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Climate change and infectious diseases of animals: A review

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Abstract
Infectious diseases of animals are of huge socioeconomic and public health importance & climate change is one of the predictable factors to affect the future pattern of disease occurrence, disease spread, spatial and temporal distribution. The earth's temperature has risen at an average of 0.3 to 0.7 °C since 1900 & 20-30% of all vertebrate animals are expected to get extinct if the average temperature rises by 2-3 °C. According to PRECIS (Providing Regional Climates for Impact Studies) projections, the mean surface temperature in India is to rise by 2.5-5 °C by the end of this century. Hydrological cycle alterations can lead to increased frequency of droughts & floods in India. In this scenario the incidence of animal disease is set to rise drastically, more so of the vector borne diseases. Further the climate change is resulting in emergence & re-emergence of plethora of infectious diseases throughout the world, mostly the zoonotic ones as 75% of the emerging animal diseases are zoonotic in nature. A two pronged approach must be adapted to tackle the alarming situation arising out of climate change impacts. Adaptation may involve the measures for future adaptation to the disease onslaught and the Mitigation focuses on reducing the level of agents/factors leading to the climate change. One health concept in one health triad needs to be followed in spirit to avert the otherwise sure to come impacts of climate change.

Keywords: Animals, climate change, infectious disease

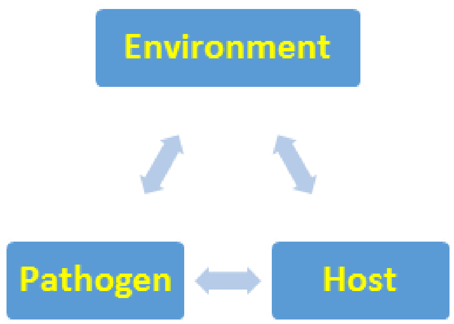
Introduction
Infectious animal diseases continue to have an impact on the overall development in terms of lowered productivity, cause financial losses, harm the environment, affect human health, and tend to increase poverty particularly in developing world [1]. Livestock as a sector is extremely important to the global economy and to rural livelihoods. As of 2013, there was an estimated 38 billion livestock in the world (FAO). The burden of animal disease in developing countries is highest with livestock diseases probably killing 20% of ruminants and more than 50% of poultry each year causing a loss of approximately USD 300 billion per year [2]. A disease particularly of the infectious nature, in future is likely to be affected by many factors including changes to livestock management practices, changes to the physical environment, developments in animal genetics and scientific approach, but the impact of these factors can't be confidently gauged/predicted. A more predictable factor which can affect the future of infectious animal disease is the climate change. Climate change has direct influence on the occurance of diseases in livestock and out of 65 important animal diseases, 58% are found to be highly climate sensitive.

What is climate change?
The statistical distribution of the weather patterns defines the climate change of a particular geographical area and that change has been found to extend for a period of millions of years. The change in average weather conditions over a period of time also refers to climate change in a particular geographical location. The climate change as per IPCC (Intergovernmental Panel on Climate Change) may be defined as a change in the state of the climate that can be identified by using different statistical tests e.g., changes in the mean and/or variability of its properties over a period of time usually decades to millions of years can be used to identify the climate change. These changes in climate over a period of time may be due to natural variability or as a result of human activity. The definition provided by UNFCCC (United Nations Framework Convention on Climate Change) describes it as a change that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere

and that is in addition to natural climate variability observed over comparable time periods [3]. Although various natural phenomenons like volcanic eruptions, tectonic disturbances, ENSO (EL NINO Southern Oscillation), North Atlantic Oscillations etc. are the contributing causes for climatic changes, certain anthropogenic activities have also been identified as significant causes of recent climate change, often referred to as global warming. The climatic change is evidenced by the manifestations like increase in mean surface temperature, increase in sea surface temperature, varying patterns in precipitation, glacier meltdown/retreat, sea level increase, frequent floods and droughts, cyclonic storms, Coastal Erosion, Biodiversity Loss, increased El-Nino events etc. As according to the U.S. Environmental Protection Agency (EPA), the sea level has risen 6–8 inches globally and worldwide precipitation has increased by about 1% during the past century. Increased use of fossil fuels, use of natural gas and coal, population explosion, industrial wastes and agricultural fertilizers along with other anthropogenic activities contribute to global warming. Earth's temperature has increased with an average of 0.3- 0.7 °C since 1900 and by the end of the 21st century is predicted to increase by 1.1-5.8 °C. Climate change could be the biggest global health threat of the 21st century [4]. The work of the Intergovernmental Panel on Climate Change (IPCC) has assembled overwhelming evidence that humans are affecting the global climate, with numerous significant implications for human and animal health. The prediction as to how a certain climatic change is going to affect a particular disease is studied using predictive models which include statistical models, process/mathematical models and landscape models. They allow investigators to link future geographically gridded projections of climate change generated by global or regional climate models to a model of the relationship between those climate variables and the occurrence of the disease of interest [5].

