Effects of Climate Change on Emerging and Reemerging Zoonotic Diseases

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ABSTRACT

The impact of globalization and climate change on newly emerging and reemerging zoonoses and animal illnesses has been unparalleled on a global scale. The climatic variability caused by naturally occurring climate phenomena like El Nio, La Nia, and global monsoons is linked to extreme weather events that alter tropical rainfall patterns. As a result, harmful bacteria, viruses, and fungi are given better habitats to survive in and are encouraged to spread to other places, disrupting natural ecosystems and leading to the emergence of zoonotic diseases. Bird migration patterns, waterfowl species populations, and the cycle of the avian influenza virus can all be affected by climate change. Due to the effects of temperature, humidity, and the demographics of the vectors, vector-borne diseases are highly vulnerable to changing environmental circumstances. Transmission is at its peak in the months with high humidity and rainfall rates for both dengue fever and malaria, which also exhibit notable seasonal variations. Aedes mosquitoes, which carry the Rift Valley fever virus, transmit it to vertebrate hosts. In addition to vector-borne diseases today, climate changes have revealed the severity of waterborne, food-borne, rodent-borne and airborne zoonoses. To better understand how climate and weather affect health outcomes, researchers should continue their research. To better understand why some communities of people and animals are more susceptible to the health effects of climatic variability and change, as well as how people respond to threats from new zoonotic diseases, physical, biological, health, and social scientists must work together. It is important to continue focusing on an integrated strategy for gathering, analyzing, and raising awareness of zoonotic illness using epidemiological, entomological, and environmental data. Therefore, Understanding the connection between zoonoses and climate change is essential to making predictions and controlling the consequences that may be encountered in various epidemic scenarios,

Keywords: Globalization, Climate change, Zoonoses, Influenza virus, Transmission.

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1. INTRODUCTION

More and more, it is understood that future epidemics and the emergence of novel illnesses are a result of interactions at the animal-human interface. According to estimates, up to 75% of newly discovered or developing infectious diseases and 60% of recognized infectious diseases have zoonotic origins (CFR workshop 2023). In this study, a zoonotic disease is one that affects both humans and animals and manifests regularly in animals but cannot be transmitted from person to person (Naicker 2011). An emerging zoonosis, according to the World Health Organization, is one that has "newly evolved, or that has already occurred but exhibits an increase in incidence or expansion in geographical, host, or vector range." How climate-sensitive zoonotic diseases are influences both their spread and occurrence. The pathogen, host, vector, or ecological determinants, as well as combinations of the aforementioned elements, are the main contributors to the emergence and spread of zoonotic illnesses (Cediel et al. 2013). The word "zoonoses" comes from the Greek words "zoon" (animal) and "noson" (disease). Additionally, it is believed that this term is the most appropriate in comparison to "anthropozoonosis" (transmission from animals to people) and "zooanthroponosis" (transmission from humans to animals), which focus on the primary method of transmission between humans and other animals (Wilson 2003). A zoonosis is any disease or infection that can transfer spontaneously from vertebrate animals to people or from humans to animals, according to the World Health Organization (WHO). About 61% of human pathogens are zoonotic in origin (Abebe et al. 2020). Zoonoses are a direct risk that poses a major harm to human health and has the potential to be lethal. The poor livestock workers in low- and middle-income countries suffer the burden of the effects of the 13 most widespread zoonoses, which annually result in 2.4 billion cases of illness and 2.7 million fatalities in humans. In addition to having a negative impact on human health, these diseases also have a significant economic impact (Christou 2011).

Zoonoses are ailments and infections that naturally spread from vertebrate animals to people (World Health Organization 1951). The transmission of zoonoses from an infected vertebrate host to humans can occur directly through contact, indirectly through the use of mechanical, biological, or fomite-related vectors, or indirectly. To complete their infectious cycle, several zoonotic illnesses need more than one species of vertebrate or invertebrate (Chomel 2009). The genesis and global spread of zoonoses are essentially being impacted by the rise in animal-human contact. Currently, zoonotic infections account for 60% of emerging infectious diseases (EIDs). These diseases usually originate as a result of dynamic interactions between populations of humans, animals, and cattle as well as rapidly evolving environments. Many EIDs have their origins in wildlife. Emerging zoonoses pose a massive and growing threat to the world's health, economy, and security (Rupasinghe et al. 2022). The current SARS-CoV-2 pandemic is a good example. Recent research indicates that both the prevalence of EIDs and their financial cost are on the rise. At the moment, post-emergence epidemic management, seclusion, vaccine research, and drug development —all of which require significant work, resources, and funding—are the main methods used to lessen the effects of EIDs. In order to effectively avoid future epidemics, respond to them more quickly, and lessen the burden of EIDs globally, it is essential to take a more proactive approach that identifies and reduces the risk elements that have aided in the disease's emergence and the spread of zoonoses (O'Callaghan-Gordo and Antó 2020).

