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Climate change and its impacts on global health: A review

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Abstract
The early costs of global climate change (GCC) are well documented. However, future impacts on ecosystem health, and on the health of humans, domestic animals, and wildlife, are much less well understood. Evidence of rising frequency of excessive weather events of geographic changes in vector-borne disease (VBD), and of altered animal behavioral responses deserves action. To make valid choices, however, practitioners and decision makers must understand what is known about GCC. There will be a huge number of microbial, vectors, and host responses to climate change, for example, and not all organisms will respond similarly or across equal time scales. During the past 50 years or so, patterns of emerging arbovirus diseases have changed drastically. Climate change, especially increasing temperatures and rainfall is a major determining factor in the spastial and temporal distribution of life cycles of arthropods and its association, evolution as well as transmission of emerging arboviruses to vertebrate hosts. Ecological disturbances, especially due to human intervention exert an influence on the emergence and proliferation of emerging and zoonotic diseases. In this brief review we are studying potential impact on human as well as animal health from vector-borne infection due to climate change.

Keywords: Climate change, emerging, VBD, zoonotic disease

1. Introduction

The Earth's climate is referred to the long-standing regional or worldwide average of temperature, humidity and rainfall patterns over seasons, years or decades. Whereas, weather refers to that occur locally over a short period (from minutes to hours or days) of atmospheric conditions includes winds, clouds, snow, rain, floods or thunderstorms etc. The Earth's climate system is determined with the interactions of the atmosphere, land surface, terrestrial and marine biospheres, cryosphere and oceans [41, 30]. Human activities have reached a level lead to increased atmospheric concentrations of greenhouse gases includes carbon dioxide, methane, and nitrous oxide, ozone, methane, and clorofluro carbon (CFC) and thus causing Global Warming. Zinyowera *et al.*, (1998) [107] expected that Average global temperatures will have to go up by 1.0–3.5 ^{o}C by 2100. The spatial and sequential changes in temperature, precipitation, rainfall patterns, humidity, evaporation, and salinization of water sources through rising sea levels that are expected to occur under different climate change circumstances will affect the biology and ecology of vectors and intermediate hosts and as a result, increased the risk of disease transmission. For survival and development of arthropods, their internal homeostasis regulation critically depends on the climate [54]. The changes in Earth's climate system leads to enhance emerging of vector-borne diseases, which is account for over 17% of all infectious diseases in humans [30,98]. For many diseases extremes of the range of temperatures at which transmission occurs i.e. 14– 18 ^{o}C at the lower end and 35–40 ^{o}C at the upper end. The extrinsic incubation period have significantly and non-linear affected at warming in the lower range, lead to consequently disease transmission, while, warming at the upper end, transmission could come to a close [104, 30]. Arthropod vectors (e.g., ticks, fleas, black flies, mosquitoes and sand flies) may have the potential to spread pathogenic bacteria, viruses, protozoa, and helminthes. Thus, there is an enormous deal of discussion among scientists regarding the extent and degree of changes in vector-borne parasitic zoonosis (VBPZ) distribution, not only because of their impact on human and animal health [105] but also because they may stand for a major hazard to the economy, causing huge economic losses to the livestock industry annually [11].

The possible consequences of climate changes are increased incidence of heat waves, changes in agricultural viability, desertification, large-scale migration in response to the rise in sea-level, serious consequences to the production of food and the maintenance of public health lead to higher mortality on susceptible groups of people as well as alter the geographic pattern and dynamics of certain vector-borne diseases [56]. Humans have close relations with companion animals which the sharing of many emerging infectious and zoonotic diseases like such infections in humans originates from animals, through direct and indirect transmission [37, 44, 68]. 1-4 % zoonotic outbreaks have been related to pets, such as poor animal husbandry, poor hygiene, sanitation precautions leads to dramatic changes in human demographics, behavior, land use practices as well as changes in the environment at both large and small scales [94]. It is estimated that the world's agricultural sector, mainly livestock production emitted about 20% of total greenhouse-gas, thus it has contributed to climate change and its effects on health, and regional food yields. Some merit and demerit points comprise the association between world food production and changes in population health over recent centuries. There are much merit points: food production capacity, maternal and child nutrition, health and life expectancies have markedly increased, at least partly because of nutritional gains, refrigeration, transport, and open markets have increased year-round access to healthy foods for many populations. Whereas demerit points on health risks are also occurring: depletion of the land cover and biodiversity due to the expansion of food production, with the diverse penalty for human welfare and health, excessive use of fertilizers leads to disrupted major earth's elemental cycles. There is increasing significantly in the role of climate changes in the epidemiology and distribution of Vector-borne parasitic zoonosis (VBPZ) [82, 76] due to the spreading of VBPZ-causing pathogens will crucial issue for the greatest animal biodiversity. However, a complete approach to predict the expansion of VBPZs should not only evaluate the effect of climatic factors but also look at the linkage between socio-economic and political issues and the emergence of these diseases.