Association between Environment/Climate & Infectious Disease.

For an infectious disease to occur, a relation between host, environment and the infectious agent/pathogen has to exist, the relationship termed as disease triangle or epidemiological triad.



The role of the environment becomes more pronounced in case of diseases whose agents/pathogens have to spend some time period outside the host in the environment whether in the form of spore, vegetative organism or larvae or as a developmental stage in the intermediate host. Diseases which are transmitted and introduced into other susceptible hosts by vectors are also highly influenced by climatic factors. For example Bacillus anthracis causing anthrax, a highly fatal disease forms spores to survive outside the host and environmental factors like suitable temperature, humidity and moisture have a definite effect on successful germination of the spore so as to cause disease again, outbreaks of which are often associated with alternating heavy rainfall and drought, and high temperatures [6]. Certain bacteria, such as Dermatophilus congolensis, the causative agent of Dermatophilosis and Pasteurella multocida that causes Haemorrhagic Septicaemia (Pasteurellosis) in bovines, survive well outside the host in moist environments. Both diseases are associated with areas of high humidity and occur during the rainy seasons [7]. Peste des petits ruminants (PPR) an acute contagious viral disease of small ruminants, which is of great economic importance in parts of Africa 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 [8], a pattern that may be related to viral survival. The closely related Rinderpest virus survives best at extremely low or high humidity, and least at 50-60% Relative Humidity [9]. Likewise the trematodes like fasciola require environmental conditions suitable for its intermediate host, the snail which includes very moist & wet conditions of pasture and soil. Vector borne infectious diseases like Blue tongue, African horse sickness, Rift valley fever etc. require suitable environmental conditions for their vectors including mosquitoes, midges, flies, ticks etc. to thrive and multiply the organism and complete the external incubation period (EIP) successfully, with EIP lengthening in the colder periods and shortening in the high temperatures. EIP is the time period between a vector first feeding from an infectious host and time for being able to transmit the disease to another susceptible host. In colder areas, some short-lived vectors, such as mosquitoes and biting midges, tend to die before the EIP is complete and transmission does not occur [10], thus affecting the disease incidence.

How climate affects the disease occurrence.

Climate exerts both direct and indirect influences on the transmission, affecting timing of an outbreak or the intensity of an outbreak, establishing a temporal linkage and affecting geographical distribution, establishing a spatial linkage of many infectious diseases in humans and animals.

Rising temperatures: May alter the population size and/or spatial and temporal distribution of pathogens, vectors and Hosts. Intergovernmental Panel on Climate Change (IPCC) estimates that 20-30% of the world's vertebrate species are likely to be at increasingly high risk of extinction from climate change impacts within this century if global mean temperatures exceed 2-3° C. This would reduce the ability of ecosystems to dilute disease transmission through biodiversity. Further phenological evidence indicates that spring is arriving earlier in temperate regions [11]. Lengthening of the warm season may increase or decrease the number of cycles of infection possible within one year for warm- or cold-associated diseases respectively. Arthropod vectors tend to require warm weather so the infection season of arthropod-borne diseases may extend.

Increased precipitation: Heavy rainfall especially following drought, can cause insect population booms by increasing larval habitats; flooding events may increase water-borne diseases such as cholera or leptospirosis; storms can increase transport of waste water diseases to groundwater. Evidence of water contamination following heavy rains has been documented for Cryptosporidium, Giardia, and E. coli.

Variations in rainfall/dry season patterns: The outbreaks of a number of infectious diseases particularly of viral nature like Ebola virus is linked to unusual rainfall patterns, as climate change disrupts seasonal rainfall, increased episodes may be expected. Rodent populations are known to increase following mild/wet winters in temperate regions, thus increasing rodent-borne diseases which may include Lyme disease/Borreliosis caused by Borrelia burgdorferi, tick-borne encephalitis and Hantavirus pulmonary syndrome. Epidemics of African horse sickness in South Africa are associated with the combination of drought followed by rainfall brought by then El Niño Southern Oscillation.

