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The Impact of Climatic Change on Animal Disease Ecology, Distribution and Emergence: A Review

Negesse Mekonnen*

Department of Animal Production and Technology, College of Agriculture and Environmental Science, Bahir Dar University, Ethiopia

ABSTRACT

The world's climate appears now to be changing at an unprecedented rate. Every environmental alteration, irrespective of its causes, namely natural or through human intervention, modifies the ecological equilibrium and setting within which diseases, hosts or vectors and parasites breed, develop, and transmit disease. Climate change would directly affect disease transmission by shifting the vector's geographic range and increasing reproductive and biting rates and by shortening the pathogen incubation period. Unpredicted natural disasters following changes of climatic contents have also significant effect in transmission of diseases. Vector borne diseases that were previously restricted to tropical areas are now spreading to previously cooler areas. Climate related increments in sea surface temperature and sea levels could lead to higher incidence of water-borne infections. Currently, climate changes at global level is becoming the key determinant for the emergence of new and re-emergence of previously available animal diseases throughout the globe such as Rift Valley Fever, Ebola, Zika, Bluetongue, Schmallenberg, Crimean-Congo haemorrhagic fever and others. Therefore, appropriate livestock husbandry and management practices, adequate disease outbreak response plans, enhancement of disease surveillance and monitoring systems, and development of effectively coordinated locally appropriate strategies should be implemented to mitigate and prevent climate sensitive animal diseases.

Keywords: Climate change, Animal diseases, Vector borne, Emerging and re-emerging diseases

INTRODUCTION

Climate change refers to any significant change in the measures of climate lasting for an extended period of time and includes significant changes in temperature, precipitation, or wind patterns, among other effects, that occur over several decades or longer [1]. Scientific evidences are indicative of climate changes having an increasing impact on life on the planet. Rise in average temperatures, rainfall patterns change, and extreme weather conditions such as storms, flooding, drought and heat waves become more frequent as well as more intense. These processes are not something that will occur in the predictable future but have already been set into motion. In this context, animal production is particularly affected by climate change owing to its climate dependent nature [2]. By 2100, the increments in global average surface temperature could range between 1.8-4.0°C (IPCC). Meanwhile, sea levels have risen 1.8 cm during the past few decades, and Arctic sea ice has shrunk by approximately 2.7% each decade [3]. With global average temperature increments of merely 1.5-2.5°C, approximately 20-30% of plant and animal species are expected to be at a potential risk of extinction [4].

Climate is a key determinant of health. Climate affects the range of infectious diseases, while weather affects the timing and severity of outbreaks [5]. Climate change is already taking place now, thus past and present changes are indicative of possible changes in the future. The average temperatures in Ethiopia have increased at about 0.2°C per decade with increments in minimum temperatures of approximately 0.4°C per decade being more pronounced. On the other hand, over the last 50 years, average rainfall has remained fairly even in the country [6].

Livestock sector is of vital importance to the global economy as well as rural livelihoods. The estimated livestock population in the world in 2013 amounted to 38 billion. Thus, globally there was a 1:5 ratio between human and livestock populations. Developing countries accounted for 81% of these livestock. There is a high prevalence of animal diseases in developing countries. Annual mortality rates from livestock diseases are approximately 20% for ruminants and exceed 50% for poultry, thus causing a loss of approximately 300 billion USD per year. While climate change can aggravate some diseases in livestock, other diseases are particularly sensitive to climate change. Amongst 65 animal diseases that constrain animal productivity in poverty stricken countries, 58 diseases were identified as climate sensitive. Weather and climate, directly or indirectly affects the occurrence of animal diseases. These links may be spatial, with climate affecting distribution and weather affecting the timing or intensity of an outbreak [7].

Ethiopia is located between 3°-15°N and 33°-48°E and endowed with a climate which is tropical in the southeastern and northeastern lowland regions. However, the climate is much cooler in the large central highland regions of the country. Mean annual temperatures range from 1520°C in the high altitude regions and from 2530°C in the lowlands [8]. Mean annual rainfall distribution has maxima of (>2000 mm) over the South western highlands and minima of (<300 mm) over the South eastern & North eastern lowlands [9]. Climate model projections for the region indicate a substantial rise in mean temperatures in Ethiopia over the 21st century. The models also indicate an increase in rainfall variability, with a rising frequency of both extreme flooding and droughts due to global warming [10]. Therefore, this paper reviews the impact of climate changes on the pathogen, host, vector, disease ecology, and the factors involved in climate change (temperature, rainfall, deforestation, etc.).