Thus this article discusses the changing earth's climate system and its impacts on human as well as animal health and epidemiological scenarios of VBPZs, which are of emerging or re-emerging concern. In addition, it discusses the extent socio-economic effect the spreading and the control of vector-borne zoonotic diseases.

2. Climate change and its effects on human health

Since thousands of years ago, the Hippocrates was given a statement of the climate which has broad ranging impacts on health. Further health researchers also have been reported that the process of climate change has led to could influence health and they will be modulated by some factors like socioeconomic development and the degree of effective adaptation measures are implemented [38]. Probable impacts of climate change on health are well documented by the World Health Organization [105] and other international organizations like IPCC [92, 73]. The direct impact of climate on human health is mortality due to augmented temperature and heat wave, flood disasters, drought, cyclones, impact on water and vector-borne diseases, malnutrition and respiratory diseases [92, 105]. The estimated a worldwide loss of 5.5 million disability-adjusted life years (DALYs) due to climate change in 2000 (compared to baseline climate of 1961–90) and the loss of 2.5 million disability-adjusted life years (DALYs) in southeast Asian countries with an estimated loss of nearly half (46.6%) of the total loss [105].

2.1 Mechanisms by which climate can affect human health.

Akhtar, (2000) [3] was reported that in India, the mortality due to heat wave mostly found in the month of March to June (1658 death) occurred in the year 1998 and the most affected states were Andhra Pradesh, Odisha, Punjab, Uttar Pradesh, Rajasthan, Bihar, and Madhya Pradesh. The National Physical Laboratory (NPL), New Delhi is working on estimation of heat stress on human health in observation of climate change and using "Providing Regional Climates for Impacts Studies(PRECIS) model " for A1B scenario and revealed high occurrence of highest temperature for three following days in the range of 45–50°C in April to June months in the years of 2030, 2050, and 2080 in some districts of Andhra Pradesh, Bihar, Gujarat, Odisha, Rajasthan, Uttar Pradesh, and West Bengal [92,85]. Increased temperatures also lead to an increase in ocular and skin diseases. The effect of global warming and UV- radiation on ocular diseases is studied in the National Capital Region of Delhi and Guwahati (R. Tandon, AIIMS, New Delhi, India personal communication). In Europe and USA, heat wave cause mortality and morbidity in 2003 and 2006 respectively [99, 48]. In seven French cities, at a maximum temperature of 35°C were leads to finding exceptional mortality, but even at higher temperatures, people survive in the eastern part of India due to the key role of local adaptive capacity of people [92].

Increased temperatures also lead to an increase in ocular and skin diseases. Regional air pollutants and aeroallergens such as pollen grains are concentrated by the warmer air temperatures lead to respiratory diseases such as asthma, emphysema and chronic bronchitis, and allergy problems [19, 17]. Chronic obstructive pulmonary disease (COPD), pneumothorax, and respiratory infections in children have been reported due to changes in the climate [18], dust storm in deserts, as well as high altitude areas, can also lead to respiratory disorders [34]. The quality of air is likely to diminish as surface ozone concentrations begin to increase with growing temperatures [52]. Floods, cyclones are lead to scarcity of availability of water for crops and elevated temperatures will affect agriculture results of loss of production [92]. Sea level rises, flooding, drought and environmental degradation associated with climate change may lead to population displacement and concurrent associations between climate and diseases. Transmission of diarrhoeal diseases due to excessive floods contaminates drinking water. In India, the figures for estimated disability-adjusted life years (DALY) lost due to diarrhoeal diseases were 23,801,447 in 2006 and by 2016, 21,486,636 DALYs are projected [95]. The Energy and Resources Institute, New Delhi (http://www.teriin.org/) and National Institute of Cholera and Enteric Diseases (NICED), Kolkata undertook a research project to examine the possible relationship between climate change and diarrhoeal diseases, evaluate the susceptibility and adaptability as well as to evaluate the economic impact [85]. There is a need to establish reliable surveillance systems and generate evidence showing the link between diarrhoeal diseases and climate change [47]. Changes in temperature and rainfall may also affect the distribution of vector born disease, e.g. those of malaria, dengue, japanese encephalitis, chikungunya, KFD and the incidence of diarrhoeal diseases. In their body of vectors, the life cycle and development of pathogen are likely to be affected at varying temperature and relative humidity. The link between re-emergence of kala-azar in northern parts of India and reappearance of chikungunya mainly in southern states of India appears to be due to changing climatic conditions affect vector born disease [22].