Due to their respective roles in the maintenance and transmission of contagious diseases, wildlife, people, domestic animals, and the environment are intricately linked. For instance, animals has long been "accused" of being the cause of zoonotic diseases that affect humans, very likely unjustly (Thompson and Kutz 2019). In any event, increased viral or bacterial diseases may spread as a result of increased human-animal contact. Zoonotic diseases are defined as "diseases and infections that are naturally transmitted between vertebrate animals and man" by the Expert Committee on Zoonoses in 1951 (Halabi 2019). But at the end of the 19th century, German pathologist and doctor Rudolf Virchow coined the term "zoonoses" to refer to illnesses that affect humans and animals alike (Leal Filho et al. 2022). However, these names have been used interchangeably for any illnesses that affect both people and animals. A third term, "amphixenoses," has also been developed to characterize illnesses that can spread either way and persist in people and lower vertebrate animals. Numerous pathogens have been transferred from animals to people. Prior to posing a threat to a population, a pathogen must first come into touch with an animal (Baker et al. 2022). A pathogen is defined as "an organism that transmits disease to its host; the pathogenicity of the disease symptoms is referred to. Pathogens include bacteria, viruses, unicellular and multicellular eukaryotes, as well as other taxonomically diverse species. (Balloux and van Dorp 2017). The pathogens that cause zoonotic diseases include, but are not limited to, *Salmonella spp*., *Campylobacter spp*., and *E. coli* pathotypes. The two most typical routes of infection are by direct animal contact and the fecal-oral route (including food and drink). Emerging infectious disease (EID) is a phrase used to describe An infectious disease that "has either appeared and first affected a population, or has existed previously but is rapidly spreading, either in terms of the number of people getting infected or to new geographical areas." (Leal Filho et al. 2022).

The rise of zoonoses is influenced by a number of additional factors, including globalization, international trade, changes in land use, and, increasingly, climate change related to vector-borne zoonoses. Through effects on the populations of hosts that serve as hantavirus reservoirs, changing climatic conditions may also be linked to the spread of hantaviruses. Over 200 zoonotic disease types have been identified so far, and they are responsible for a sizable part of newly discovered and ongoing human ailments. Additionally, it is known that around 60% of all human pathogens and 75% of new infectious diseases are animal-borne (Mohammadpour et al. 2020).

1.1. CLASSIFICATION OF ZOONOSES

Numerous microorganisms are responsible for zoonotic illnesses. According to their etiological causes, zoonoses can be divided into bacterial, viral, parasitic, fungal, rickettsial, chlamydial, and microbiological zoonoses as shown in Fig. 1. Bacterial zoonoses include illnesses like plague, anthrax, salmonellosis, tuberculosis, Lyme disease, and brucellosis. Among the viral zoonoses is rabies, AIDS and Ebola (Rahman et al. 2020).

Therefore, zoonotic illnesses are split into four classes based on epidemiological classification that takes into account the zoonosis maintenance cycle: direct zoonoses (orthozoonoses), cyclozoonoses, pherozoonoses (metazoonoses), and saprozoonoses (Rahman et al. 2020).

1.1.1. DIRECT ZOONOSES

(Orthozoonoses) can be transferred mechanically, through direct contact with a fomite, or by contact with an infected vertebrate host. The agent goes through little to no propagative modification and little developmental changes during such a process. Only a few instances are anthrax, brucellosis, trichinosis, and rabies (Grace et al. 2012).

1.1.2. CYCLOZOONOSES

A few kinds of vertebrate hosts, but no invertebrate hosts, to finish the agent's evolutionary cycle. The three most common cyclozoonoses are pentastomid infections, echinococcosis, and human taeniasis.

