Review on the Relationship of Climate Change and Prevalence of Animal Diseases

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Abstract: Climate change is a subset of the larger set of ecosystem change that is promoting the emergence and re emergence of animal diseases. It affects livestock health through several pathways. These includes effects on pathogens, such as higher temperatures affecting the rate of development of pathogens or parasites; effects on hosts, such as shifts in disease distribution that may affect susceptible animal populations; effects on vectors, such as changes in rainfall and temperature regimes that can affect both the distribution and the abundance of disease vectors; and effects on epidemiology, like altered transmission rates between hosts, food safety and animal production. Furthermore, Climate change influences the emergence and proliferation of disease hosts or vectors and pathogens and their breeding, development and disease transmission. Consequently, it affects distributions, host–parasite relationships and its assemblages to new areas. Indirectly the climate change can affect quantity and quality of fodder crops, animal production, severity and distribution of diseases in both domestic and wild animal that result in their migrations. Most developing countries are highly vulnerable to this climatic impact. From this developing countries Ethiopia is the one that faces recurrent drought due to climate change in its different parts that ends in economic crises. Even though this climatic change causes different economic impacts in the country, a few researches were conducted on it. Now climate models suggest that Ethiopia will see a further warming of between 0.7°C and 2.3°C by the 2020s and between 1.4°C and 2.9°C by the 2050s. So that, it is important to create awareness for the society how climatic change can occurred and result in prevalence of infectious animal disease that end up with economic crises of the country.

Keywords: Climate change, disease transmission, host, pathogen, vector.

1. INTRODUCTION

Agriculture remains the backbone of most African economies [1]. The agricultural sector is the largest domestic producer across the continent and employs between 70% and 90% of the total labor force [2]. In addition, agriculture supplies up to 50% of household food requirements and up to 50% of household incomes. Most of the income is generated by beef cattle, dairy cattle, goats, sheep and chickens. Together these five species generate 92% of the total revenue from livestock in Africa. In many rural communities, livestock is the only asset of the poor, but it is highly vulnerable to climate variability and extremes [3, 4].

The impact of climate change is expected to heighten the vulnerability of livestock systems and reinforce existing factors that are affecting livestock production systems [5]. This climate change refers to long-term statistical shifts of the weather, including changes in the average weather condition or in the distribution of weather conditions around the average [6]. A warming and unstable climate is playing an ever-increasing role in driving the global emergence, resurgence and redistribution of infectious diseases.

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Three components are essential for most infectious diseases: an agent (or pathogen), a host (or vector) and transmission environment. Some pathogens are carried by vectors or require intermediate hosts to complete their lifecycle. Appropriate climate and weather conditions are necessary for the survival, reproduction, distribution and transmission of disease pathogens, vectors, and hosts. Therefore, changes in climate or weather conditions may impact infectious diseases through affecting the pathogens, vectors, hosts and their living environment [7].

This effect is by one (or a combination) of four primary mechanisms: the first is *via* range shifts in host or vector distribution that bring these hosts and vectors into contact with new animal populations; the second is through changes in the population density of the host or vector that would result in increased or decreased frequency of contact with animal or with other hosts and vectors; the third mechanism is *via* changes in the prevalence of infection by the pathogen in the host or vector population that would increase or decrease the frequency of animal contact with an infected host or vector; and the fourth is through changes in pathogen load brought about changes in rates of pathogen reproduction, replication, or development in hosts or vectors [8].

The impact of climate change on livestock production and health in Africa is determined largely by

E-ISSN: 2310-0796/18

the vulnerability of African livestock production systems [9]. From African tropical countries the potential impact of climate change on health has been recognized in Ethiopia, but developing specific actions and responses needed to mitigate its consequences need further work. Some impacts of climate change observed so far in the country are recurrent drought, flood, malnutrition and the re-emergence of climate-sensitive infectious diseases [10].

A few researches have been conducted on the impacts of climate change on livestock health. Regardless of its vital importance in the country unfortunately, there are poor information on the relationship between long climate change and animal health. Monitoring its impact is a complex task since there are other confounding factors which may contribute to animal health problems.

Therefore the objective of this seminar paper is:

- To delineate the impact of climatic change on epidemiological triangles (pathogen, host and environments or disease transmission) that creates a window for animal diseases.
- To review and provide information on how climatic change can result in prevalence of animal infectious diseases.

2. CLIMATE CHANGE AND PREVALENCE OF ANIMAL DISEASES

2.1. Impact of Climate Change on Animal Health

The distribution of infectious diseases, the timing and intensity of disease outbreaks are often closely linked to climate. Climate change may affect livestock health through several pathways both direct and indirect. The direct effects of climate on animal health are likely to be most pronounced for diseases that are vector-borne, soil associated, water or flood associated temperature/humidity associated and sensitive to climate [11]. These directly or indirectly effects by weather and climate may be spatial, with climate affecting distribution, temporal with weather affecting the timing of an outbreak, or relate to the intensity of an outbreak. Global climate change alters ecological construction which causes both the geographical and phonological shifts [12]. These shifts affect the transmission pattern of the pathogen and increase their spectrum in the hosts [13].