Table 1: Effects of weather and climate and possible impact of climate change on infectious disease incidence and burden (Source: Greer and Fisman, 2008) [33]

Infectious disease	Known effects of weather and climate	Possible impact of climate change
Zoonotic and VBD (e.g. Chikungunya, Lyme disease, West Nile virus, dengue, malaria, tularemia, KFD)	• Increased temperature cause shortening of pathogen development time in vectors lead to increases the duration of infectiousness, allowing for prolonged periods of transmission to humans. • Inflation of the geographic range and loads in both vectors and reservoir hosts due to climate change. • Enhance populations of reservoir animals and their predators due to Warming and altered rainfall patterns (e.g., rabbits and foxes). • Prolonged transmission cycles due to early onset of favourable transmission circumstances. • • More frequent outbreaks of diseases due to flooding that provides breeding habitats for vectors and reservoir hosts and increasing their loads as well as geographic range.	• Elevation of some zoonotic diseases transmission due to increased temperature, rainfall variability and altered dynamics of reservoir populations. Changes may permit institution of novel imported infectious diseases in regions that were in the past unable to support endemic transmission. • Changes likely to vary geographically.
Water and food-borne diseases (e.g., *Vibrio,* Verotoxigenic *E. coli*, *Campylobacter, Clostridium botulinum, Salmonella, Shigella, Cryptosporidium Legionella, Giardia,*)	Temperature directly influenced and improved to survival, proliferation as well as persistence of pathogenic organisms by • Augmented air and water temperatur (e.g., Vibrio). • Availability and quality of water affected by climate conditions. • Quickly moving of disease-causing pathogens into water supplies assisted by flooding and heavy rainfall • Flooding and extreme weather events leadin to displacement of environmental refugees.	• It is predicted that increase the intensity and frequency of water- and foodborne diseases due to increased temperature and rainfall.
Communicable respiratory diseases (e.g., influenza, COPD, *Streptococcus pneumoniae*)	• Increase winter temperatures cause decrease occurrence of respiratory diseases. • Increase the concentration of harmful air pollutants lead to damage of respiratory mucus membranes. • Introduction of novel diseases into nonimmune populations due to forced migration of ecological immigrant could enhance transmission of disease due to merger of populations.	• Decrease the number of respiratory diseases in shorter, warmer and wetter winter season but it may be compensated by changes in air quality and mass movements of immigrants.
Invasive fungal diseases (e.g., *Blastomycoces, Cryptococcosis, Coccidioides immitis*)	• Local soil ecology, hydrology and climate may affect by ecological and meteorological alteration lead to the persistent invasion fungal pathogens release of infectious spore forms in the environment.	• Warm, dry summers in mixtured with heavy wintertime precipitation give optimal conditions for infectious fungal spore persistence and expansion. • Changes likely to vary geographically.

3. Climate change and effects on animal health

Climate change affected animal health in four ways: (1). heat-related diseases and stress, (2). Extreme weather events, (3). Adaptation of animal production systems to new environments, (4). Emergence or re-emergence of infectious diseases, especially vector-borne diseases significantly dependent on ecological and climatic conditions (Forman *et al.*, 2008) [26].

The augmented frequency and intensity of heat waves lead to intensifying by increased temperature and humidity resulting in increased the risk of death and serious illness [57]. For pigs, 5% decreases of feed intake, as well as 7.5%, decreased activity by rising of 1°C above their optimal growth temperature. Excessively elevated temperatures lead to not only causes suffering heat stress but also reduces productivity and fertility [26]. Over the past 100 years, a distinct trend of increases in the intensity and frequency of extreme weather events such as typhoons, droughts, storms, floods, and sandstorms has been observed in different areas and seasons in Asia [14]. The quality and availability of some vector breeding sites may be altered by the related changes in rainfall, humidity and the El Niño/Southern Oscillation (ENSO) may alter [51]. It was reported that the outbreaks of dengue fever are the result of floods [103]. Increased frequency and intensity of extreme weather events brought about by climate change can thus affect animal health through a variety of mechanisms. It is estimated that agriculture and land use originate from livestock production emitted 35% of global greenhouse gas [58]. Food and Agriculture Organization of the United Nations (FAO, 2004) [25] on the impact of climate change on agriculture in Asia and the Pacific is reported that the climate change-induced modifications of ecological conditions are strongly influenced to livestock diseases. The geographical coverage of diseases may alter and influenced by the migration and spread of birds such as HPAI and West Nile virus.

3.1 Impacts
3.1.1 Direct impact
Direct impacts include ambient temperature temperature-related disease and fatality, and the morbidity of animals during tremendous weather events [64]. The increased ambient temperature and parallel changes in heat exchanges between the animal and their environment are direct effects of climate change on animal health, wellbeing and production (e.g. growth, reproductive performance, milk production) due heat stress [98]. Animals are to some extent able to acclimatize to elevated ambient temperatures with prolonged experiences but losses of production will occur [83]. Extremely hot temperatures will also be beyond the climatic envelope for *B. indicus*, resulting in reduced milk and meat production and reduced time for foraging because the animals have a preference to stay behind in the shade [98]. Extreme weather events, such as droughts or floods, as the result of climate change, have on numerous occasions resulted in very high mortality in the livestock population [98].