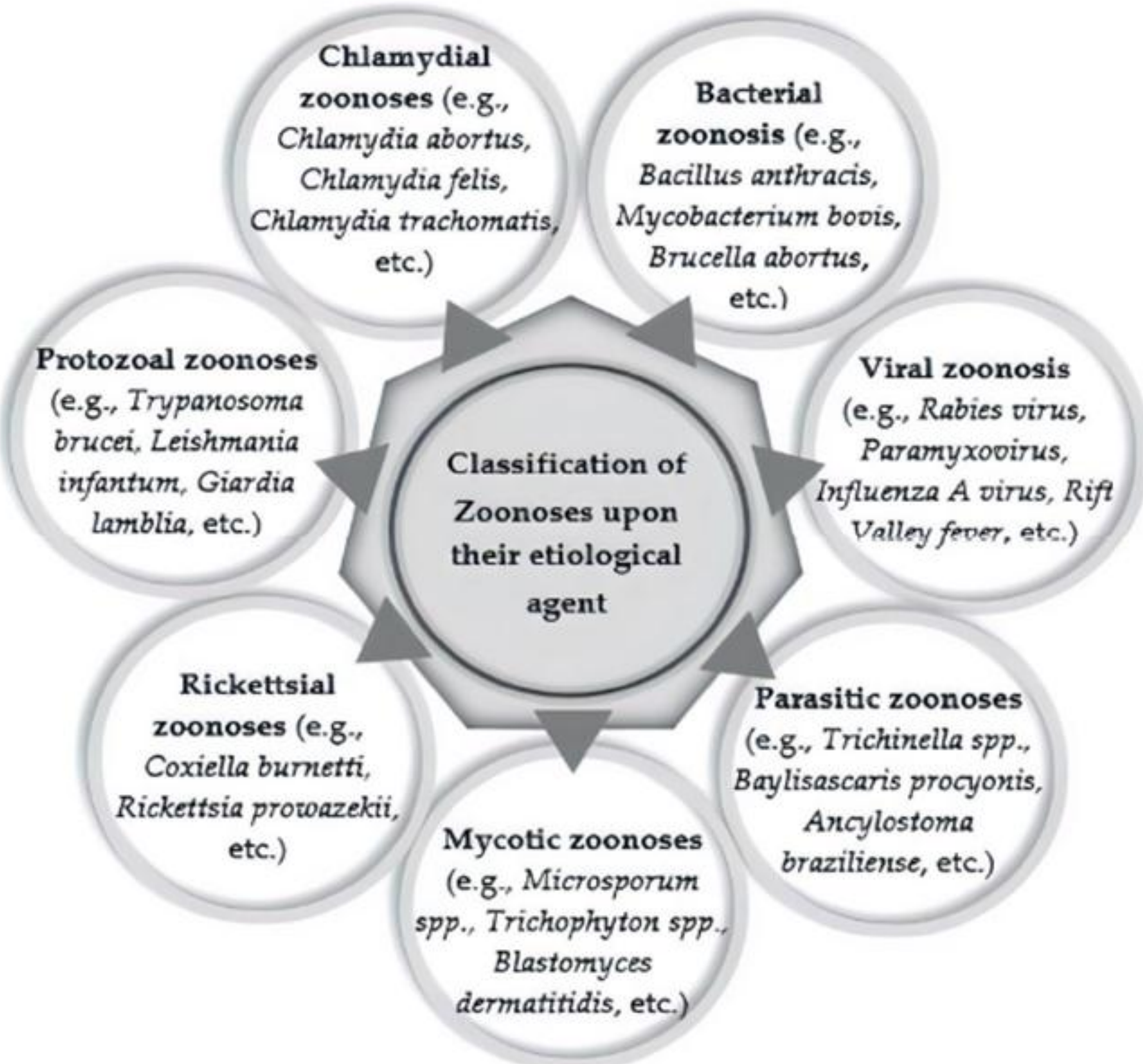

Fig. 1*:* Classification of zoonoses upon their etiological agent (main groups) (Leal Filho et al. 2022)

1.1.3. INVERTEBRATE VECTORS TRANSMIT PHEROZOONOSE (METAZOONOSES)

Wherever conceivable, before transmission to another vertebrate host, there is a prepatent phase of intrinsic incubation. The agent in the invertebrate multiplies, changes, or does both. Schistosomiasis, plague, and arbovirus infection are only a few specimens.

1.1.4. SAPROZOONOSES

They have an animal host that is a vertebrate and a non-animal reservoir for growth, such as food, soil, and plants. Examples include numerous larval migrations and some mycosis types (aspergillosis) as shown in Fig. 2. (Rahman et al. 2020).

1.2 CLIMATE CHANGE AND ZOONOSES

The greatest significant threat to human and animal populations is climate change, which has an impact on some species' population densities, reproductive success, and population dynamics. Furthermore, climate change may extend the current boundaries of agricultural activity, raising the possibility of interactions between species that would not typically occur there. Numerous microorganisms with zoonotic potential are excreted by livestock. These infections can spread through food and water, and the risk of human infection rises if food crops are watered with tainted water (Atwill 2005). Urban areas that are extremely crowded, especially those with poor sanitation, are a major public health problem because they can spread disease outbreaks (Singh et al. 2011).

Disease transmission is substantially impacted by climate change. Variable temperatures are thought to be a contributing factor in the rise in zoonotic disease cases because they prolong periods of vegetation growth and increase habitat availability, which in turn gives zoonotic pathogens and associated vectors better living conditions that support survival and reproduction. In addition, rising temperatures are causing the permafrost in the region to thaw, raising fears that this could uncover ancient human graveyards and lead to the resurgence of vectors that spread deadly illnesses (Singh et al. 2011).

The geographic distribution of diseases that are spread by insects may potentially be impacted by climate change (Singh et al. 2011). Zoonotic viruses that were formerly restricted to hot climes, such as the tropics, have been found to have expanded to subtropical climates and high altitude regions. Various geographical

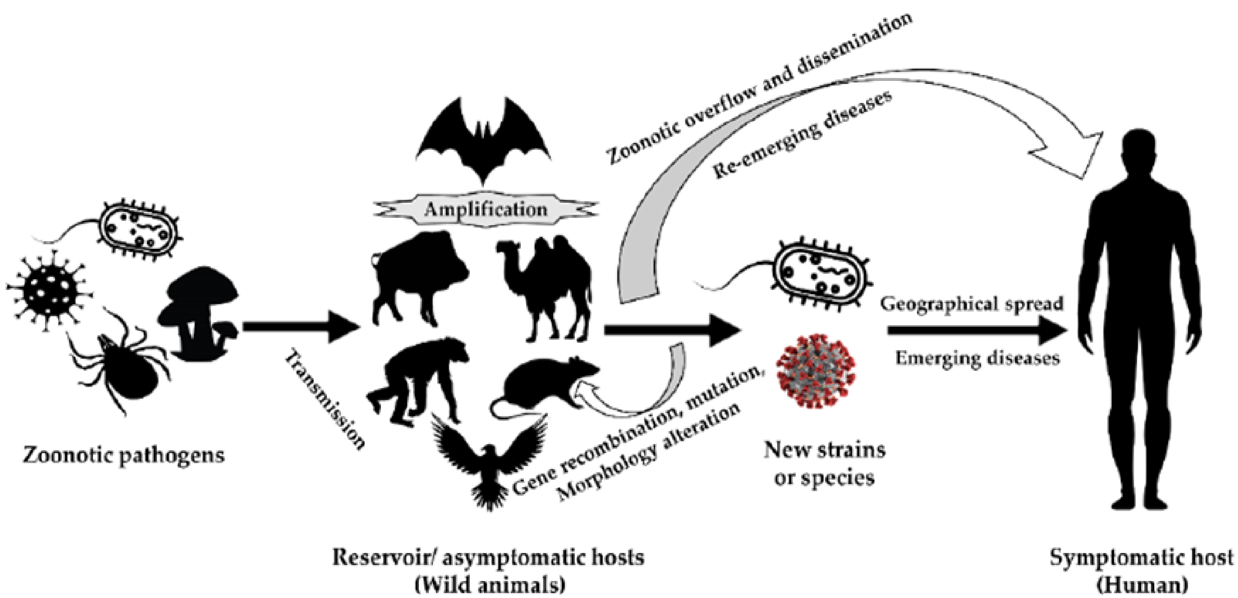

Fig. 2*:* The role of wild animals in zoonoses' emergence and reemergence, as well as in the transmission and amplification of their etiological agents (Rahman et al. 2020)

regions have experienced temperature shifts due to climate change, which has led to an increase in infection prevalence in formerly disease-free areas. Additionally, if people's overall health declines as a result of climate change, zoonotic infections are more likely to spread, as demonstrated by the dengue and Zika viruses, which are currently a worldwide problem (Polley and Thompson 2009). More frequent droughts and flooding have reduced freshwater supply in less developed areas, which has led to human intake of Zoonotic waterborne infections like schistosomiasis contaminate the water (Patil 2010; Polley and Thompson 2009).