Increased drought and heat: The disease transmission between livestock and wildlife and also between livestock and humans has been found to be greatly influenced by drought conditions. In these circumstances due to limited water resources, livestock and wildlife tend to congregate resulting in pathogen transmission e.g. proliferation of bovine tuberculosis occurs in such a manner [12]. Restricted food availability due to limited vegetation growth, leading to stress, immunosuppression and finally predispose animals to different diseases.

Forced migration of animals: The water resources and vegetation cover are highly dependent on climate change and are subsequently altered due to changing climate patterns, thus forcing animals to migrate to different geographical locations. These movement patterns of animals increase the potential for introduction of novel pathogens. The increased and random movement of animals during drought in search of food also plays an important role in disease transmission. A series of droughts in east Africa resulted in pastoral. The transmission of Rinderpest disease both to other cattle and to susceptible wildlife during series of drought in east Africa between 1993 and 1997 has been found to occur due to migration of pastoral communities, moving their cattle to graze in areas normally reserved for wildlife, resulted in devastation of certain populations [13].

Reducing the number of long-distance migrations: Changes to habitats and weather conditions may encourage animals to remain at one site instead of undertaking traditional migrations. In China rising temperatures causing increased glacial runoff into nearby wetlands have been cited as one reason why unusually large numbers of geese are remaining at Qinghai Lake over the winter instead of migrating to India. With greater concentrations of birds comes greater concern about increased transmission of avian viruses such as highly pathogenic avian influenza H5N1.

Increased high speed winds /cyclones/storms: The causative agents of a number of bacterial and viral diseases have been found to travel long distances through the winds. Blue tongue and African horse sickness can be transported over hundreds of kilometers of sea by winds carrying virus-infected culicoides vectors.

Effect Of Varying Climatic Factors On Disease Triangle Components

Pathogens: Pathogens which have one or more stages of their life outside the host in the environment may witness an increased growth and development with an increase in temperature of the ambient environment. This may shorten generation times and possibly increase the total number of generations per year, leading to higher pathogen/parasite population sizes [14]. Conversely, some pathogens are sensitive to high temperatures and their survival may decrease with climate warming. Certain pathogens may successfully overwinter and avoid mortality due to cold during winter, thus may be able to cause infections in next season.

Vectors: Increased temperature and moisture level may reduce restrictions on insect distribution and may allow them to flourish in areas previously not fit for the vectors to survive. Mosquitoes can now be found at Everest base camp, traditionally a place where low temperatures and high altitude have deterred the insect. A mean annual temperature increase of 0.9 °C has caused this shift in their distribution. Temperature changes may also affect vectors by altering biting rates or length of the transmission period. 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. For example, Culicoides sonorensis females feed every three days at 30 °C but only every 14 days at 13 °C. Small changes in vector characteristics can produce substantial changes in disease [15].

Hosts: Host distributions have already altered due to the climate change. In the Arctic, southern species such as white-tailed deer Odocoileus virginianus are invading areas normally occupied by caribou Rangifer tarandus. The deer can carry ticks and therefore have the potential to distribute tick-borne parasites such as those responsible for Lyme disease [16]. Increased exposure of hosts to harmful UV radiations expectedly due to ozone depletion has been observed to cause immune suppression and thus increased predisposition to infectious diseases [17].

Evidences of climate change affecting animal disease

One can conclude if a certain disease has been in fact affected by the change in climate when both the climate and the disease change in the same place, same time and in a positive direction [18], and this has been set as a standard for linking a disease with climate change.

African lions, drought and disease

An example of how increasing extreme weather may cause the expansion of animal diseases occurred in 1994 and 2001 in Tanzania. During these years there was an unusually high mortality of lions Panthera leo due to canine distemper, an endemic disease that is not usually fatal. Post mortem analyses had also revealed higher than usual levels of the tick-borne parasite Babesia leo and it was this co-infection that had reduced the lions' immunity and caused them to succumb to canine distemper. A link was drawn between the environmental conditions and the deaths: In 1994 and 2001 there had been extended droughts that had weakened the local herbivore population and allowed the ticks that parasitized the herbivores to prosper; the lions feeding on the weakened herbivores were then exposed to greater infection by Babesia causing susceptibility to canine distemper. With climate change expected to increase the number of drought events in Africa, lion populations are likely to continue to suffer large losses to an already threatened population [16].