3.1.2 Indirect impact
Indirect impacts follow more complicated pathways and include those obtained from the attempt of animals to acclimatize to thermal environment or from the influence of climate on microbial populations, host resistance against infectious agents, allocation of vector-borne diseases, feed and water scarcity or food-borne diseases [64]. The changes in the quantity and quality of food and water and the distribution and prevalence of disease, mean annual precipitation, interannual variability in rainfall, increased weather extremes (droughts), agricultural practices, overgrazing, and deforestation lead to fundamental change to the ecosystem structure and function are the mainly indirect effects of climate change on animal health and production, resulting in a fundamental change to the ecosystem structure and function.

The relationship between climatic conditions and the presence or absence of livestock health disorders over a long period of time. The main factor affecting disease occurrence is the climatic range that limits the transmission and distribution of a disease and it's also affected by economic, social, cultural, Institutional and environmental factors [59]. The future impact of climate change is best to calculate approximately by based on empirically experiential relationships between climatic conditions and their effects on the biological processes that determine disease transmission in space and/or in time [80]. Regrettably, these models cannot be widespread and do not take the description of associated changes in factors that are not related to climate change, but may have important effects on disease transmission or impact [12].

3.2 Non-vector-borne diseases
The distribution and prevalence of non-vector-borne diseases vary greatly affected by climate change. Changes in ecological circumstances, as results of direct or indirect consequence of climate change, can enhance or diminish the continued existence of the infectious agent in the environment or influence the susceptible animal to infection as well as amplified or reduced contact between infected and susceptible animals and thus affect transmission [98]. The spatial and temporal distribution of the non-vector borne diseases (NVBD) pathogens that spend a period of time outside the host and are very sensitive to changes in temperature and humidity, such as aerosol droplets, the infective spores of anthrax and blackleg, Peste des petits ruminants (PPR) and foot and mouth disease (FMD) viruses, dermatophilus, haemorrhagic septicaemia, coccidiosis and haemonchosis. The prevalence of infections of may increase *Fasciola hepatica* in areas heavy rainfall and *F. gigantica* in the creation of permanent water bodies for irrigation in drier areas due to the survival of their intermediate snail hosts [98]. Increased migration and mass movements of livestock and wildlife for searching of water or grazing due to changes in the ecosystem transmission of pathogens directly between animals in close contact [62], such as FMD, PPR and CBPP etc. Important trigger mechanism for epidemics of soil-borne diseases are drought, overgrazing and severe ecological stress as the consequences of climate change, and mass migrations, may become a such as anthrax and outbreaks of blackleg, mostly occurs in young cattle are often associated with heavy rainfall, foot rot is a flood-related bacterial disease affecting the interdigital tissue of ruminants [98].

3.3 Acclimation and path-physiological impacts
The acclimation of the animals to meet the thermal challenges and to reduce heat load results in the reduction of voluntary feed intake as well as alteration of many physiological functions (e.g. increase in respiration rate and water intake and changes in hormonal signals) impaired health and productive as well as reproductive efficiency [28,7,50,15]. The reduced feed intake results in a negative energy balance (NEB), and animal lose significant amounts of body weight and body score when subjected to heat stress [50]. Lower feed intake, change in endocrine status and lower metabolic rate tends to reduce metabolic heat production and might be responsible for modifications of energy, lipids, protein, and mineral metabolism, and liver function in heat-stressed subjects lead to increased sensitivity of heat-stressed animals to metabolic diseases with negative consequences on production, reproduction and infectious disease sensitivities in intensive and extensive livestock production systems [50, 63, 81] and studies done by others [42, 61, 66, 84, 101]. Blood glucose level as well as hepatic glucose synthesis and non-esterified fatty acids (NEFA) is usually reduced in heat-stressed subjects due to the lower feed intake occurring in a hot environment lead to decreased growth and performance [42, 81, 84, 63]]. In a hot environment, accomplished of producing moderate or severe heat stress, cause oxidative stress in dairy cows [8] and broiler chickens [53]. In addition, panting ruminants drool and drooling reduces the quantity of saliva reduction in the

amount of saliva produced and salivary buffer HCO3− content, that make animal for much more susceptible to sub-clinical and acute rumen acidosis [46], which indirectly enhances the risk of other concurrent health and productive problems (laminitis, milk fat depression, etc.). Elevated temperatures and moisture have suitable for growth of mycotoxin-producing fungi which lead to the alteration of animal health, mycotoxins can cause acute disease episodes when animals consume critical quantities of these toxins [50, 100].