In addition, diseases and vectors have had to create adaption mechanisms as a result of the climate changes. Due to this development, illnesses have become more resilient to conventional therapies as a result of their improved survival strategies, which favors the spread of infection. In some cases, climatic changes may help bacteria and viruses become more resistant, making treatment more difficult and promoting the spread of disease (Pal et al. 2013).

2. CLIMATE CHANGE PRODUCE GLOBAL WARMING

Geoclimatic changes can be explained by variations in land and ocean temperatures, sea level and acidity, precipitation and wind patterns, land characteristics and use, soil conditions, and extreme weather events such heavy rain, floods, extreme wind events, heat waves, and droughts. Global warming is the unusually rapid increase in Earth's average surface temperature over the past century, and it is primarily the result of greenhouse gas (GHG) emissions caused by human activity (Ussiri and Lal 2017). The Intergovernmental Panel on Climate Change (IPCC) projects that, compared to the 1850–1900 (preindustrial) period, the average global surface temperature increased by 1.09˚C (0.95–1.20˚C) between 2011 and 2020. For the same time period, increases over land were higher (1.59 [1.34–1.83] than over water (0.88 [0.68–1.01]˚C). The pace of temperature increase has nearly doubled over the preceding 50 years (NOAA National Centers for Environmental Information, 2018). According to the IPCC, under scenarios with extremely low (SSP1-1.9) to very high (SSP5-8.5) greenhouse gas concentrations, temperatures will rise by 0.2˚C (0.1˚C) every decade and by 1.4˚C to 4.4˚C by the end of the 21st century. CO^2 emissions (Intergovernmental Panel on Climate Change 2021; Allen et al. 2018b). In addition to many other negative effects, rising sea levels brought on by melting glaciers and polar ice caps would result in coastal floods and altered ocean currents. The atmosphere, hydrosphere, cryosphere, lithosphere, and biosphere are among the Earth's systems that interact intricately to control the climate. These interactions between elements of the Earth system will be impacted by global climatic changes, which will change the usual hydrological cycle. A substantial risk to human populations can result from changes in the hydrological cycle, which can alter mean meteorological observations and increase the frequency of extreme occurrences such excessive precipitation, storm surges, floods, and droughts. Water supply, quality, and accessibility may be impacted by a number of circumstances (Ussiri and Lal 2017). Precipitation and the frequency of heavy precipitation events have both increased by 0.5-1% over most of the mid- and high-latitude continents of the northern hemisphere in the 20th century. The average global water vapour concentration, precipitation (especially in the deep tropics and polar latitudes), and year-to-year variability in precipitation are all predicted to rise during the twenty-first century. The RCP8.5 scenario predicts that the average global sea level will rise by 0.52 to 0.98 m at a rate of 8 to 16 mm per year by the year 2100. (Church et al. 2013). The El Nio-Southern Oscillation (ENSO), sometimes known as the ENSO, is a set of irregular, cyclical oscillations that affect the surface temperature and air pressure of the equatorial Pacific Ocean. Extreme weather phenomena including heat waves, torrential rain, droughts, floods, tornadoes, and hurricanes are more likely while it is in its warming (El Nio) or cooling (La Nina) stages. Several oscillations, including the North Atlantic Oscillation (NAO), Pacific Decadal Oscillation (PDO), and Antarctic Oscillation (AAO), have been connected to extreme events (Machado et al. 2021). These extreme weather events will happen more frequently and with increasing severity as a result of climate change. By the 2080s, according to various emission scenarios, an additional 2 to 50 million people worldwide may experience annual coastal flooding (Nicholls, 2004). The ferocity of tropical storms (hurricanes and typhoons) is anticipated to increase due to climate change

(Ussiri and Lal 2012). Global warming and geoclimatic changes alter the dynamics of hosts, vectors, and infections as well as their interactions, which has an effect on the epidemiology of zoonotic diseases. For example, it has been noted that there is a strong link between ENSO/extreme weather events and epidemics of a number of new illnesses, such as the hantavirus, malaria, cholera, plague, and rift valley fever (RVF) (AchutaRao et al. 2006). The zoonoses Lyme borreliosis and tularemia were linked to NAO in earlier studies (AchutaRao et al. 2006). The PDO and above-average temperatures were connected to plague in the Western United States, according to Ari et al. (2008). PDO increases precipitation, which increases flea survival and the availability of food for small animals (Glass et al. 2002).

3. FACTORS INFLUENCING PREVALENCE OF ZOONOSES HUMAN FACTORS

There are numerous anthropogenic reasons causing zoonotic illnesses to emerge, persist, and spread.

3.1 TRAVEL AND TOURISM

Travel across continents makes it easier for new viruses to spread. Disease containment is challenging due to effective air and land transportation links, as the SARS-coronavirus outbreak shows (Poon et al. 2004). Eco-adventure travel is becoming more and more popular, as is travel to increasingly exotic locales. Additionally, widespread across Asia and Africa is volunteerism. Non-immune travelers are thereby exposed to endemic diseases. Athletes participating in adventure sports are exposed to "recreational zoonoses". Leptospirosis epidemics have been linked to water sports such as canoeing, kayaking, and river rafting because animals excrete the bacteria in their urine (Sejvar et al. 2003).