The emergence of bluetongue

Between 1998 and 2005, bluetongue accounted for the deaths of more than 1.5 million sheep in Europe making it the longest and largest outbreak on record, being reported in Europe for the first time in 20 years. The disease occurred in several countries of Europe that had never previously reported any Culicoides-borne arboviral disease, namely European Turkey, Mainland Greece, Bulgaria, several Balkan countries, Mainland Italy and Tunisia. Two key things noticed in the outbreak included transmission of Blue Tongue Virus in the Balkans by novel Culicoides vectors, and dramatic spread of Culicoides imicola into the sterile areas of mainland Greece mainland Italy, north-eastern Spain, southern continental France and northern Italy. Thus the vector's range extended significantly northward. These events have now been linked to recent climate warming in Europe [19]. A mean annual minimum temperature surface map of Europe for the 1980s was subtracted from the equivalent surface map for the 1990s, to create a 'difference map', showing which areas have warmed or cooled most during the period in which bluetongue began to emerge. The results indicated significant warming in the very parts of Europe which have seen the invasion of Culicoides imicola or transmission by novel vectors. In contrast, the region where no detectable change in bluetongue vectors has taken place like western Iberia, has not warmed.

Future climate at a glance

Europe: The average temperature in Europe has continued to increase, with regionally and seasonal different rates of warming, being greatest in high latitudes in Northern Europe. Since the 1980s, warming has been strongest over Scandinavia especially in winter whereas, the Iberian Peninsula warmed mostly in the summer [20]. The decadal average temperature over land areas for 2002–2011 is 1.3° ± 0.11 °C above the 1850–1899 average, based on Hadley Centre/Climatic Research Unit gridded surface temperature data set 3 –"HadCRUT3" [21]. Since 1950, high-temperature extremes (hot days, tropical nights, and heat waves) have become more frequent, while low-temperature extremes (cold spells, frost days) have become less frequent [22]. In Eastern Europe, including the European part of Russia, summer 2010 was exceptionally hot, with an amplitude and spatial extent that exceeded the previous 2003 heat wave [23]. Climate models show significant agreement for all emission scenarios in warming (magnitude and rate) all over Europe with strongest warming projected in Southern Europe in summer and in Northern Europe in winter [24]. Even under an average global temperature increase limited to 2 °C compared to preindustrial times, the climate of Europe is simulated to depart significantly in the next decades from today's climate [25]. There will be a marked increase in extremes in Europe particular in heat waves, droughts, and heavy precipitation events [26]. There is a general high confidence concerning changes in temperature extremes (toward increased number of warm days, warm nights, and heat waves). Changes in extreme precipitation depend on the region, with a high confidence of increased extreme precipitation in Northern Europe (all seasons) and Continental Europe (except summer). In winter small increases in extreme wind speed are projected for Central and Northern Europe. Extreme sea level events will increase, mainly dominated by the global mean sea level increase.

Asia: Changes in mean annual temperature exceed 2 °C above the late-20th-century baseline over most Asiatic land areas in the mid-21st century and range from greater than 3 °C over South and Southeast Asia to greater than 6 °C over high latitudes in the late-21st century [27]. Warming trends, including higher extremes, are strongest over the continental interiors of Asia, and warming in the period 1979 onward was strongest over China in winter and northern and eastern Asia in spring and autumn [27]. From 1900 to 2005, precipitation increased significantly in northern and central Asia but declined in parts of southern Asia. Future climate change is likely to affect the water resource scarcity with enhanced climate variability and more rapid melting of glaciers. Increased risk of extinction for many plant and animal species in Asia is likely as a result of the synergistic effects of climate change and habitat fragmentation. Projected sea level rise is very likely to result in significant losses of coastal ecosystems. Due to projected sea level rise, a million or so people along the coasts of South and Southeast Asia will likely be at risk from flooding. Future increases in precipitation extremes related to the monsoon are very likely in East, South and Southeast Asia. All models and all scenarios project an increase in both the mean and extreme precipitation in the Indian summer monsoon. The ocean in subtropical and tropical regions will warm in all scenarios and will show the strongest warming signal at the surface [27].