LITERATURE REVIEW

Climate change impacts on animal disease distribution

Impacts of climatic changes on disease distribution

There exists a direct link between the factors involved in climate change and animal diseases. These links between climate and diseases have been identified. The direct effects of climate change on animal diseases are likely to be the most for diseases that are vector-mediated, soil, water or flood, rodent, air, temperature/humidity related [7]. On the other hand, the indirect effects of climate change on diseases are more complex. These includes effects on the pathogens, vectors, on the disease reservoirs, and on the host itself. Diseases that can be directly affected by climate change include those that are related with chemical and physical factors such as temperature or humidity extremes or air pollution. For instance, intense heat waves could lead to aggravated illnesses and mortality whereas milder winter temperatures could minimize the risk of hypothermia and hypoglycaemia in new born of animals such as lambs. Increased concentrations of pollutants such as ozone would cause respiratory diseases of animals [4].

Indirect health effects arise from disturbances of more complex ecological systems, and includes changes in the ecology, range and activity of vectors and their associated diseases such as malaria, West Nile virus, Rift Valley Fever, Avian flu, Chickungunya, and Dengue [11]. Also included are, water-borne diseases and associated pathogens for gastrointestinal infections such as vibrio diseases including cholera, diseases from polluted water; changes in the atmospheric strata, and transmission of air-borne diseases such as meningitis, respiratory ailments; changes in agro-industrial practices and food availability. Massive migration waves along narrow coastal regions, and regional conflicts over exhausted agricultural and water resources could be of great public health concern. The endemic range of some diseases, such as Leishmaniasis in Southern Europe has been already extended. Climate change could enhance habitat extension for sand-fly and other phlebotomy vectors northwards. The ecology and geography of the tick species that transmits Lyme disease could change remarkably [12].

Climatic factors affecting disease distribution

Temperature: Some infectious diseases are more prevalent in tropical and subtropical areas than in temperate or cold areas. Therefore, global warming would tend to expand their area of dominance, thus increasing the seriousness of outbreaks. Some of these diseases are food- or water-borne infections; after introduction into a region, they have the potential to spread over the entire region. Viral, bacterial, and protozoan agents that cause diarrhoea can survive especially in warmer water for an extended duration of time and thus result in enhanced transmit ability during rainfall periods [3].

Rising sea temperatures and the consequent, melting of polar ice caps and glaciers, increases in sea levels are also of major concern. Rising sea level could lead to coastal flooding, thus increasing the risks for water borne zoonoses. Carbon uptake by oceans would lead to ocean acidification, thus threatening marine ecosystems [3]. The incidence of Vibrio cholera, a zoonotic bacterial pathogen has been linked to climate variability. More intense and erratic weather patterns could result in a rise of ocean temperatures could lead to more plankton blooms that provide nutrients for *Vibrio cholera* [13], thus escalating the outbreaks.

Drought: The potential for drought to impact vector-borne diseases depends on climatic conditions that affect the ecology of the arthropod vectors and their animal host and on the life cycles of the disease-causing pathogens they harbour. Drought can influence various aspects of a vector's life cycle including: survival, population numbers, behaviour, distribution, and vector-pathogen-host interactions. For example, during drought conditions certain mosquito species might be favoured as larger pools become shallower and the velocities of rivers and canals decrease [14].

Drought, also influences tick borne diseases. The most important tick and disease vector species that affect sheep and deer in the UK and Europe is *Ixodes ricinus*. *Ixodes ricinus* is a vector of *Borrelia burgdorferi* that causes tick-bite fever and louping illness to animals. Environmental and ecological factors affect the ability of ticks to maintain their moisture balance and host blood availability. It is probable that the impact of drought would affect the moisture balance of *Ixodes ticks*. Studies on *I. scapularis* in Illinois for the duration of an year following drought, revealed that larval densities were significantly lower compared to the average larval densities that were previously observed during a period of eight years [15]. Drought severely damaged vegetation, as well as negatively impacted mouse populations; both these factors would have indirectly affected the tick populations by increased desiccation and a loss of host blood. In more extreme environments, such as found in sub-Saharan Africa, tick species have spread from drought-stricken regions to more suitable habitats. Drought can also impact on pathogen infection rates in ticks [16].