4. Climate change and zoonotic vector borne diseases

Table 2: List of zoonotic vector borne diseases and its ecology

Pathogen	Vector Transmission	Ecological distribution	Susceptible Host	Disease
Plasmodium				
Plasmodium vivax [16]	Anopheline mosquitoes	Tropics, subtropics, and temperate zones	Humans	Simian malaria
Plasmodium falciparum [16]	Anopheline mosquitoes	Tropics	Humans	Simian malaria
Plasmodium malariae [16]	Anopheline mosquitoes	unevenly distributed	Humans	Simian malaria
Plasmodium ovale [16]	Anopheline mosquitoes	Africa and some South Pacific islands	Humans	Simian malaria
Plasmodium knowlesi [16, 29]	*Anopheles latens*	South- East Asia	Monkey, Humans	Simian malaria
Trypanosoma				
Trypanosoma cruzi [16]	*Triatoma infestans, Rhodnius prolixus, Triatoma dimidiata*	Brazil and other Latin American countries	Humans	Chagas disease
Leishmania				
L. tropica & L. major [23, 77]	*Phlebotomus sp.*	Indian subcontinant	Humans	Cutaneous Leishmaniases/ oriantal sore/ delhi boil
L. infantum & L. donovani [23, 77]	*Phlebotomus spp.*	Indian subcontinant, Europe and America	Dogs, Humans	Visceral Leishmaniases/ Kala azar/ Dum –Dum Fever
Babesia				
B. bigemina [45, 60, 21]	*Boophilus spp., Rhipicephalus spp.*	Asia, Africa, USA, Australia	Cattle, buffalo	Cattle babesiosis
B. bovis [45, 13, 21]	*Boophilus spp.*	Asia, Africa, USA, Australia	Cattle, buffalo	Cattle babesiosis
B. major [45, 93, 21]	*Haemaphysalis spp.*	Europe	Cattle	Cattle babesiosis
B. ovate [45, 55, 21]	*Haemaphysalis spp.*	Asia	Cattle	
B. occultans [45, 67, 21]	*Hyalomma spp.*	Africa	Cattle	
B. divergens [45, 20, 21]	*Ixodes spp.*	Europe	Cattle, Human	Cattle babesiosis
B. microti [45, 10, 20, 21]	*Ixodes scapularis*	America, Canada	Human, Rodents	
B. canis [45, 86, 21]	*Rhipicephalus sanguines, Dermacentor reticulatus, D. marginatus*	worldwide	Dogs	Dog babesiosis
B. vogeli [86, 21]	*Rhipicephalus sanguines*	Africa, Asia, Europe, North/Central/South America, Australia	Dogs	Dog babesiosis
B. rossi [45, 21]	*Haemaphysalis leachi*	Southern Africa, Nigeria, Sudan	Dogs	Dog babesiosis
B.gibsoni [45, 43, 21]	*Haemaphysalis bispinosa, H. longicornis, Rhipicephalus sanguines*	Africa, Asia, Europe, North/Central/South America, Australia	Dogs	Dog babesiosis
B. ovis [45, 90, 21]	*Rhipicephalus bursa, R. turanicus*	Africa, Asia, Europe	Sheep	Sheep Babesiosis
B. motasi [45, 39, 21]	*Haemaphysalis spp.*	Africa, Asia, Europe	Sheep	Sheep babesiosis
B. caballi [45, 21]	*Dermacentor spp. Rhipicephalus evertsi evertsi*	Africa, America Asia, Europe	Horses, Mules, donkeys	Horse babesiosis
B. felis [45, 21]	-	Africa	Cats	
B.bicornis [65, 21]	-	Southern Africa	Black rhinoceros (Dicerous bicornis)	
B. odocoilei [87, 21]	*Ixodes scapularis*	America	Cervidae and wild bovidae	
Theileria				
T. annulata [96, 21]	*Hyalomma spp.*	Asia, Eurasia, Africa,	Cattle, Camels	Tropical theileriosis
T. orientalis [36, 21]	*Haemaphysalis spp.*	Asia	Cattle, Asian buffalo	
T. parva [75, 21]	*Rhipiciphalus appendiculatus*	Africa	Cattle	East Coast Fever
T. lawrencei [102, 21]	*Rhipiciphalus zambeziensis*	Africa	Cattle	Corridor disease
T. mutans [89, 102, 21]	*Amblyomma hebraeum, A. lepidum, A.variegaum, A.cohaerens, A. gemma*	Africa	Cattle	Benign Theileriosis
T. taurotragi [36, 21]	*Rhipiciphalus appendiculatus, R.pulchellus, R. zambeziensis*	Africa	Cattle	Benign Theileriosis
T. ovis [4, 21]	*Hyalomma spp. Rhipiciphalus bursa*	Asia, Africa	Sheep	Sheep theileriosis
T. lestoquardi [21]	*Hyalomma spp.*	Mediterranean countries, Asia	Sheep, Goat	malignant Sheep and goat theileriosis
T. separate [21]	*Rhipiciphalus evertsi mimeticus, Haemaphysalis punctata*	Africa	Sheep, Goat	Non pathogenic
T. bicornis [65, 21]	-	Sothern Africa	Black rhinoceros	-