India: The climate of India includes a wide range of weather conditions across a large geographic scale and varied topography. However, all areas of India experience four seasons: winter, summer, advancing monsoon and retreating monsoon [28]. Climate change is likely to have an impact on all the natural ecosystems and socio-economic systems of India, as indicated in the National communications Report of India to the United Nations Framework Convention on Climate Change-UNFCCC [29]. The latest high-resolution climate change scenarios and projections for India are based on a regional climate modeling system known as PRECIS (Providing Regional Climates for Impact Studies), which was developed by the Hadley Centre (the research centre of the national weather service in the United Kingdom) and applied in India using scenarios developed by the Intergovernmental Panel on Climate change.

The projections for future climate in India include [30].

- Annual mean surface temperature will rise by the end of the century from 2.5 °C to 5 °C, with warming more pronounced in the northern parts of India.
- A more than 20% rise in summer monsoon rainfall is projected over all states except Punjab, Rajasthan and Tamil Nadu.
- The range of maximum temperatures in any one season is predicted to vary more widely (for example, between 27 °C and 44 °C to between 26 °C and 45 °C), variations in minimum temperature are expected to increase in the same way.
- The hydrological cycle is likely to be altered and the severity of droughts and intensity of floods in various parts of India is likely to increase [29].

Emerging and re-emerging infectious diseases Global warming is a subcomponent of climatic change happening worldwide. This universal rise in temperatures has disrupted not only environmental factors such as biodiversity, rainfall, heat trends, air pollution, sea level changes but also creating a plethora of existing and emerging infectious diseases. New diseases emerge for a number of reasons: world trade, animal translocation, ecological disruption, climate change, pathogen adaptation and agricultural husbandry changes [31]. Indirect effects of climate change which may include disturbances in ecological relationships driven perhaps by agricultural changes, deforestation, 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. Constant changes in the living organisms take place while acquiring the adaptation to changed environment may be in terms of either different mode of life-cycle, change in habitat or change in host range [32]. All these strategies of better survival under changing atmospheric conditions acts as a route cause of new world emerging and many re-emerging diseases [33]. A possible example in this regard is the re-emergence of bovine tuberculosis in the UK 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 etc., is a risk factor for the disease, affecting the rate of contact between cattle and badger. Climate change due to global warming may trigger an ecological invasion evolving a sorting process that brings genetic adjustment with the evolution of new disease agents or complexes [12], which may in turn be responsible for the emergence of new infectious diseases. Further the climatic changes induced by global warming exert a selection pressure that will modify the biodiversity of pathogens and the epidemiology of the infections. Assembly of the World Organization for Animal Health has highlighted that climate change will have considerable impact on the (re-)emergence of infectious diseases in animals (OIE, May 2009). These livestock diseases have been seen to have serious impacts on human health, as over 60% of human pathogens are zoonotic or transmissible from animals [34]. A study by the World Bank in 2012, found that over the last couple of decades zoonotic emerging diseases have had global costs of $6 billion. Moreover, each year there is a one in a hundred chance of the world experiencing a $1 trillion dollar pandemic. Out of all microbial pathogens, 61% are zoonotic with 13% species regarded as emerging or reemerging. Among emerging infectious diseases, 75% are zoonotic with wildlife being one of the major sources of infection [35].

In recent years, numerous vector-borne and other zoonotic diseases have emerged or re-emerged in Europe with major health and socio-economic consequences [36]. There is growing evidence that these new threats can be associated with global and local changes, resulting from climate influences including hotter summers, warmer winters, varying precipitation patterns. These changes can be either abrupt and unanticipated or gradual and protracted. There is also quite a bit of evidence of global warming effects on migratory birds which can transmit a novel infectious disease/ zoonotic infection in a previously sterile geographical area when they change their routes due to rise in temperatures, thus causing the emergence of the disease in that area. Plague caused by a bacterium Yersinia pestis is one of the re-emerging disease as there is a report of re-emergence in Algeria in 2003 after a gap of 50 years. It is a bacterial zoonosis with rodents being the principle reservoir. The black rat (Rattus rattus) and oriental rat flea (Xenopsylla cheopis) are notorious reservoir and transmitting agent for human plague in India. Listerosis is an emerging zoonotic disease. It is estimated that *Listeria monocytogenes* is responsible for 28% deaths due to food borne illnesses in the United States [35].