The increased spectrum of pathogens increases the disease susceptibility of the animal and thus, supports the pathogenicity of the causative agent. The livestock systems are susceptible to changes in severity and distribution of livestock diseases and parasites as potential consequences. Incidence of external parasite (43.3%) was first ranked as the problems in the warm temperate (vector-borne diseases are especially sensitive to climate change. [14]. Changes in rainfall and temperature regimes may affect both the distribution and the abundance of disease vectors, as can changes in the frequency of extreme events. Arthropod vectors tend to be more active at higher temperatures; they therefore feed more regularly to sustain the increase in their metabolic functions, enhancing chances of infections being transmitted between hosts. Small changes in vector characteristics can produce substantial changes in disease [11]. A changing environmental spectrum also may result in increased or reduced contact between infected and susceptible animals and thus affect transmission. Temperature and humidity changes will also affect the spatial and temporal distribution of the pathogens of non-vector borne diseases that spend a period of time outside the host and are thus very sensitive to such changes. These pathogens include: the infective spores of anthrax and blackleg, the viruses causing peste des petits ruminants (PPR) and foot and mouth disease (FMD), contained in wind-borne aerosol droplets the agents causing dermatophilosis, haemorrhagic septicaemia, coccidiosis and haemonchosis [15].

Anthrax is an acute infectious disease of most warm-blooded animals, including humans, with worldwide distribution. The causative bacterium, *Bacillus anthracis*, forms spores able to remain infective for 10-20 years in pasture. Temperature, relative humidity and soil moisture all affect the successful germination of anthrax spores, while heavy rainfall may stir up dormant spores. Outbreaks are often associated with alternating heavy rainfall and drought, and high temperatures [16].

Foot-and-mouth disease (FMD) is a highly contagious, viral infection of cloven-footed animals, including cattle, sheep and pigs. It is a major threat to the United Kingdom's (UK's) livestock and of considerable economic importance to Africa. Most transmission is by contact between infected and susceptible animals, or by contact with contaminated animal products. However, FMD can also spread on the wind. The survival of the virus is low at relative humidity below 60% [17], and wind-borne spread is favored by the humid, cold weather common to the UK.

In warmer drier regions, such as Africa, wind-borne spread of FMD is considered unimportant [18].

Peste des petits ruminant (PPR) is also another acute, contagious, viral disease of small ruminants, especially goats, which is of great economic importance in parts of Africa and the Near-East. It is transmitted mostly by aerosol droplets between animals in close contact. However, the appearance of clinical PPR is often associated with the onset of the rainy season or dry cold periods [19], a pattern that may be related to viral survival. African horse sickness (AHS), a lethal infectious disease of horses, is caused by a virus transmitted by Culicoides biting midges. Large outbreaks of AHS in the Republic of South Africa over the last 200 years are associated with the combination of drought and heavy rainfall brought by the warm phase of the El Niño Southern Oscillation (ENSO) [20].

Rift Valley Fever (RVF), is another zoonotic viral disease of sheep and cattle that transmitted by *Aedes* and *Culex* mosquitoes. Epizootics of RVF are associated with periods of heavy rainfall and flooding [21] or, in east Africa, with the combination of heavy rainfall following drought associated with ENSO [22]. ENSO–related floods in 1998, following drought in 1997, led to an epidemic of RVF (and some other diseases) in the Kenya/Somalia border area, causing the deaths of more than 2000 people and two-thirds of all small ruminant livestock [23]. Diseases transmitted by tsetse flies (trypanosomiasis) and ticks (such as anaplasmosis, babesiosis, East Coast fever, heartwater) impose a tremendous burden on African livestock. Ticks, as ectoparasites, are a further direct burden. Many aspects of the vectors' life cycles are sensitive to climate, and spatial distributions can be predicted using satellite- derived proxies for climate variables [24].

2.2. How Climate Change Affect Animal Diseases

There is a substantial scientific literature on the effects of climate change on health and disease, but it has a strong focus on human health and vector- borne disease [25, 26]. By contrast, the effects of climate change on animal or non-vector-borne disease has received comparatively little attention [27]. Given the global burden of diseases that are not vector-borne, and the contribution made by animal diseases to poverty in the developing world attention to these areas is overdue [28].