T. equi [21]	*Dermacentor spp., Rhipiciphalus spp., Hyalomma spp., Boophilus spp., Amblyomma cajennense*	Asia, Africa, Europe	Horse Mules, Donkeys	Equine billiary fever
T. cervi [21]	*Ambylomma americanums*	Nearctic	White tailed deer	Non pathogenic
Hepatozoon				
H. canis [6, 21]	*H. longicornis, Rhipicephalus sanguines*	Southern Europe, Middle East, Far East, Africa	Dogs	Hepatozoonosis
H. americanum [6, 21]	*Ambylomma maculatum*	USA	Dogs	Hepatozoonosis
Cytauxzoon				
Cytauxzoon felis [9, 74, 21]	*Dermacentor variabilis*	USA, Brazil	Domestic Cats and wild felids	Cytauxzoonosis
Aegyptianella				
A. pullorum [21, 40]	*Argas walkerae, A. persius, A. reflexus*	Africa, southern Europe, Middle Asia, Indian subcontinent	Domestic poultry	Aegyptianellosis
Rickettsia				
R. Rickettsii [17, 21, 69, 70, 69]	*Dermacentor andersoni, D.variabilis, Ambyomma cajennense, A. aureolatum, Rhipicephalus sanguineus*	Americas	Human, dog	Rocky Mountain spotted fever
R. amblyommii [21]	*Amblyomma americanum, A. neumanni, A. cajennense, A. coelebs*	Americas	Human	Spotted fever rickettsiae
R. conorii conorii [20, 69, 70, 71]	*Rhipicephalus sanguineus*	Europe, Africa, Asia	Human, dog	Mediterranean spotted fever
R. conorii israelensis [69, 70]	*Rhipicephalus sanguineus*	Israel	Human	Israeli spotted fever
R. conorii caspia [21, 69, 70]	*Rhipicephalus sanguineus, R. pumilio*	Africa, Asia	Human	Astrakhan fever
R. conorii indica [72]	*Rhipicephalus sanguineus*	India	Human	Indian tick typhus
R. sibirica sibirica [27, 69, 70, 71]	*Dermacentor nuttalli, D. marginatus, D. silvarum, D. sinicus, Haemaphysalis concinna*	Asia	Human	Siberian or North Asian tick typhus
R. australis [21]	*Ixodes holocyclus, I. tasmani*	Australia	Human	Queensland tick typhus
R. japonica [21]	*Ixodes ovatus, Dermacentor taiwanensis, Haemaphysalis longicornis, H. flava*	Japan	Human	Oriental or Japanese spotted fever
R. africae [20, 21, 69, 70, 71]	*Amblyomma herbraeum, A. variegatus,*	Africa, West Indies	Human	African tick bite fever
R. honae [21]	*Bothiocorton hydrosauri, Amblyomma cajennense, Ixodes granulatus*	Australia, USA, Thailand	Human	Flinders island spotted fever
R. slovaca [21]	*Dermacentor marginatus, D. reticulatus*	Europe, Asia	Human	TIBOLA, DEBONEL[7]
R. Helvetica [27, 21]	*Ixodes ricinus*	Europe	Human	Pathogenicity suspected in humans
R. heilongjiangensis [72, 71]	*Dermacentor silvarum*	China	Human	Unnamed
R. aeschlimannii [21, 69, 70, 71]	*Hyalomma marginatum marginatum, H. m. rufipes, Rhipicephalus appendiculatus*	Europe, Africa	Human	Unnamed
R. marmionnii [21, 70, 91]	*Haemaphysalis novaguineae, Ixodes holocyclus*	Australia	Human	Australian spotteed fever
Ehrlichia				
E. chaffeensis [20, 21]	*Amblyomma americanum, Dermacentor variabilis*	North America	Human and various mammals	Human monocytic ehrlichiosis
E. ewingii [21]	*Amblyomma americanum*	USA	Human, dogs	Canine granulocytic ehrlichiosis, Human ehrlichiosis
E. ruminantium [21]	*Amblyomma hebraeum, A. astrion, A. cohaerens, A. gemma, A. marmoreum, A. lepidum, A. pomposum, A. variegatum A. americanum*[8]	Africa, Caribbean	Cattle, Human	Heartwater
E. canis [21]	*Rhipicephalus sanguineus*	Southern USA, southern Europe, Africa, Middle East, eastern Asia	Dogs, Human	Canine ehrlichiosis
Anaplasma, Francisella and Coxiella				
Anaplasma phagocytophilum [20, 24, 35]	*Haemaphysalis concinna, H. punctata, Rhipicephalus bursaIxodes scapularis, I. pacificus, I. ricinus, I. hexagonus,*	Europe, North America	Human and various mammals	Human granulocytic anaplasmosis
A. marginale [5]	Various ticks	Endemic in tropical and subtropical areas	Cattle	Bovine Anaplasmosis
A. central [5]	Various ticks	Worldwide	Cattle	Bovine Anaplasmosis
A. ovis [5]	Many species of ticks of different genera	Worldwide	Sheep	Ovine Anaplasmosis
A. platys [2]	*Rhipicephalus sanguineus*	Worldwide	Humans, Dog	Canine ehrlichiosis
F. tularensis [20, 71]	Various species of ticks of different genera	Asia, Europe, North America	Human and various mammals	Tularemia
C. burnetii [20, 71]	Various species of ticks of different	Africa, Asia, Australia,	Human and various	Q fever

