboration between experts such as epidemiologists, climatologists, and ecologists is crucial, as is international collaboration among academics. Entomologists, epidemiologists, and climatologists must collaborate to research the relationships between shifting vector habitats, disease patterns, and climatic conditions, as in the case of a thorough study of mosquito-borne diseases. Policymakers can use epidemiological statistics to inform the development of preventive measures.

19. IMPROVEMENTS IN PUBLIC HEALTH INFRASTRUCTURE

Programs for preventive and control, emergency response, and public health training are some of them. It is important to have a better grasp of both the population's ability to respond to expected climate change health effects and the ability of individuals to adapt to those outcomes.

20. CONCLUSION

As this analysis's conclusion has demonstrated the local factors that may favor the spread of new infections that are currently emerging and reemerging in the future include human demography, unfavorable health conditions, and landscape modification as a result of human activities like resource extraction and agricultural growth. In order to better understand the local conditions that lead to sickness production and more effectively improve healthcare systems, we also invite other research consortiums around the world to revisit and adapt the same kind of examination of local vs. global elements. Environmental factors, such as changes in land use, climate change, and habitat fragmentation, can alter the dynamics of disease transmission between livestock and wildlife. Livestock trade and movement facilitate the spread of diseases across regions and countries. The use of antibiotics in livestock farming contributes to the emergence of drug-resistant pathogens, posing challenges for treatment. Socioeconomic factors, including poverty and limited access to healthcare, impact disease surveillance and control efforts.

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