Many animal diseases of significant impact in the UK and Africa are influenced by climate. Such influences are not the sole preserve of vector-borne

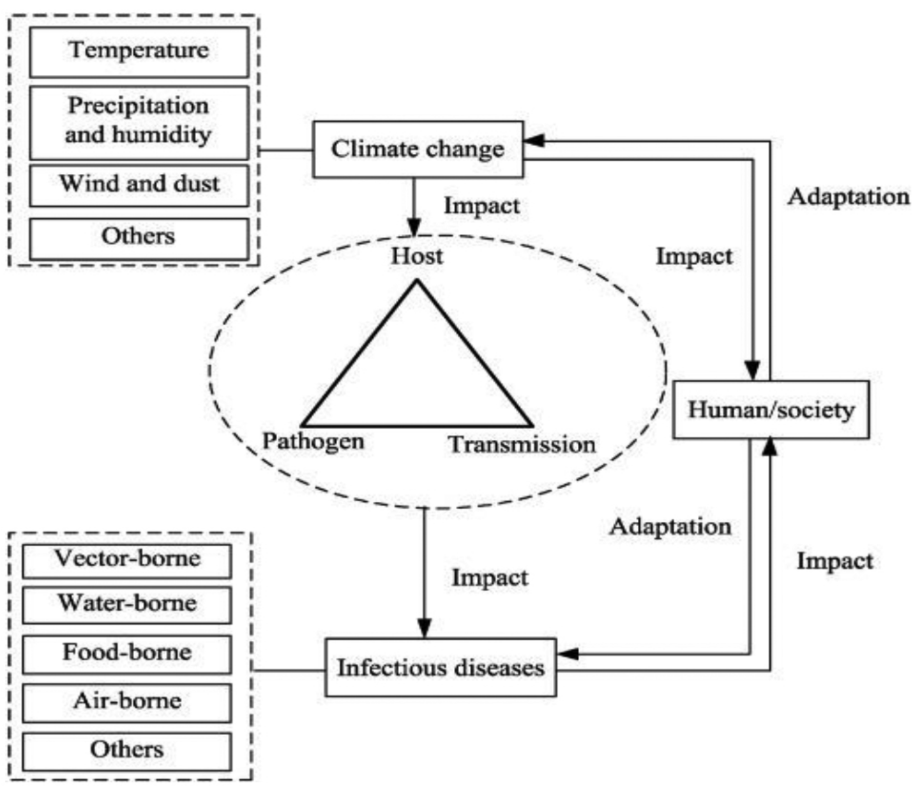

Figure 1: Climate change, animal infectious diseases, and human society [29].

diseases. Indeed, certain directly transmitted, food/waterborne and aerosol-transmitted diseases are also affected. Additionally, climate appears to be more frequently associated with the seasonal occurrence of non-vector borne animal diseases than their spatial distribution. By contrast, the associations of vector-borne diseases with climate are equally apparent in time and space - a reflection of the strong influence of climate on both the spatial and temporal distributions of the intermediate vectors [28].

In the scientific literature many processes have been proposed by which climate change might affect infectious diseases. These processes range from the clear and quantifiable to the imprecise and hypothetical. They may affect pathogens/parasites directly or indirectly, the hosts, the vectors (if there is an intermediate host), disease transmission or the natural environment. Only some of these processes can be expected to apply to any single infectious disease [27].

The first set describes the components of diseases: pathogen, host or vector, and disease transmission. The second set describes the climate and weather, including climate variables or large-scale extreme weather events. The third set describes the selected infectious diseases, including Vector-Borne Diseases, water-borne diseases, air-borne diseases, food-borne diseases [29].

2.2.1. Effect of Climate Change on Pathogen

Pathogen refers to a wide range of disease agents, including virus, bacterium, parasite germ, and fungi. The impact of climate change on pathogens can be direct, through influencing the survival, reproduction, and life cycle of pathogens, or indirect, through influencing the habitat, environment, or competitors of pathogens. As a result, not only the quantity but also the geographic and seasonal distributions of pathogens may change [30]. Temperature may affect disease through impacting the life cycle of pathogens. First, a pathogen needs a certain temperature range to survive and develop. Excessive heat can increase the mortality rates for some pathogens. The extended periods of hot weather can raise the average temperature of water bodies and food environment, which may provide an agreeable environment for microorganism reproduction cycles and algal blooms, For example, *Salmonella* species [31]. *Salmonellas* are a food-borne disease; the reproduction of the bacteria increases as temperature rises in that range between 7 °C and 37. Lastly, rising temperature may limit the proliferation of other pathogen through favoring its competitors. For example, *Campylobacter* species, the bacteria of food-borne disease *Campylobacter*, was found to be more concentrated in surface water at low temperature and during winter it is believed that warmer temperature supports other bacteria to out compete *Campylobacter* species. And that ultraviolet light prohibits the survival of *Campylobacter*.

Climate change may also cause shifts in precipitation, which affects the dissemination of water-borne pathogens, while rainfall plays an important role in the development of water-borne disease pathogens. Rainy season is related to the increase of fecal pathogens as heavy rain may stir up sediments in water, leading to the accumulation of fecal microorganisms, However, unusual precipitation after a long drought can result in an increase of pathogens, causing a disease outbreak. Droughts/low rainfall lead to Low River flows, causing the concentration of effluent water-borne pathogens [31].

Humidity change also impacts the pathogens of infectious diseases. The pathogens of air-borne infectious disease such as influenza tend to be responsive to humidity condition. For example, absolute humidity and temperature were found to affect influenza virus transmission and survival. Cold temperature and low relative humidity are favorable to the spread of influenza virus. Humidity change also affects the viruses of water-borne diseases. For example, the survival of water-borne viruses near water surface is limited due to the drying effect of surface water. Lastly, virus of vector-borne diseases may be impacted by humidity change [32].