Rainfall and humidity: Rainfall and humidity have significant value in disease outbreaks and distributions. Rainfall variability could have direct consequences on infectious disease outbreaks. Increased precipitation may increase the presence of disease vectors by expanding the size of existent larval habitat and creating new breeding grounds. In addition, increased rainfall would lead to a spurt in plant growth and consequent increase in food supplies for the vertebrate reservoirs [17].

In 1993, there was a Hantavirus outbreak in the southwest U.S, after the end of a six-year drought preceded by heavy snows and rainfall. The precipitation supported prolific growth of plants and animals leading to a rapid increase of the deer-mice population. The mice would have carried Hantavirus for several years, but abruptly, humans were exposed to contact with mice. The routes of infection for humans were from direct contact with infected mice or their droppings. Hantavirus Pulmonary Syndrome has been reported in 34 states. As of 2013, 637 cases were reported in the U.S with approximately 230 fatalities [18].

Rift Valley fever (RVF) virus may survive in mosquito eggs for several years, until a prolonged heavy rainfall facilitated an awakening of Aedes mosquitoes that feeds on ruminants and thus be the trigger for a RVF outbreak. Infected ruminants that end up in densely populated irrigation areas may also attract mosquitoes that feed on human blood and thus contribute to the transmission of RVF among humans [19]. RVF epidemics usually occur in 5-15 year cycles after periods of excessive rainfall. Two important observations emerge from these rainfall-disease outbreak patterns. Firstly, whenever "permissive" ecological and climatic conditions converge, there is an RVF outbreak in defined ecologies. In some of these areas where, RVF is known to be endemic, little information on the processes that permit persistence is known. Therefore, it is plausible that many of such environments that currently harbour dormant transmissions might experience a wave of massive epidemics in the future as climate and land use changes. The main driver for RVF epidemics for the geographical area that encompasses: East and South Africa, and to certain extent, West Africa and Saudi Arabia have been excessive precipitation. Whereas epidemics in eastern Africa occur after the El-Nino weather phenomenon, those in West Africa, particularly Senegal, are believed to occur after a "productive" rainfall. The rainfall pattern is characterized by: a primary rainfall event exceeding 10 mm and separated from a secondary but heavier rainfall event by a dry period of about 6 days [20]. This rainfall pattern is believed to favour breeding and hatching of the specific mosquito vectors. A few other epidemics have also been associated with irrigation/dams, for instance, the 2000-2001 outbreak in Yemen [21] and the 1977 outbreak in Egypt [22] and the 1987 epidemic in the Senegal River basin [23].

Some scientists believe that climate change, with its increase in the onset of sudden and extreme weather events, plays a role in Ebola outbreaks: dry seasons proceeded by heavy rainfalls that produce an abundance of fruit have coincided with Ebola outbreaks. With the abundance of fruits, bats (the suspected carriers of the recent Ebola outbreak) and apes may collectively gather, thus providing the opportunities for the disease to jump between species. Humans can contract the disease by consuming or handling an infected animal [18].

Wind pattern: Sometimes, midges are blown by wind across wider geographic areas. It is plausible that bluetongue virus (BTV8) was introduced in the United Kingdom, in the summer of 2006 in this manner. Then, the virus further spread westwards across Belgium [24]. It is also very likely that the flare up of the Schmallenberg virus (SBV) in the United Kingdom in early 2012 resulted from wind-carried infected midges arriving from mainland Europe [25].

Deforestation: Deforestation is the conversion of forests to non-forests by cutting, clearing and removal of rainforest or related ecosystems resulting in ecosystems with less biodiversity and could serve as pasture, cropland, plantation, urban use, logged area or wasteland [26]. Deforestation declines the intensity and frequency of rain fall and also increased mean temperature. Approximately, 75% of all new, emerging, or re-emerging diseases that infected humans since the beginning of the 21st century are of zoonotic origin (USAID). These includes: acquired immune deficiency syndrome (AIDS), severe acute respiratory syndrome (SARS), H5N1 avian flu and the H1N1 flu. Owing to deforestation, more wild animals, which may have been carriers for various diseases are being exposed to humans. Sierra Leone, where Ebola is originated, suffered a loss of 96 % of its forest by the 1920's and is at risk of losing the remaining by 2018 (UN). Similarly, Guinea, where the Ebola outbreak began in 2014, had lost 20% of its forests since 1990. Anthropogenic activities responsible for deforestation includes, logging, mining, slash and burn agriculture, demand for firewood and road construction. This implies that with human populations invading forests, reservoir animals such as bats are forced into finding new habitats that are in proximity to human settlements [18].