	genera	Europe, North America	mammals	
Borrelia				
B. burgdorferi [20, 71]	*Ixodes pacificus, I. persulcatus, I. ricinus, I. scapularis*	Asia, Europe, North America Africa	Human	Lyme disease
B. theileri [1, 79]	*Boophilus spp., Rhipicephulus evertsi*	Africa, America, Australia	Cattle	Bovine borreliosis
B. hermsii [24, 71]	*Ornithodoros hermsi*	America	Human	New World tick-borne relapsing fever
B. turicatae [24, 71]	*Ornithodoros turicata*	America	Human	New World tick-borne relapsing fever
B. parkeri [24, 71, 102]	*Ornithodoros parkeri*	America	Human	New World tick-borne relapsing fever
B. venezuelensis [24, 71]	*Ornithodoros rudis*	America	Human	New World tick-borne relapsing fever
B. duttonii [24, 88, 71]	*Ornithodoros moubata*	Africa	Human	Old World tick-borne relapsing fever
B. anserina [1, 88]	*Argas persieus, A.sanehezi, A. radiatus*	Worldwide	Birds	Avian borreliosis
B. coraciae [20, 24]	*Ornithodoros coriaceus*	America	Cattle	Bovine epizootic abortion
Dermatophilus				
D. congolensis [21]	*Amblyomma variegatum*	Africa	Ruminants	Dermatophilosis
Viruses				
Bunyaviridae, Nairovirus [20, 24]	*Hyalomma marginatum, Hy. a. anatolicum, Hy. truncatum, Amblyommma variegatum, Haemaphysalis punctata, Ixodes ricinus, Dermacemtor spp., Rhipicephalus spp*	Africa, Asia, Europe	Human	Crimean-Congo Hemorrhagic Fever virus
Bunyaviridae, Nairovirus [21]	*Rhipicephalus appendiculatus, R. pulchelus, Amblyomma variegatum*	Africa	Sheep, goats, wild ruminants, rodents	Nairobi Sheep Disease
Reoviridae, Orbivirus [49]	*Ixodes ricinus, I. ventalloi*	Europe	Human	Eyach virus
Reoviridae, Orbivirus [49]	*Dermacentor andersoni, D. occidentalis, D. albipictus*	Nearctic	Human	Colorado tick fever
Reoviridae, Orbivirus [24, 71]	*Argas monolakensis, A. cooleyi*	America	Human	Mono Lake virus
Flaviviridae, Flavivirus [20, 24]	*Dermacentor reticulatus*	Asia	Human	Omsk Hemorrhagic fever
Flaviviridae, Flavivirus [20, 24]	*Ixodes ricinus, I. persulcatus, Haemaphysalis concinna, H. punctata*	Europe, Asia	Human	Tick Borne Encephalitis
Bunyaviridae, *Phlebovirus* [31]	Wide range of mosquito species.	Africa	Aanimals and humans	Rift Valley fever
Orbivirus, Reoviridae [31]	*Culicoides spp.*	Africa, Asia Australasia	Sheep, goat	Bluetongue
Flavivirus [31]	*Culex spp.*	tropical and subtropical regions worldwide	birds, horses, mosquitoes	West Nile virus
Flavivirus [92]	*Culex spp.*	Asia	Human, Pig	Japanese encephalitis
Flaviviridae, Flavivirus [32]	*Ixodes granulatus, Haemaphysalis papuana*	Malaysia	Wild rodents	Langat virus
Flaviviridae, Flavivirus [78]	*Ixodes ricinus*	United Kingdom	Sheep	Louping ill
Flaviviridae, Flavivirus [20, 45, 49]	*Ixodes cookie, I. marxi, I. scapularis, Dermacentor andersoni*	Russia, North America	Human, rodents	Powassan Encephalitis
Flaviviridae, Flavivirus [5, 20]	*Haemaphysalis spp. (mainly H. spinigera* and *H. turturis)*	Indian subcontinent	Human, monkeys	Kyasanur Forest disease
Asfaviridae [21]	*Ornithodoros moubata, O. erraticus, O. turicata, O. coriaceus, O. puertoricensis16*	Africa, sourthern Europe, Caribbean (outbreaks in Brazil, likely imported)	Domestic pigs	Asfavirus African Swine Fever