3.2 TRADE

As a result of globalization, items can now be transported by air, rail, sea, and land to almost any location on the earth. For mosquitoes (*Aedes aegypti* and *Aedes albopictus*) adapted to urban environments and small-container reproduction, the trade in used tyres provided as a breeding ground. This made it possible for the Asian tiger mosquito to invade quickly, shifting the previous chikungunya outbreaks from sylvatic to widespread human epidemics (Gould and Higgs 2009). Moreover, during trade, international traffic of products such as wool, bone meal, meat, etc. obtained from a region where some zoonoses are endemic, allows the disease to be transmitted to new regions.
Multiple exotic species are brought together in Asia's live animal marketplaces, producing a breeding ground for the spread of interspecies diseases. The coronaviruses found in civet cats are 99% identical to the strain. In the province of Guangdong, it was the cause of the SARS coronavirus (SARS-CoV) outbreak. Civet cats helped the disease spread to people, which started in these trading markets, despite not being its native reservoirs (Gould and Higgs 2009).

3.3 PETS

Zoonotic disease transmission is linked to close interaction between companion animals and their humans. Humans can become infected with pet-associated zoonotic infections by biting, scratching or direct contact of their skin or mucous membranes, contact with animal saliva, contaminated feathers, feces and bodily secretions, and aerosol (Mani 2009) Salmonellosis in humans is linked to owning exotic reptiles as pets. Urban areas frequently host petting zoos, and animal contact has resulted in Escherichia coli O157:H7 epidemics (Alelis et al. 2009).

The domestic dog serving as the primary reservoir host has contributed to the recent rise of zoonotic leishmaniasis in Europe. In the Mediterranean region, Leishmania infantum causes cutaneous and visceral leishmaniosis, which can spread through travel and the importation of infected dogs (Alelis et al. 2009).

The primary reservoir for Bartonella species is domestic cats. Due to the likelihood that the reservoirs will not be eradicated, diseases such as Cat Graze Disease, Baculiform Angiomatosis, and Peliosis are likely to remain and even worsen (Chomel et al. 2006).

3.4 AGRICULTURAL PRACTICES AND LIVESTOCK FARMING

The rapid growth in human population increases the need for food, increases the amount of land used for farming, and causes ecosystems to be disrupted.

Dams and canals constructed for agricultural purposes could serve as new mosquito vector breeding grounds. The production of large-scale animal husbandry is increasing to meet consumer demand. Because there are many animals or different species being raised together, there is a greater chance of infection between different species (Chomel et al. 2006). Animal farming enables novel viruses to proliferate exponentially. This "high intensity" farming enables diseases, such as E. coli O157:H7 strains, which may only be present in trace amounts, to spread quickly. The zoonotic diseases that affect domestic animals can be found in them. One of the earliest reports of methicillin-resistant *Staphylococcus aureus* (MRSA) associated with pig husbandry was made (Wulf et al. 2008). These ST398 porcine strains, which are circulating throughout Europe, cannot be typed using standard techniques. Livestock-associated MRSA (LaMRSA) is now thought to be at danger due to farming. Antibiotic resistant strains of bacteria have emerged in cattle and poultry as a result of the selection pressure brought on by the use of antibiotics in livestock production to enhance growth and treat infection (Wulf et al. 2008).

3.5 FOOD-BORNE

Food delivery, processing, and manufacture on a large scale are all contributing to an increase in food-borne zoonotic diseases. There are 31 main food-borne pathogens that are responsible for infections; these significant elements, including Salmonella nontyphoidal, Campylobacter, Listeria, and Escherichia coli, are tracked by national agencies and control and eradication studies are carried out to prevent potential outbreaks (Gupta 2016) Undercooked meat is linked to epidemics of hemorrhagic E. coli O157:H7. Antibiotic addition to poultry feed was linked to the growth of Campylobacter species that were resistant to flouroquinolones. *Salmonella* spp. strains *S. Typhimurium* DT104 that are multi-drug resistant are also becoming more prevalent (Velge et al. 2005).

3.6 DEFORESTATION AND URBAN EXPANSION

The "dilution effect" of deforestation's loss of biodiversity has an effect on how zoonotic illnesses spread. According to this logic, the disease is less severe in places with great biodiversity because more animals support disease vectors. The burden of disease is greater when there are fewer species. While selective cutting may increase the risk of zoonoses if the forest's biodiversity is protected, the risk of zoonoses is not increased by clear-cut logging. (Velge et al. 2005).

Deforestation disrupts the natural balance of different species and changes ecosystems. For instance, deforested areas' water puddles are better mosquito breeding grounds because they are less acidic, opening up new biological niches for some vectors. (Velge et al. 2005). The frequency of interactions

between people and Population development and the expansion of human settlements into natural environments result in an increase in wildlife, which facilitates the transmission of zoonotic diseases. This has been demonstrated in Malaysia by the human-to-macaque transmission of *Plasmodium knowlesi* (Velge et al. 2005).
Additionally, urbanization draws immigrant settlers. The danger of bringing in new pathogens or diseases exists with human migration for job or refuge. Additionally, people who go to foreign lands lack immunity to diseases that may exist there. These informal communities, which typically have poor infrastructure and rodent- and tick-borne zoonoses, are common in developing nations. Emerging illnesses spread more readily as a result of the expansion of road and rail networks. New highways expose rural, immune-deficient people to emerging diseases (Velge et al. 2005; Naicker, 2011).