Wind is another key factor that affects the pathogens of air-borne diseases. Literature suggested a positive correlation between dust particle association/attachment and virus survival/transport. It has been reported that the presence of desert dust in the atmosphere during Asian dust storms (ADSs) is associated with increased concentration of cultivable bacteria, cultivable fungi, and fungal spores. The concentration of influenza A virus was significantly higher during the ADS days than normal days. Studies further suggested that the viruses of infectious diseases be transported across ocean by dust particles which may facilitate the transmission of viruses between distant hosts [33].

2.2.2. Effect of Climate Change on Vectors and Hosts

Hosts refer to living animals or plants on or in which disease pathogens reside. Vectors are intermediate hosts and they carry and transmit pathogen to living organisms which become hosts. This review focuses on animal hosts, especially insects. The geographical locations and population changes of insect vectors are closely associated with the patterns and changes of climate. Thus, climate change may cause changes in range, period, and intensity of infectious diseases through its impacts on disease vectors [27].

No disease or vector distribution can be fully understood in terms of climate only. The supply of suitable hosts, the effects of co-infection or immunological cross-protection, the presence of other insects competing for the same food sources or breeding sites as vectors, parasites and predators of vectors themselves, could have important effects. Climate change may affect the abundance or distribution of hosts or the competitors/predators/ parasites of vectors and influence patterns of disease in ways that cannot be predicted from the direct effects of climate change alone [27].

Equally, it has been argued that climate change-related disturbances of ecological relationships, driven perhaps by agricultural changes, deforestation, the construction of dams and loss of biodiversity, could give rise to new mixtures of different species, thereby exposing hosts to novel pathogens and vectors and causing the emergence of new diseases. A possible ‘example in progress’ is the re-emergence in the UK of bovine tuberculosis, for which the badger (Meles meles) is believed to be a carrier of the causative agent, *Mycobacterium bovis*. Farm landscape, such as the density of linear features like hedgerows and other is a risk factor for the disease, affecting the rate of contact between cattle and badger. Climate change will be a force for modifying future landscapes and habitats, with indirect and largely unpredictable effects on diseases [34].

Effects on hosts: Mammalian cellular immunity can be suppressed following heightened exposure to ultraviolet B (UV-B) radiation - an expected outcome of stratospheric ozone depletion [35]. In particular, there is depression of the number of T helper lymphocytes, the cells involved in the immune response to intracellular pathogens. In terms of animal disease, such pathogens include viruses, rickettsia (such as *Cowdrio* and *Anaplasma*, the causative agents of heartwater and anaplasmosis) and some bacteria, such as *Brucella*, the organism causing brucellosis. Furthermore, increased UV-B exposure may diminish the host’s response to certain vaccinations. Continued ozone depletion could possibly impact on certain animal diseases, but it should be borne in mind that the association of UV-B with immunity has only been investigated in humans and mice. Diurnal animals that live outdoors may be less susceptible to heightened UV-B exposure [36].

A second host-related effect worthy of consideration is genetic resistance to disease. Many animals have evolved a level of genetic resistance to some of the diseases to which they are commonly exposed. For example, wild mammals in Africa may be infected with trypanosomes, but rarely show signs of disease. Local Zebu cattle breeds, which have been in the continent for millennia, show some degree of trypanotolerance (resistance) whereas recently introduced European cattle breeds are highly susceptible to trypanosomiasis. In stark contrast, African mammals proved highly susceptible to rinderpest which swept through the continent in the late 19th century, and which they had not previously encountered. It seems unlikely that climate change will directly affect genetic or immunologic resistance to disease in livestock [37].

However, significant shifts in disease distributions driven by climate change pose a greater threat than simply that of the exposure of new populations. Naïve populations may, in some cases, be particularly susceptible to the new diseases facing them. Certain diseases show a phenomenon called endemic stability. This occurs when the disease is less severe in younger than older individuals, when the infection is common or endemic and when there is lifelong immunity after infection. Under these conditions most infected individuals are young, and experience relatively mild disease. Counter-intuitively, as endemically stable infections become rarer, a higher proportion of cases are in older individuals (it takes longer, on average, to acquire infection) and the number of cases of severe disease rises. Certain tick-borne diseases of livestock in Africa, such as anaplasmosis, babesiosis and cowdriosis, show a degree of endemic stability [38].

Effects on vectors: Much has already been written about the effects of climate change on invertebrate disease vectors. Indeed, this issue, especially the effects on mosquito vectors, has dominated the debate so far. Remember, though, that mosquitoes are less significant as vectors of animal disease than they are of human disease. Mosquitoes primarily, and secondarily lice, fleas and ticks, transmit a significant proportion of important human infections. By contrast, biting midges, brachyceran flies (e.g. tabanids, muscids, myiasis flies, hippoboscids), ticks and mosquitoes (and, in Africa, tsetse) all dominate as vectors of livestock disease. Therefore, a balanced debate on the effects of climate change on animal disease must consider a broad range of vectors [22].