5. Conclusions

Expanding the ranges of species known to carry zoonotic diseases and increase the risk of infectious disease burden, changing pathogen dynamics in ecological reservoirs and changing pathogen transmission cycles are results of the climate change. Changes in environmental temperature directly affect the availability of vectors, pathogens, and transmissions, as well as interaction to the definitive hosts, lead to the increasing incidence of VBDs. The deleterious effects of climate change will be overcome by the enhancement of public health infrastructure (adaptation measures, early warning system, surveillance, and outbreak forecasting, provision of safe food and water, and vector control). There are currently many national and multinational and collaborative scientific efforts underway that are directly or indirectly related to climate change, control infectious diseases and global health. Interdisciplinary communication between veterinarians, health professionals, environmental scientists, economists, geographers and ecologists seeking to understand climate change will be key to protecting people worldwide against the threats of animal and environmental reservoirs of disease. However, the climate is just one of the ecological factors of vector-borne diseases (VBDs). However, there are other factors that must be measured such as the population and the socio-demographic background, urbanization and also host factors such as immunity. The impacts of climate and environmental changes on animal health, which is characterized by elevated animal densities, large and rising populations, extremely diverse climate zones, landforms, cultures and practices resulting rising in sea-level, enormous land losses and combining with altered temperature and humidity and more recurrent extreme weather events, will drastically affect agricultural systems and water availability as well as animal health. The changing pattern of some animal and human diseases (particularly arthropod-borne diseases) highlights the urgent need to undertake action in response to a series of events that may be attributed, among other factors, to climate variability. Some developing Asian countries are not until now prepared to face such a threat and need to be part of a 'win-win' process with the support of international organizations such as the OIE, FAO, WHO and World Bank. The climate change is being addressed by the Govt. of India by introducing compressed natural gas (CNG) for transport and replacement of wood fire for cooking by the liquid petroleum gas (LPG) in villages. It is an excellent example of co-benefits of other sectors to human health. National Institute of Disaster Management, set up by the Government of India is making headway in imparting training to different sectors and mapping the disaster-prone areas in India which should serve as a baseline for development of preparedness plans to meet adverse impacts (http://nidm.gov.in/default.asp). Documentation of lessons learned in combating disasters should be encouraged so that preventive/adaptation measures can be advocated. In order to minimize the effects of livestock production on the environment, changes in production systems are necessary. Such changes may have repercussions on animal health. Policies of intensification of dairy production in India, pig rearing in China and poultry production in Viet Nam will need to adapt to this trend to avoid increases in climate and environmental alterations, which may lead in turn to new animal health challenges. More and more awareness should be created for masses about human activities that are increasing GHG levels in the atmosphere and thus causing Global Warming Investigation of VBDs outbreaks in the respective area using innovative technologies. Collaborative study on economic losses due to VBDs and their control measures should be done.

Asian industrialized countries need to combine their animal and public health systems and maintain a strong surveillance network incorporating inventive risk analysis tools. Finally the vision of Veterinary Services as a 'Global Public Good' has never been more accurate than it is today, and Asian Governments, like others, must put more focus and resources into strengthening these services in order to be able to respond to the new challenges that climate change imposes on animal and public health. Economics would play a major role in combating the potential threat. Countries with good GDP would be able to introduce the best available tools of intervention and can fill up the lacunae in the health system.

Health issues identified by the Prime Minister's National Action Plan on Climate Change in India (Singh & Dhiman, 2012) [92]

1. Provision of improved public health care services
2. Assessment of augmented disease load due to climate change
3. Providing high-resolution weather and climate data to study the regional pattern of diseases
4. At the state level a high-resolution health impact model to be developed
5. Accessment of routes to health facilities by GIS mapping in climatic extremes proned areas
6. Prioritization of geographic areas based on epidemiological data and the extent of vulnerability to adverse impacts of climate change
7. Environmental study of air pollutants and pollen grains (as the triggers of asthma and respiratory diseases) and how they are affected by climate change
8. Studies on the response of disease vectors to climate change
9. Enhanced provision of primary, secondary and tertiary health care facilities and implementation of public health procedures, including vector control, sanitation, and clean drinking water supply.

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