3.7 BUSHMEAT AND HUNTING

Deforestation and logging operations facilitate hunting in emerging nations. In certain nations, like Cameroon, the trade in bushmeat has resulted in an increase in hunting activities. It has long been recognized that hunting non-human primates causes the creation of new illnesses. the threat of zoonoses spreading through contact, droplets, and the air is significant when corpses are butchered in woods. Tularemia is one of the most important diseases transmitted by hunting. Hunters should take precautions especially when handling wild animals such as rabbits, hares and rodents. Game meat should be thoroughly cooked. They should wear gloves during contact. (Karataş yeni, 2021) The risk associated with cooking and eating the meat may be reduced (Naicker 2011).

3.8 HOST SUSCEPTIBILITY

Immunosuppressive drugs, chemotherapy, the development of HIV/AIDS, and organ transplantation. All alter human susceptibility to infections in negative ways. Leishmaniasis co-infections are more common in patients with HIV/AIDS. Additionally more prevalent are bacillary angiomatosis, peliosis, and cryptosporidiosis (Naicker 2011).

3.9 PATHOGEN ADAPTATION

Zoonotic infections may develop new virulence features that provide advantages for survival. The A336V mutation, which is exclusive to strains of *A. albopictus* mosquitoes, has helped the chikungunya pathogen adapt. *Salmonella* spp., which are multidrug resistant, serve as an example of how antibiotic use may exert a selective pressure that leads to the emergence of antibiotic resistance. Madagascar's antibiotic resistance has led to the outbreak of Yersinia pestis there (Naicker 2011).

3.10 ANIMAL MIGRATION

Herd migration contributes to the dissemination of RVF. RVF may spread to new areas as a result of any changes to this brought on by deforestation or altered land use. Wild bird migration has a role in the spread of WNF. Seasonal variations may result in modifications to migration patterns and duration (Naicker 2011). Highly pathogenic avian influenza (HPAI) is a natural reservoir in wild aquatic birds, and it has been demonstrated that these migratory birds excrete and spread HPAI across long distances (Naicker 2011).

3.11 ROLE OF WILDLIFE

The likelihood of zoonotic diseases emerging is influenced by how frequently different wildlife species come into contact with humans. For instance, *P. knowlesi* is known to exist naturally in long-tailed and pig-tailed macaques, and it has now been found that *Anopheles cracens* mosquitoes, which feed on humans, are the vectors of this disease. Unknown diseases have known hosts that may unexpectedly transcend the species barrier include several animals. Other infections may have an animal source that is not yet identified, like in the case of the coronaviruses that resemble SARS that were found in bats as the SARS-CoV's most likely natural reservoir. The significance of this diverse and extensive species for the spread of new zoonotic illnesses including the Nipah virus, Hendra virus, Marburg, Ebola, and mutant rabies is demonstrated by this (Naicker 2011).

4. EMERGING TYPES OF ZOONOSES DUE TO CLIMATE CHANGES

4.1 VECTOR-BORNE ZOONOSES

Many pathogens that affect animal and human health play a role in the formation of vector-borne zoonoses (VBZ). It can transmit bacteria, protozoa, helminths and viruses by transmission of many vectors such as mosquitoes, ticks, fleas, sandflies, lice. In particular, these diseases depend on many factors such as climate changes, geographical location, socioeconomic status. It is quite common in poor rural areas in subtropical regions. It affects the whole world as a major public health problem (Filipe 2014). With the exception of a few isolated regions in north-west India, a rise in average temperature of 2.5̊C to 5̊Cand an overall increase in rainfall intensity of 1mm to 4mm/day are predicted by climate change predictions. The intensity and timing of the migration of these vectors, their rates of survival and reproduction, and the rates of pathogen development, survival, and reproduction inside their hosts are all assumed to be impacted by these climate variations (Singh et al. 2011). Changes in global climate affect the distribution of vector arthropods and are transmitted to new regions by infecting susceptible animals. In Turkey, 107 zoonotic infections in all have been documented. 19 of them are spread by arthropod vectors. 21 of these zoonotic illnesses are also of high priority in Europe. Likewise, notifications come from different countries (Düzlü 2020) In the South-East Asia region, including India, vector-borne diseases have recently become a severe public health concern. Numerous of these illnesses, in particular dengue fever and Japanese encephalitis, are now epidemic in nature and practically yearly, generating significant morbidity and mortality. The risk factors that are essential to dengue and other vector-borne illness transmission include:

- Globalisation,
- Unplanned
- uncontrolled
- urbanisation,
- development projects
- subpar domestic water storage
- subpar drainage of water
- frequent travel
- human migration are all examples of environmental sanitation issues.

These problems are quite troubling and require thorough attention. Given that these diseases are widespread in the surrounding nations; it is difficult to fight vector-borne diseases because of how easily they can cross international borders. For instance, Pakistan has reported cases of West Nile disease virus-neutralizing antibodies have been found and the Crimean-Congo hemorrhagic fever virus, which is the underlying cause of CCHF (Singh et al. 2011), is widespread in Pakistan. vector prevalence Vector-borne zoonoses inflict significant harm. There have been reports of three genera of soft ticks and seven genera of hard ticks (Singh et al. 2011).

5. CLIMATIC VARIATION ON VIRUS TRANSMISSION

5.1 CHIKUNGUNYA VIRUS

Due to an increase in mosquito population caused by climate change, Chikungunya virus (CHIKV) exposure was favored, which helped the virus emerge in some regions. (Chretien et al. 2007). Asian tiger mosquitoes (Ae. albopictus), which are currently established in Southern Europe, are more adapted to cooler temperatures than Ades aegypti, the primary vector of the Chikungunya and dengue viruses (Woolhouse and Gaunt 2007).