Climate change and infectious disease distribution

Vector borne diseases

Vector-borne diseases are caused by agents such as parasites, bacteria or viruses and are transmitted by the bite of hematophagous arthropods such as ticks and mosquitoes. Their management requires a multidisciplinary approach, especially as the majority of these diseases are zoonotic [27]. Global climate change has the potential to expand the distribution of vector-borne pathogens in both time and space, thereby exposing host populations to longer transmission seasons, and immunologically susceptible populations to the newly introduced pathogens [28].

Vector-borne diseases are of clinically importance in both humans and animals, but were initially considered to be of tropical origin and affect livestock involved in production. This no longer holds true since currently they are prevalent in companion animals and they are also found in temperate countries such as Europe. The development of diagnostic techniques could have contributed to an increase in the detection of vector borne diseases both among humans and animals [29]. Vector-borne diseases are particularly sensitive to climate change. Changes in temperature and rainfall patterns could affect both the distribution and the population of disease vectors, as can changes in the frequency of extreme climatic events. Arthropod vectors tend to be more physiologically active at higher temperatures; they therefore feed more voraciously in order to sustain their metabolic activities. This enhances the probability of disease transmission between hosts. Minor changes in vector characteristics could lead to substantial changes in disease distribution [30].

Fleas are competent vectors for numerous microbial pathogens of medical and veterinary importance. Plague, murine typhus and cat-scratch disease are examples of well-known flea-transmitted diseases. Despite regular ant parasitic treatment of domestic carnivores, cat and dog fleas remain their most common ecto parasites [31]. Several literatures indicate that cat-scratch disease and other Bartonella infections are emerging in Europe and that their epidemiology is changing [32].

Non-vector borne diseases

H5N1, is a highly pathogenic tropical virus affecting birds in tropical countries. Wild aquatic birds harbour Avian Influenza virus and they are the natural reservoir for all influenza A viruses. Global climate change would affect the spread of avian influenza viruses through various mechanisms. With global warming, bird distributions would shift northwards and southwards in the northern southern hemisphere, respectively. Scientific evidences already indicate a shift in the timing of migration. Climate change would result in changes in the composition of local species and these changes in turn may cause the redistribution of avian influenza into various age groups, species and migratory pathways [33].

Climate has important influence on the development and mortality of the free-living stages of nematodes of grazing ruminants. Higher temperatures lead to higher parasite abundance and increased risk of disease from midsummer onwards. Extremely higher temperature increases larval dehydration and mortality [34]. Nematodes have developed a mechanism to escape harsh dry climate by staying in the host gut by arresting their development at early stage of larvae. They shift to develop and mature from such dormancy to complete development to adult-hood during the spring [35]. One study conducted in UK had identified climate change in the UK, with a trend towards heavy rainfall in the autumn and winter. Warmer average temperatures would prevail throughout the year. The herbage growing season has been extended by 4 weeks over the past 40 years. Such climate change with prolonged moisture and warm temperature has created suitable environment for pathogenic nematode parasites to breed, develop and infect host continuously. Several disease outbreaks caused by *Haemonchus contortus*, *Nematodirus battus*, *Teladorsagia circumcincta* and *Fasciola hepatica* in sheep flocks in south eastern Scotland has been attributed to climate change [36].

The prevalence of infections with *Fasciola hepatica* could increase in those areas receiving increased rainfall due to the creation of temporary water bodies in which the intermediate snail host survives. The creation of permanent water bodies for irrigation in drier areas may facilitate the survival of the intermediate snail host of *F.gigantica* [37]. Diseases transmitted between animals in close proximity to each other are less related to climate. However, climate changes leading to the disappearance or limited availability of water resources or grazing land could cause mass migration of livestock and wildlife in search of water or for grazing. This migration increases the contact between livestock from various areas, and between game and livestock, and could lead to increased transmission of pathogens [38]. Such mass migrations of animals for sharing of water and food resources are known to contribute significantly to the spread of important African trans-boundary diseases that includes: foot and mouth disease, peste des petits ruminants and contagious bovine pleura-pneumonia. In the past, mass migration due to draughts in eastern Africa have been important factors in the flare up of rinderpest in stressed cattle and wild life populations [39].