Likewise Nipah Virus infection (NiV) is an emerging infectious disease of public health importance in the South-East Asia. The virus is named after the Malaysian village where it was first discovered. This virus along with Hendra virus comprises a new genus designated Henipavirus in the subfamily Paramyxovirinae. Fruit bats (Genus Pteropus) have been identified as natural reservoirs of NiV. There were focal outbreaks of NiV in Bangladesh and India during winter in 2001 [35].

Climatic changes are going to cause extremes in the weather leading to heavy rainfall. This weather condition can lead to increase in the spread of rodent-borne diseases like Leptospirosis. Leptospirosis is an emerging zoonotic disease which is associated with flooding. Major outbreaks have been reported from the states of Gujarat, Orissa, Maharashtra and Tamil Nadu in India and also in Northern Thailand during the last 10 years [37]. An outbreak of leptospirosis was also reported in 2002 in Mumbai following prolonged water logging due to heavy rainfall [35].

Rift valley fever has remained an important emerging zoonotic disease which is seen to be affected widely by climate changes. Rift Valley Fever (RVF) was detected outside Africa for the first time in 2000, with cases in Saudi Arabia and Yemen [16]. RVF epidemics usually occur in 5-15 year cycles following periods of excessive rainfall. The main driver for RVF epidemics in eastern and south Africa and to some extent West Africa and Saudi Arabia has been above-normal precipitation. Whereas epidemics in eastern Africa follow El Nino weather phenomenon, those in west Africa [mainly Senegal] are thought to occur after a “productive” rainfall where a primary rainfall event exceeding 10 mm is separated from a secondary but denser rainfall event by a dry period of about 6 days [38]. This rainfall pattern is thought to favour breeding and hatching of the key mosquito vectors. However, emergence is also linked to the gradual expansion of the geographical range of the virus via travel and livestock trade. Pastoralists, game and other animals are likely to respond to climate change by moving more frequently and widely, therefore aiding the dissemination of RVF virus and other infectious pathogens. Wind-aided dispersion of RVF virus-infected mosquito vectors could also play a role in introducing the virus to new environments; Aedes spp for example can travel 175 km or more in wind currents at altitudes of 1-2 km if temperatures are favorable [39].

Epidemics of the mosquito-borne West Nile virus infection can occur during times of drought. This happens because mosquitoes and birds—the primary hosts of the virus are brought into close proximity at scarce water sources, enhancing transmission of the disease between mosquitoes and birds (and thus to humans). In addition, natural predators of mosquitoes are greatly reduced during times of drought as wetlands dry up [40].

In the southern United States one of the most severe summertime outbreaks of yellow fever (viral disease transmitted by the Aedes aegypti mosquito) occurred in 1878, during one of the strongest El Niño episodes on record [5].

Disease situation in India

At least 11 pathogens have emerged or re-emerged in India during 1992-2009, majority of which were of animal origin [35]. New animal disease is not only emerging or re-emerging in our country at an alarming rate but are potentially dangerous to humans such as HAPI (Highly Pathogenic Avian Influenza), swine influenza virus, Nipah, Hendra, Hanta, SARS and recent outbreak of Crimean Congo hemorrhagic fever in Ahmedabad, Gujarat since 18th January 2011. Vector borne diseases like Japanese encephalitis, Dengue, West Nile virus, KFD etc. are also spreading to a much wider areas.

After an interval of more than 20 years, chikungunya fever reappeared in several countries including India, Indonesia, Maldives, Thailand and various Indian Ocean islands. Monkeys, and possibly other wild animals may serve as reservoirs of the virus. It is mainly caused by the bite of infected Aedes Aegypti mosquitoes [35].

Kyasanur Forest Disease (KFD) is a tick-borne flavi virus infection, with monkey as reservoir/amplifier host. The disease spreads to humans by biting of ticks (Haemaphysalis spinigera) acting as a vector for the disease. The disease has been reported from certain parts of Karnataka.

Nipah virus: Fruit bats (Genus Pteropus) have been identified as natural reservoirs of NiV. There were focal outbreaks of NiV in Bangladesh and India during winter in 2001. The drinking of fresh date palm sap, possibly contaminated by fruit bats (Pteropus giganteus) during the winter season, may have been responsible for indirect transmission of Nipah virus to humans [41]. Cases of human illnesses have also been reported from west Bengal during the year 2007.