5.2 DENGUE HEMORRHAGIC FEVER VIRUS

Dengue hemorrhagic fever typically affects youngsters and most frequently occurs in Asia. Haemorrhage, shock, and occasionally death make it more difficult. The dengue virus is spread and reproduced by mosquitoes. Ae. aegypti thrives in increased nighttime warming temperatures, although Ae. albopictus has been allowed to endure subfreezing temperatures (Chunsuttiwat 2001).

5.2 WEST NILE VIRUS

Climate variables have a direct impact on the zoonotic pathogen West Nile virus's ability to spread. The virus is stored in birds, and mosquito vectors transmit it from birds to people. According to the four seasons, the virus's strength varies throughout the year, peaking in the summer and troughing in the autumn and winter when the mosquitoes sleep. The number of mosquitoes will increase due to wetter, warmer summers, and the virus will move more readily in milder winters (Barker and Lindsay 2000).

5.3 AVIAN INFLUENZA VIRUS H5N1

Avian influenza is an excellent illustration of a zoonotic disease pandemic that could be affected by climate change. Wild birds' naturally occurring avian influenza viruses don't make them sick, but the H5N1 form of the virus does, which is extremely virulent and can infect humans and have a high case fatality rate, is currently a serious worry. Climate change has the potential to affect bird migration patterns, waterfowl species numbers, and the cycle of avian influenza virus transmission (Slenning 2010).

5.4 RIFT VALLY FEVER (RFV)

The virus that causes Rift Valley fever is predominantly a zoonotic illness that is transmitted between vertebrate hosts via the mosquito Aedes species. Culex mosquitoes may bite infected ungulate hosts, usually during flood circumstances. Culex mosquitoes may bite infected ungulate hosts, usually during flood circumstances. Because it also feeds on humans, this vector is known as a "bridge species," which causes the virus to propagate outside of the typical zoonotic cycle (Wilson 2001).

5.5 LYME DISEASE

Tick dispersal has been discovered to be impacted by climate change. The boundary of tick distribution in the EU is moving northward and up into higher elevations; in addition, the change to milder winters may result in an increase in the tick population and, as a result, a greater risk of Lyme borreliosis and tick-borne encephalitis exposure in humans. Additionally, there have been reports of alterations in the sand fly's geographic range, which is a vector for Leishmania species (Myaing 2011).

5.6 HANTA VIRUS

Numerous zoonoses, such as the Hantavirus, plague, and leptospirosis, are transmitted by rodents. Hantavirus is a zoonosis that can be spread to people directly and is kept in rodent reservoirs by nature. It is more contagious when the reservoir is more prevalent locally (Parmenter et al. 1999). Impacts of climatic variations on zoonoses has been shown in Fig. 3.

6. RE-EMERGENCE OF ZOONOSES

Globally applicable preventative approaches and efficient therapies are required in response to the (re)emergence of zoonoses and the rising threat of antibiotic resistance. Customized strategies are now possible thanks to research in several fields, including enhanced hygiene practises, cutting-edge vaccinations and antibiotics, the use of bacteriophages, and extremely targeted immunomodulatory therapies. However, due to microorganisms' flexibility, (co-) evolution, and gene exchange between different species, science is a never-ending endeavor (Huber et al. 2020).

A widely acknowledged idea for examining zoonoses and combating infectious diseases is the One Health approach (Bidaisee and Macpherson 2014), as a number of elements affect the dynamics of their occurrence and propagation. Climate, ecosystems, food safety, animal and human health, public health, environmental safety, and a full bio-medical analysis of the infections, their vectors, and hosts must all be taken into account. Ecosystems, soil dynamics, land use, and climate change. Ecosystems in permafrost adapt to climate change rather quickly. As a result of warming in subarctic areas, which is reportedly ten times quicker than the average pace for the entire world, permafrost thawing, wildfire frequency, and lake size all are increasing (Bidaisee and Macpherson 2014). The status of the frozen ecosystems and landscapes in Eastern Siberia has already been significantly impacted by the 2-3°Cincrease in mean annual air temperature over the past three decades. Higher ground temperatures between 0.4°Cand 1.3°Ccause the seasonal melt to intensify and cryogenic processes to accelerate. The emergence of thermokarst affects the ecology and land usage in places devoid of forests. The northward expansion of many animals' and plants' habitats has also signaled a substantial change in the geographic and natural zones. Because of this change, new plant and animal species, including diseases and crop pests, are being introduced into the northern regions. The University of Hohenheim's Sergey Blagodatskiy and Holger Pagel expanded on this scenario by mentioning additional elements including animal and human movement, the soil's suitability for farming and animal husbandry as well as its capacity to release greenhouse gases. The greenhouse effect will be amplified and the rise in land surface temperature will be hastened if CO_2 and CH_4 emissions are increased in response to global warming. This could make greenhouse gas emissions particularly important. The mineralization of organic soil matter, which is primarily controlled by temperature and moisture, is the main source of greenhouse gas emissions from soil. Resilient ecosystems and "soil health," or the ability of soil to function in accordance with its potential and management techniques, are ensured by maintaining the proper balance between natural processes and anthropogenic activities (Doran 2002). Both are seen to be crucial for preserving biodiversity and advancing human welfare. A poster presentation on the latter