There are several processes by which climate change might affect disease vectors. First, temperature and moisture frequently impose limits on their distribution. Often, low temperatures are limiting because of high winter mortality and a relatively slow rate of population recovery during warmer seasons. By contrast, high temperatures are limiting because they involve excessive moisture loss. Therefore, cooler regions which were previously too cold for certain vectors may begin to allow them to flourish with climate change. Warmer regions could become even warmer and yet remain permissive for vectors if there is also increased precipitation or humidity. Conversely, these regions may become less conducive to vectors if moisture levels remain unchanged or decrease, with concomitant increase in moisture- stress [39].

However, rainfall is not always agreeable for vectors. Excessive precipitation may have catastrophic impacts on mosquito population because strong rain may sweep away their breeding sites. On the contrary, drought in wet regions may decrease flow velocity in brooks and provide mosquitoes with more pools of stagnant water as breeding places [40]. The primary carrier of WNF is a type of mosquito named *Culex*, which usually breeds underground in the nasty water pools in city drains and catch basins. Drought allows for rotten organic materials to accumulate in those pools, forming favorite condition for *Culex*; heavy precipitation would wash the drains and water down the pools, limiting the spread of West Nile virus [38, 20].

2.2.3. Effect of Climate Change on Disease Transmission

Depending on the transmission route, disease transmission can be direct or indirect. Direct transmission refers to the transmission of a disease from one animal to another through droplet contact, direct physical contact, indirect physical contact, air-borne transmission, or fecal–oral transmission. Indirect transmission refers to the transmission of a disease to animal *via* another organism, a vector, or an intermediate host [40].

Many studies have proved that climate variables and weather conditions may affect disease transmission, despite some uncertainty about the specific mechanisms. Rather than focusing on the disease transmission mechanisms, this section discusses the impacts that climate change may impose on the spreading of animal infectious diseases. This impact can be direct as changes in climate condition may alter disease transmission by directly influencing the viability of pathogens. It can be indirect if a change in the transmission routes resulted from the responding behaviors of animals and vectors/hosts to climate change [41].

Temperature change alone, or together with other variable changes such as rainfall, may alter the transmission of diseases. Studies have reported an association between interannual variability in temperature and malaria transmission in the African highlands [40]. Hemorrhagic Fever with Renal Syndrome incidence closely correlates with meteorological factors that include temperature, rainfall, and humidity [41]. Wind and dust storms may also affect the transmission of infectious diseases. Wind can act as a transportation means for pathogen and virus of air-borne diseases. Pathogens can spread from endemic regions to other regions through interregional dust storms [35]. In other ways climate change can affect the transmission of infectious diseases through altering the contact patterns of animal–pathogen, animal–vector, or animal–host. Evidences showed that diseases transmitted by rodents sometimes increase during heavy rainfall and flooding events because of altered patterns of animal–pathogen–rodent contact [40]. For example, there have been reports on flood associated outbreaks of leptospirosis (Weil's diseases) in Central and South America and South Africa. The risk factors for leptospirosis for peri-urban population in low-income countries include flooding of open sewers and streets [42].

Climate variation plays an important role in shaping the patterns of human and other host activities and behaviors, such as seasonal occupation, migration, winter–summer lifestyles, and physical exercises these in turn can significantly influence the patterns of disease transmission [43]. The seasonal prevalence patterns of influenza infection in Europe are believed to be related to peoples and animals spending longer hours indoor during winter. It was shown that within each wild fowl migratory flyway, the timing of H5N1 outbreaks and viral migrations are closely associated [30].

Live poultry markets particularly in the holiday season serve as sources of human infected avian influenza and interacting with migratory birds may also contribute to the transmission of the virus. The elevated morbidity of gastroenteritis in temperate developed countries during summer months could be related to increased picnics and other outside-cooked meals. The re-emergence of kala-azar (visceral leishmaniasis) in the cities of the semi-arid northeastern region in Brazil in the early 1980s and 1990s was caused by the rural–urban migration of the subsistence farmers [43].

Climate change can harm animal immunity and susceptibility to disease, thereby affecting disease transmission. It may lead to ecosystem degradation, which will possibly bring pressure on agricultural productivity, causing issues such as crop failure, malnutrition, starvation, increased population displacement, and resource conflict. These pressures can contribute to increased animal susceptibility to infectious diseases [25].

2.3. Indirect Impacts of Climate Change

Specific studies describing the impact of climate change on livestock and wildlife diseases or pathogen emergence are not abundant. Factors such as landscape changes that remove portions of host populations (example habitat alteration or destruction), alteration of host migration patterns or increased host density that are likely to influence disease emergence have been described [44].

Climate change is indirectly affecting the abundance and distribution of the competitors, predators and parasites of vectors themselves, thus influencing patterns of disease. It may also be that changes in ecosystems, driven by climate change and affect land-use, could give rise to new mixtures of species, thereby exposing hosts to novel pathogens and vectors and causing the emergence of new diseases [45]. Changes in the frequency and distribution of diseases due to climate variability have been reported; however, estimating the real impact of climate change on livestock health over a long period still is a challenge [46].