Effect of climatic change on disease ecology

Effects on epidemiology

Climate change could alter transmission rates between various hosts not only by affecting the survival of the pathogen/parasite or the intermediate vector, but also by other, indirect forces that are impossible to predict with accuracy. Climate change could be one of the major factors that lead to changes in future patterns of international trade, local animal transportation routes and farm size, all of which may affect the probability of an infected animal coming into contact with a susceptible one. For example, a series of droughts that occurred in East Africa between 1993-1997, resulted in pastoral communities moving their cattle to graze in areas that were normally reserved for wildlife. This led to the infection of cattle with a mild lineage of rinderpest, thus transmitting the disease to both other cattle and also to susceptible wildlife [40].

In temperate regions, Anthrax epidemics occur during summer months in which dry periods are followed by prolonged periods of heavy rainfall. Prolonged heavy rainfall promotes runoff and results in stagnation of standing water. It has been proposed that water plays its role in anthrax epidemics by the collection (aggregation) and concentration of spores in spore "storage areas", a term that is intended to describe the stage of the life cycle of *Bacillus anthracis* more accurately than does the term "incubator areas" [41]. The surface of the *B. anthracis* spore is highly hydrophobic. Thus, the spores become dissolution resistant by water and could be transported in masses of organic matter by runoff to stagnated pools of water. With the advent of dry weather and subsequent evaporation of the stagnated pools of water and increasing concentrations of floating anthrax spores, as these pools of water gradually shrink. The high buoyancy of *B. anthracis* spores facilitates their adherence to vegetation as the vegetation is exposed due to evaporation of the surrounding water. Effects of water on anthrax spores is summarized in to three steps: (1) successive cycles of run-off and evaporation that would concentrate anthrax spores in storage areas, (2) evaporation redistribution of the spores from the soil onto vegetation, and (3) susceptible herbivores consuming the contaminated vegetation, becoming exposed to *B. anthracis*, and some developing anthrax [42].

Effects on pathogen

In general, higher temperatures and humidity increase the rate of development of parasites of some pathogens that have a life cycle outside the host. Changes affecting wind flow can drastically affect the dissemination of pathogens. Flooding that follows extreme climate events provides favourable conditions for many water-borne pathogens. Drought and desiccation are critical to most pathogens [7]. This could lead to shorter generation times and consequently increase the total number of generations annually; leading to higher pathogen/parasite population ratios [42]. Pathogens may also be disseminated following the introduction of uninfected hosts into new habitats, with these hosts allowing disease emergence. This is exemplified as in the case of varroasis on a global scale that followed the continuous expansion of disease-free European honeybee stocks into enzootic areas of Asia) and also in the case of bovine tuberculosis in New Zealand that followed the introduction of brush tail opossums from Australia, which became a novel reservoir for the disease in New Zealand [43].

Effects on hosts

Expansion of range of some pathogens and their vectors would potentially expose some animals to new pathogens and the consequent impact could be severe. Climate stress that includes, thermal distress, shortage of food and water could also lead to low immunity [7]. The most significant host-related effect includes genetic resistance to disease. During the course of evolution, many animals have developed a level of genetic resistance to some of the diseases to which they are commonly exposed. This is best exemplified by wild mammals in Africa that may be infected with trypanosomes, but rarely show symptoms of the disease due to 'antigenic variation'. Local Zebu cattle breeds show some degree of trypano-tolerance or resistance whereas recently introduced European cattle breeds are highly susceptible to the disease. But, African mammals were highly susceptible to rinderpest which swept through the continent in the late 19th century, since they had no prior exposure to the pathogen. It seems unlikely that climate change will directly affect genetic or immunologic resistance to disease in livestock. However, significant shifts in disease distributions induced by climate change pose a greater threat rather than exposure of new populations to new pathogens. At least in some cases, native populations may be particularly susceptible to the new diseases that infect them.