Plague is a highly fatal re- emerging zoonotic disease caused by a bacterium, Yersinia pestis. The disease has been recently reported from many areas of India including Maharashtra, Gujarat, Karnataka, Uttar Pradesh, Himachal Pradesh etc.

Another highly infectious arboviral disease, the Crimean Congo Hemorrhagic Fever (CCHF) caused by RNA virus of the Bunyaviridae family, has claimed many lives in the Gujarat state of India in 2010–12 period. The CCHF virus is mainly transmitted via infected tick bites [42]. In a survey carried out in northeast India, 65 out of 500 people (13%) were positive for Borelia burgdorferi -specific immunoglobulin-G. Seropositivity to B. burgdorferi suggests infection by the organism and the presence of Lyme disease in these areas [28].

Avian influenza (H5N1) outbreaks were first reported in the South East Asian region in 2003.Sporadic outbreaks are continuing in many countries including in Bangladesh (2007), India (2006-2007), Indonesia (2004-2007). The swine flu A (H1N1) is a viral infection that originated from pigs and was first isolated from pigs in the 1930s [37] and recently swine flu outbreaks were reported from many parts of India including J&K.

Leptospirosis is an important emerging waterborne disease which is also prevalent in the southern states and in the Andaman Islands [43]. Hepatitis E virus infection (HEV) is another important new waterborne emerging pathogen with a zoonotic potential [44].

Future Strategies

The future strategies to combat the effects and impact of climate change through emergence/ re-emergence and significant alterations in terms of distribution and intensity of infectious diseases on animals and thus the above all human welfare, mainly involves two aspects: 1. Adaptation & 2. Mitigation.

Adaptation: Adaptive responses are made through many ways and particularly focus on areas for future adaptation to the disease onslaught due to climatic changes which may include:

Improve surveillance and response capacity: Disease surveillance is an information-based activity that involves the collection and analysis of information on disease occurrence. Well-functioning surveillance systems and timely responses may reduce the cost of outbreaks by 95% [45].

Most developing countries currently lack the capacity to detect disease. Promising surveillance and reporting opportunities for poor countries include:

1. Risk based (targeted) surveillance- This involves concentrating surveillance on the diseases, sectors, sub-populations or areas most likely to be affected thus saving costs and increasing efficiency.
2. Surveillance: Pilot programs involving veterinarians, community animal health workers and farmers for surveillance using mobile phones have been successful in several countries.
3. Participatory disease surveillance involves local communities in detection and reporting of several diseases including avian influenza. However, reports typically require confirmation.

Forecasting and prediction of disease: Disease prediction and forecasting has become an important tool in combating any future disease since traditional knowledge is no longer reliable for designing coping mechanisms.

Improve animal health service delivery: There has been a rising interest in better linking human, animal and environmental health, an approach called “One Health” and Eco health. Community animal health programs have been successfully implemented in many countries but require an enabling national animal health policy especially in developing countries.

Support eradication and control of priority diseases: Global eradication of diseases may not be feasible, but many diseases can be controlled by a combination of treatment, vaccination, culling, and reduction of transmission. Some control technologies with potential to improve control of climate sensitive disease include:

- Multivalent vaccines that can confer immunity to multiple diseases.
- Thermo-tolerant vaccines that do not require a cold-chain.
- Insecticides (e.g. pyrethroids) which are effective against several multiple vectors.

Improve the resilience of livestock systems: Changes that could be instituted to help livestock farmers adapt better include:

- Diversification of livestock and livelihoods.
- Integrating livestock farming with agriculture.
- Identifying and improving breeds that are better adapted to the environment and disease.
- Adopting farming practices that limit greenhouse gas emissions e.g. better management of manure, replacing fertilizers with biological/nitrogen fixing legumes, soil conservation tillage.

Mitigation: The response aims at reducing the overall production and release of all those agents/factors that tend to increase the phenomenon of global warming. This has to be taken care of by international agreements and commitments through implementation of environmental policies in letter and spirit by respective nations. These may include:

- Reducing fossil fuel consumption, especially of coal to lessen the release of greenhouse gases.
- Promotion of biodegradation and recycling procedures.
- Energy saving and utilizing alternative source of energy methods like energy saving stoves, hydroelectric power, wind energy, solar energy, biogas energy. [46].

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