It seems difficult to separate non-climatic factors from climatic factors. The best way in estimating a future impact of climate change based on empirically observed relationship between climatic conditions and their effects on the biological processes that determine diseases transmission in space and time [47].

2.3.1. Impacts of Climate Change on Food Safety and Nutrition

Climate already influences food safety within an agricultural system prior to, during, and after the harvest, and during transport, storage, preparation, and consumption. Changes in climate factors, such as temperature, precipitation, and extreme weather are key drivers of pathogen introduction, food contamination, and food borne disease, as well as changes in the level of exposure to specific contaminants and chemical residues for crops and livestock [48].

The impact of climate on food safety occurs through multiple pathways. Changes in air and water temperatures, weather-related changes, and extreme events can shift the seasonal and geographic occurrence of bacteria, viruses, pests, parasites, fungi, and other chemical contaminants [49]. For example: Higher temperatures can increase the number of pathogens already present on produce and seafood. Bacterial populations can increase during food storage which, depending on time and temperature, can also increase food spoilage rates [50]. Sea surface temperature is directly related to seafood exposure to pathogens [51]. Precipitation has been identified as a factor in the contamination of irrigation water and produce which has been linked to food borne illness outbreaks [52].

2.3.2. Impacts on Behavior, Distribution and Movements of Wildlife

Climate change will affect wildlife habitats and food sources, which could result in changes in wildlife behavior and feeding patterns in response to the new conditions. For example, the Daubenton's bat, 2% of which are sero-positive for European bat lyssavirus is increasing in abundance across Great Britain (GB) and feeds on insects over water. The effect of climate change (e.g. hot, dry summers interspersed with periods of extreme flooding) on the behavior of this bat is not known [53]. Competition between wildlife species within an ecosystem often limits the abundance and /or distribution of one or more species. For example, global decline in amphibian populations is already occurring as a result of habitat loss, infection by a chytridiomycete fungus and climate change, with some species now extinct in Latin America [54].

Climate change will affect animal migration and distribution. In the long term, could wild bird movements be reduced by climate change? This would depend on the availability of food and the day length for finding food in the breeding grounds during winter. Climate change could also result in wild bird breeding ranges shifting northwards from Mediterranean regions into GB, as occurred with the little egret in the mid 1990s and more recently with the cattle egret. Little egrets, in particular, are vulnerable to long periods of cold that may be diminishing as a result of climate change. The serotine bat is currently restricted to southern England [55] and climate change might facilitate a northwards expansion of its range. Warming trends in Fenno-Scandinavia have allowed badgers to extend their distribution 100 km northwards in Finland since the mid 1940s and badgers now occur as far north as the Arctic Circle [54].

2.3.3. Impact of Climate Change on Animal Production

In IPCC Third Assessment Report (2001) there is a section devoted that the vulnerability of animal production, warming those animal production facilities will be affected both directly and indirectly by climate change. The direct effects include the interchange of heat between the animal and its environment, associated with temperature, humidity, wind spread and thermal production. These are factors that influence animal performance (growth, milk and wool production, reproduction), as well as animal health and welfare [55].

The indirect effects include the influence of climate on the quantity and quality of fodder crops and grains, and severity and distribution of diseases and parasites. When the magnitudes (intensity and duration) of adverse climate conditions exceed certain limits, with little or no possibility of recovery, animal, functions are adversely affected as a result of stress.

Genetic variation, the stage in the life cycle and nutritional status also influence their vulnerability and resilience to environmental stress. For example milk production from dairy cattle and conception rates can fall dramatically, and vulnerable animals may die as a result of extreme events [6].

2.4. Climate Change and Zoonotic Diseases

Climate and environmental change could be associated with many emerging and re- emerging zoonoses that can be transmitted from animals to humans and from humans to animals. An estimated 75% of emerging infectious diseases in humans have evolved from exposure to zoonotic pathogens [57]. Climate change may cause increased environmental survival of pathogens. It may also cause changes in prevalence of pathogens in animal reservoirs, and changes in host–parasite ecology. Climate change could also shift boundaries for spatial distributions, host–parasite assemblages, and demographic rates. Life-cycle phenologies, associations within ecosystems, virulence, and patterns of infection and disease may also be caused by climate change [58].