Certain diseases show a phenomenon called endemic stability. This occurs when the disease is less severe in younger than older individuals and also when the infection is common or endemic resulting in conferment of lifelong immunity. Although most of the infected individuals are young, they experience only milder disease. In contrast, with the endemically stable infections becoming rarer, a higher proportion of older individuals are infected. In other words, on an average, it takes a longer period of time to acquire infection and the number of individuals with severe disease rises. For example, a certain degree of endemic stability is shown by some tick-borne diseases of livestock in Africa such as anaplasmosis, babesiosis and cowdriosis. With climate change introducing such diseases to new regions, irrespective of age, all the individuals who are not immune to the disease will be exposed resulting in severe outbreaks of the disease. Climate change also prompts behavioural changes of animals that make them more susceptible to disease. For example, during periods of drought animals will cluster together more at waterholes. The close proximity will allow diseases to spread more and the animals, often in worse physical condition will be unable to resist [44].

Effects on vectors

Rising temperatures will favour the breeding and abundance of mosquitoes. Rainfall affects larval habitats and vector populations as mosquitoes due to their egg laying habit in water-filled containers. In some cases, rainfall may alter larval habitats and vector populations. Due to excessive rain, habitats could be removed through flooding. Scanty rainfall could lead to the creation of new habitats because, with the water in rivers being drawn into pools serves as new breeding sites for various species of mosquito species during the dry season [45].

Climate change effect on emerging and Re-emerging animal diseases

People and animals have been in close contact since the domestication of animals, which has assisted in the swapping of diseases and their spread. Emergence may be due to the fact that an established disease can be traced to an infectious origin. Emergence may also be used to describe the resurgence/resumption of a previously known infection after it diminished in its incidence of the spread of an agent or the recognition of an infection that has been present in the population but has gone undetected [46].

Mechanism of emergence

The mechanisms allowing emergence or re-emergence of infections are numerous. A key source of emergence is the opening of previously closed ecosystems, which leads to new contacts between unrelated species and shows that a species previously unknown to be susceptible to an infection (because of the lack of opportunity to be infected) is in fact fully susceptible. The extreme variability of viruses (particularly RNA viruses) leading to generations of populations of quasi species, allows them to easily cross the species barrier. Viruses evolve far quicker than their hosts, by several mechanisms: point mutations, deletions, recombination, re-assortment and acquisition of cellular genes. Moreover, viruses have co-evolved with their natural hosts, often leading to unapparent infections [47].

Evidence of emergence

The Zika Virus: The Zika virus was identified over 50 years ago in Africa where it is reasoned to have originated. It is known to have spread to various geographic areas of Asia and the Pacific Islands, with the most recent spread eastward to the Americas [48]. The Zika virus drew worldwide attention in 2016 when it caused a widespread epidemic in Brazil [49]. Zika's vector, the Aedes aegypti mosquito, has its habitat in the hot, humid regions in Central and South America, Mexico, and the South eastern United States. They breed in stagnant water. Zika virus is spread by female mosquitoes while feeding on human and animal blood. Rising temperatures favour their breeding, accelerate their reproduction rate, and reduces the maturation period for the microbes to disseminate. Shifts in temperature, precipitation and humidity can alter the lifespan, biting frequency, number of progeny, and replication time of the virus in the mosquito. All these changes could potentially expose more humans to mosquitoes [50].

Middle East Respiratory Syndrome (MERS-CoV): Middle East respiratory syndrome (MERS) is a viral respiratory disease caused by a novel coronavirus (Middle East respiratory syndrome coronavirus, or MERSCoV) that was first identified in Saudi Arabia in 2012. Since then, (MERS-CoV) outbreaks have been reported in 26 countries and recently in South Korea [51]. Today, animal MERS-CoV infections are being reported to the world organization for animal health as an emerging disease [52]. Animals common to the Middle East, such as goats and camels, have been suggested, and recently evidence for previous infection of dromedary camels have been reported [53]. Although Bats have been implicated as a reservoir host of MERS-CoV, but it is highly unlikely for them to be the source of the outbreak, due to their limited contact with humans in the Arabian Peninsula. Plausibly, camels could be potential intermediate hosts as there are reports that some MERS-CoV–infected persons had been exposed to camels [54].