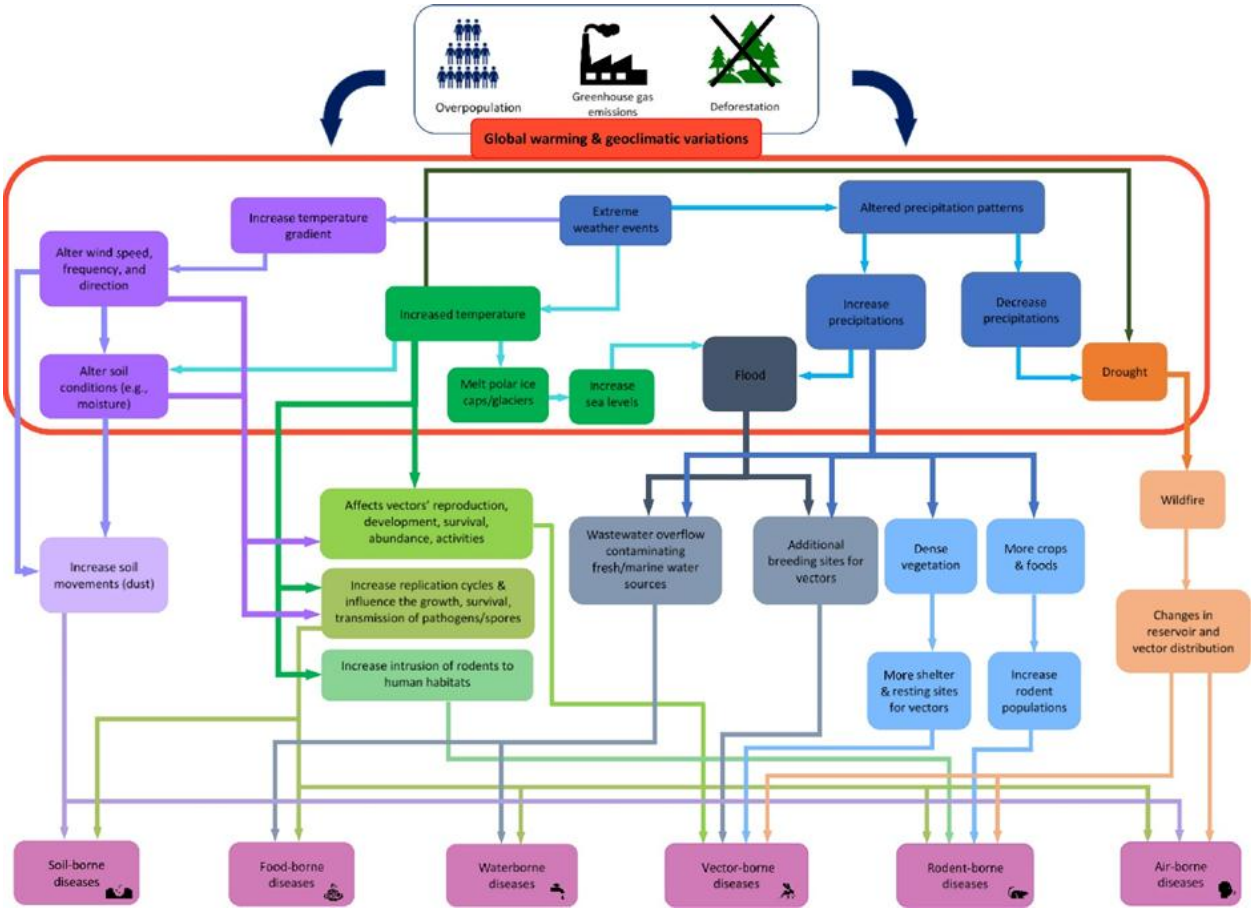

Fig. 3*:* Impacts of climatic variations on zoonoses. (Rupasinghe et al. 2022)

covered the experience and potential for preserving agro-biodiversity in the face of shifting permafrost conditions. Yakutia's predicted warming may cause the permafrost to thaw quickly, which might affect a variety of "soil health" factors, including a greater danger of losing arable land owing due to the opening of burial places, there is a higher risk of disease and exposure to thermokarst processes (Doran 2002). In the next five years, there is a 48% possibility that temperatures would climb above the 15˚Ccap set by the Paris Agreement, according to the proclamation on human health and climate change that was issued on October 25, 2022. This situation will especially affect any zoonosis type that is transmitted through water, food, a vector, rodents, or the air, and it will increase the number of novel diseases that have the potential to spread throughout the world (Diseases TLI 2023).

7. CONCLUSION

Zoonotic diseases are becoming a more serious global environmental issue. The proclamation on human health and climate change, which was released on October 25, 2022, estimates that there is a 48% chance that temperatures would rise above the 15˚Climit set by the Paris Agreement during the next five years. This circumstance will particularly impact all zoonosis kinds coming from water, food, vector, rodents, or air and will increase the number of new illnesses with the potential to spread globally. In order to conduct testing for yet exotic or rare diseases, disease monitoring must be linked with a network of professional institutes with the proper diagnostic capabilities. For the benefit of worldwide experts' knowledge sharing and enhancement, an integrated strategy to epidemiological, entomological, and environmental data collecting and analysis is crucial. A thorough investigation of zoonoses diseases that calls for the collaboration of entomologists, epidemiologists, and climatologists to look into the relationships between shifting vector habitats, disease patterns, and climatic conditions. One of the first measures to be taken should be to seek remedies to stop climate change. We must take major measures to reduce the risk of zoonotic disease. In order to predict possible hazards, it is important to create various models and plan precautionary strategies. Identifying disease surveillance in areas experiencing climate change, especially geographically, provides the basis for an effective fight against new and emerging zoonoses. International organizations such as WHO, the Food and Agriculture Organization of the United Nations (FAO) and the World Organization for Animal Health (OIE) should continue to work with cross-country policies, collaboratively and comprehensively, to prevent and manage the threats of such pandemics across countries. Aware of and ready for animal diseases. The impact of climate change on the future epidemiology of zoonotic and other illnesses has to be studied further.

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