Climatic variation also creates new ecological niches for vectors. It may also influence the

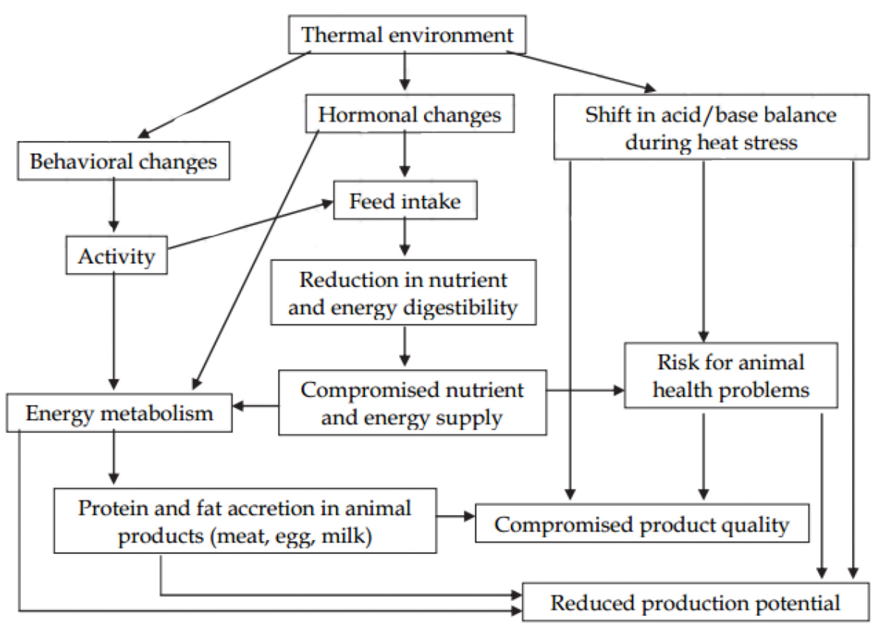

Figure 2: Effects of inconvenient thermal environment on the production potential and product quality of livestock [56].

epidemiology of zoonotic diseases, and causes changes in reservoir and vector dynamics [59]. Zoonotic infections are on the rise. The infection poses significant additional threats to human health. The threat gets worsened due to the complexity of the different organisms involved. In low-income countries, zoonoses are estimated to be responsible for one-fifths of the infectious diseases in human [60].

Ethiopia was identified as a "hotspot" for zoonotic disease events. The country ranked number one hotspot for leptospirosis, the fourth largest hotspot for Q fever and Trypanosomosis, and the tenth for tuberculosis. Much of the burden of zoonosis (68%) is distributed among only 13 countries. Ethiopia has the 4th highest burden caused by zoonosis. These ranks indicate an already existing burden of zoonotic disease in the country. The burden has the potential to be exacerbated by the effects of climate change [61].

3. CURRENT STATUS AND FUTURE PRESPECTIVE EFFECT OF CLIMATE CHANGE IN ETHIOPIA

Africa is a vast continent with a wide variety of climate regimes. The continent is predominantly tropical, hot and dry but there are small regions of temperate, rather cool climate in the extreme north and south and at higher altitudes. Nevertheless, observations show that the African continent is warmer than 20 years ago, with an average rate of warming of about 0.05°C per decade. Moreover, the African climate has, during the 20th Century, experienced wetter and drier intervals than during previous centuries. Projections for the rates of change in temperature and precipitation for the 21st Century vary but, irrespective of this uncertainty, future annual warming is expected to be highest in the interior of the semi-arid regions of Saharan and central southern Africa, resulting in desertification because people living in Africa are hardest hit. So that large effects of climate with respective animal disease will be expected [58].

From the tropical countries of East Africa; Ethiopia is considered a center of diversity for animal genetic resources in general and to cattle in particular. Indigenous cattle breeds in Ethiopia are a valuable source of genetic material because of their adaptation to harsh climatic conditions, their ability to better utilize the limited and poor quality feed resources and to their tolerance a range of diseases found in these regions. Despite the significant contribution of cattle to the country, little attention is given to identify, characterize and conserve the diversity of the various classes of livestock [62].

Climate change is of critical importance to Ethiopia; mainly due to changes in the climate Ethiopia has faced recurrent droughts across its different parts. The mean annual temperature has, for example, increased by 1.3°C between the years 1960 and 2006. This is estimated to be an average rate of 0.28°C increase in temperature per decade [63]. This change is currently adversely impacting the health and lives of people and animal around the country. This is particularly true in low-income countries. It affects social and environmental determinants of health – clean air, safe drinking water, food security and shelter. The two most mentioned emerging and re-emerging cattle diseases in a recent OIE survey are Catarrhal fever (Bluetongue) and Rift Valley fever [64].

Climate models suggest that Ethiopia will see a further warming of 0.7°C and 2.3°C by the 2020s and between 1.4°C and 2.9°C by the 2050s [65]. The current population (over 87 million) is growing annually by 2.6% and is expected to be more than double by 2050 [10]. The country is extremely vulnerable to the impacts of climate change. The impact may potentially hold back economic progress or reverse the gains made in development, and thus exacerbates social and economic challenges due to expansion of both human and animal diseases [10].

Animal in the afar regional state already suffer from the burden of endemic and news emerging varieties of animal disease which can be linked to the changing climate and the extreme weather conditions. Cold-blooded vectors are sensitive to direct effects of climate such as temperature, rain fall patterns and wind. Rising temperature influence the production and maturity rate of infective agents as well as the survival rate of the vector organisms, thereby further influencing disease transmission [6]. Climate also affects their distribution and abundance through its effects on host plants and animals [66].