Ebola: Scientists have warned that there could be more frequent Ebola outbreaks due to climate change, as the severe and often fatal disease struck through four countries across West Africa. Climate change may also be driving humans into closer proximity with virus-harbouring bats, as low agricultural productivity force humans into the forest for food. The extensive forests that were pristine habitats for bats, have undergone continuous deforestation due to population growth , land use and climate change. With bat habitats threatened and humans moving into their once thriving habitats, has brought bats and humans to close contact thus allowing possible viral infection. WHO had already issued warnings, even before the 2014 Ebola outbreak that climate change could be the main factor for the increasing number of infectious diseases. The interaction between climate change and deforestation potentially positions humans in close proximity to infected animals. As habitats are overwhelmed by deforestation, humans are often left with fewer options but to hunt "survivor species," such as bats, which are one of the most habitual reservoirs of the Ebola virus. The route of transmission of the filovirus Ebola from bats to humans is a classic example to demonstrate the intricacy of the spread of such diseases and its links to climate change and land use. Direct bat-human contact is not just the satisfactory condition for the filovirus Ebola to erupt. There exists a sequence of events that brings together bats, apes, and humans together in unconventional ways and intensified to some extent by unusual climatic conditions [55].

Schmallenberg: The large-scale outbreak of disease across Northern Europe caused by a new orthobunyavirus known as Schmallenberg virus (SBV) has caused considerable disruption to lambing and calving up to 2012. The virus was confirmed in many European countries (Germany, Holland, Belgium, France, Luxembourg, Italy, Spain, England and Denmark). The distribution follows that of Blue tongue virus serotype 8 (BTV-8) outbreaks in Northern Europe in 2006-2008. Affected animals include cattle, sheep, goats and bison. Schmallenberg virus is transmitted by biting midges (Culicoides species). The virus was found inseveral *Culicoides* species. (*C. obsoletus* complex, *C. dewulfi*, *C. chiopterus*, *C. scoticus*, *C. punctatus*).

A horizontal transmission through animal contact is unlikely. Vertical transmission of Schmallenberg virus and infection of the foetuses could lead to embryonic mortality, malformed newborns, abortions and stillbirths. Climate change influences the distribution of vectors by shifting their latitudinal and altitudinal limits.

Bluetongue Disease: Since climate change will further the range of tropical agents and other causative agents, it will favour the emergence of the arthropod borne 'Blue Tongue Disease'. Bluetongue (BT) is a non-communicable insect-transmitted disease affecting ruminants, particularly sheep and certain species of non-African wild ruminants. Wind-borne insects are believed to have also been responsible for the recent spread of BTV from North Africa to southern Europe and between Mediterranean islands, in some instances involving distances of up to several hundred kilometres [56]. Severe climatic events such as storms, typhoons and hurricanes have been proposed to be responsible for the wind-borne dissemination of virus-infected Culicoides midges, although long-distance dissemination of virus-infected insects likely can occur simply on usual or regular winds. There is strong evidence that in 2007, the BTV serotype 8 was spread from continental Europe to adjacent regions of England by wind-borne insects [24].

Crimean-Congo Haemorrhagic Fever: Crimean-Congo haemorrhagic fever (CCHF) is a tick-borne viral infection caused by Nairovirus. It was first identified in the Crimean region in 1944 [57]. CCHF is a widely distributed arboviral disease, ranging from Southern Russia and the Black Sea region to the southern tip of Africa [58]. With reports of new infections, CCHF is now considered as ‘emerging’ across the world. Recently, many countries have reported new infections in humans, including Albania in 2001 [59], Turkey in 2002 [60] and Georgia in 2009 [61]. Both wild and domesticated animals are important links in the disease transmission cycle, acting as reservoirs for continued tick re-infection. Hyalomma ticks that serve as the vector are adapted to hot and dry or semiarid environments, and are found in many parts of Africa, Asia and Europe [62].

CONCLUSION AND RECOMMENDATIONS

There is clear evidence that global climate is extremely changing due to anthropogenic and other natural factors. Climatic changes have been known for a while for their deleterious impact on the biology, fecundity, growth and biodiversity of aquatic, terrestrial and aerial animals. The emergence and re-emergence of various vector and non-vector borne diseases in many regions of the planet clearly indicates the link between climate change and disease distributions. Climatic change will distort the complex interrelationships between microbes, insect vectors, animal reservoirs of infectious diseases and humans, thereby affecting the distribution of infectious diseases. Therefore, we recommend an in-depth understanding of the effects of climate change on disease epidemiology for early detection with rapid control and prevention strategies of climate sensitive diseases, regular epidemiological surveillance in those areas that are affected by climate change, production and use of disease tolerant breeds, formulation and implementation of strategies in order to mitigate the impacts of climate change.

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