Changes in frequency and severity of extreme climate events have significant consequences on food production and food security [6]. In the future, the investigators stated that about 1.3 billion poor people, at least 90% of them, would be located in Asia and sub Saharan Africa, and climate change will have major impacts on more than 600 million livestock dependent people [67]. Climate change could be particularly damaging to countries which are dependent on rain fed agriculture and are under heavy pressure from food insecurity and often famine caused by natural disasters [68].

Climate change is predicted to reduce the gross domestic product (GDP) growth of the country by between 0.5 and 2.5% each year. Climate change has the potential to hold back economic progress. Worse is that it can even reverse the gains made in the development and exacerbate social and economic problems in the country. Dou to this reasons diseases which are vurnaleble to high temperature are expected at the future [64].

4. IMPACT OF CLIMATE CHANGE ON ECONOMY

Animal diseases due to climate change generate a wide range of biophysical and socio-economic impacts that may be both direct and indirect, and may vary from localized to global [69]. The direct effect of climate change as a result of increased ambient temperature and concurrent changes in heat exchanges causes heat stress which influences growth, reproduction performance, milk production, wool production, animal health and welfare. Mainly the economic impacts of diseases are increasingly difficult to quantify, largely because of the complexity of the effects that they may have, but they may be enormous: the total costs of foot-and-mouth disease in the UK may have amounted to $18–25 billion between 1999 and 2002 [70].

Changes in frequency and severity of extreme climate events have also significant consequences on food production and food security [6]. In the future, the investigators stated that about 1.3 billion poor people at least 90% of them would be located in Asia and sub Saharan Africa including Ethiopia, and climate change will have major impacts on more than 600 million livestock dependent peoples [66]. This climatic change could be particularly damaging to countries which are dependent on rain fed agriculture and are under heavy pressure from food insecurity and often famine caused by natural disasters [67].

Additionally, heat related mortality and morbidity would increase. Climate change is also expected to increase the risks of drought and floods that occur with El Niño in the future and this could result in serious high mortality of livestock due to drought resulting in pasture shortage and water scarcity which will aggravate the existing conflicts on natural resources and food insecurity in the region. Similarly El Niño may result in diseases outbreaks related to flooding that result in high economic loss in the country [50].

5. CONCLUSION AND RECOMMENDATIONS

In conclusion, the livestock sector globally is highly dynamic. In developing countries, it is evolving in response to rapidly increasing demand for livestock products. In developed countries, demand for livestock products is stagnating. This livestock production system can be affected due to different factors from this; global climate change is a common phenomenon today. It has been proven that the change affect the emergence and spread of infectious diseases. This applies to both climate changes as a whole, as well as individual factors such as temperature, rainfall, humidity and others. These changes may directly impact the pathogen, and indirectly the vectors of these pathogens. They can also affect the resistance of humans and animals and disease transmission mechanisms. In addition to this climate change can also induce its effects on the nutrition, movement and distribution of both domestic and wild animal then the association between the emergence of infectious disease outbreaks and global climate change can be seen. Even if there is a substantial scientific literature on the effects of climate change on health and disease, there is a strong focus on human health and vector-borne disease. By contrast, the effects of climate change on animal or non-vector-borne disease has received comparatively little attention. Therefore, awareness creation about its effect on animal health is an important means of reducing its impacts on occurrence of animal diseases.

Based on the above conclusion, the following recommendations are forwarded:

- Livestock keepers could be made more aware of climate change and variability so surveillance systems should be established or improved.
- More research should be needed in areas were knowledge about effect of climate on animal health is lacking.
- Increased inter-sector collaboration and actions, nationally and internationally in relation to climate change is needed.
- Fast and coordinated action is needed to secure high veterinary and food safety standards.

LIST OF ABBREVIATIONS

ADSs = Asian Dust Stroms

AHS = African Horse Sickness

EIP = Extrinsic Incubation Period

ENSO = El Nino Southern Oscillation

FAO = Food and Agricultural Organization

FDRE = Federal Democratic Republic of Ethiopia

FMO = Foot and Mouth Disease

GB = Great Britain

GDP = Growth Domestic Product

HPS = Hantavirus Pulmonary Syndrome

IFAD = International Fund for Agricultural Development

IPCC = Intergovernmental Panel on Climate Change

OIE = Office of International des Epizootics

PPR = Pestdes Petitis Ruminant

RVF = Rift Valley Fiver

UK = United Kingdom

Uv-B = Ultra Violate Beta

WHO = World Health Organization

WNF = West Nile Fever

ACKNOWLEDGEMENTS

First of all, we would like to praise the Almighty God who helped us in every aspect and condition for our success to review this seminar paper.

We would like to acknowledge School of Veterinary Medicine, Wollega University for its services and all of my partners for their contributions in all aspects for the success of the paper.

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Received on 25-03-2018 Accepted on 25-05-2018 Published on 02-08-2018

DOI: http://dx.doi.org/10.12970/2310-0796.2018.06.02