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Climate change, zoonoses and India

B.B. Singh, R. Sharma, J.P.S. Gill, R.S. Aulakh & H.S. Banga

Department of Veterinary Public Health, Department of Veterinary Pathology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab 141004, India

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Summary

Economic trends have shaped our growth and the growth of the livestock sector, but at the expense of altering natural resources and systems in ways that are not always obvious. Now, however, the reverse is beginning to happen, i.e. environmental trends are beginning to shape our economy and health status. In addition to water, air and food, animals and birds play a pivotal role in the maintenance and transmission of important zoonotic diseases in nature. It is generally considered that the prevalence of vector-borne and waterborne zoonoses is likely to increase in the coming years due to the effects of global warming in India. In recent years, vector-borne diseases have emerged as a serious public health problem in countries of the South-East Asia region, including India. Vector-borne zoonoses now occur in epidemic form almost on an annual basis, causing considerable morbidity and mortality. New reservoir areas of cutaneous leishmaniosis in South India have been recognised, and the role of climate change in its re-emergence warrants further research, as does the role of climate change in the ascendancy of waterborne and foodborne illness. Similarly, climate change that leads to warmer and more humid conditions may increase the risk of transmission of airborne zoonoses, and hot and drier conditions may lead to a decline in the incidence of disease(s). The prevalence of these zoonotic diseases and their vectors and the effect of climate change on important zoonoses in India are discussed in this review.

Keywords

Climate change – India – Zoonosis.

Climate change in India

India is a federal union of states comprising 28 states and seven union territories, covering an area of approximately 3.2 million square kilometres (Fig. 1). The climate of India defies easy generalisation as it includes a wide range of weather conditions across a large geographic scale and varied topography (Fig. 2). However, all areas of India experience four seasons: winter, summer, advancing monsoon and retreating monsoon. India is a large developing country in which 70% of the population live in rural areas and are directly dependent on agriculture and natural resources, such as water, coastal zones and grasslands, for their subsistence and livelihood. Further, the adaptive capacity of dryland farmers, forest dwellers, fishermen, and nomadic shepherds is very low (42). 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 (19). The latest high-resolution climate change scenarios and projections for India are based on a regional climate modelling 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 latest projections are (27):

– annual mean surface temperature will rise by the end of the century, by 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

Fig. 1
Map showing states of India
Source: India Meteorological Department

– the range of maximum temperatures in any one season is predicted to vary more widely (for example, from 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

– precipitation is expected to increase substantially, particularly over the west coast of India and west central India.

The hydrological cycle is likely to be altered and the severity of droughts and intensity of floods in various parts of India are likely to increase (19). Further, it is predicted that there will be a general reduction in the quantity of run-off available for agricultural use and drinking water. These are substantial problems for a nation in which large numbers of the population depend on the productivity of primary resources (19). Indications show that, unless something is done, there will be a shift towards wetter forest types in the north-eastern region and drier forest types in the north-western region (19). Increasing atmospheric CO_2 concentration and climate warming could also result in a doubling of net primary productivity (43). It is important to note that the climate-sensitive sectors (forests, agriculture, coastal zones) and natural resources (groundwater, soil, biodiversity, etc.) are already

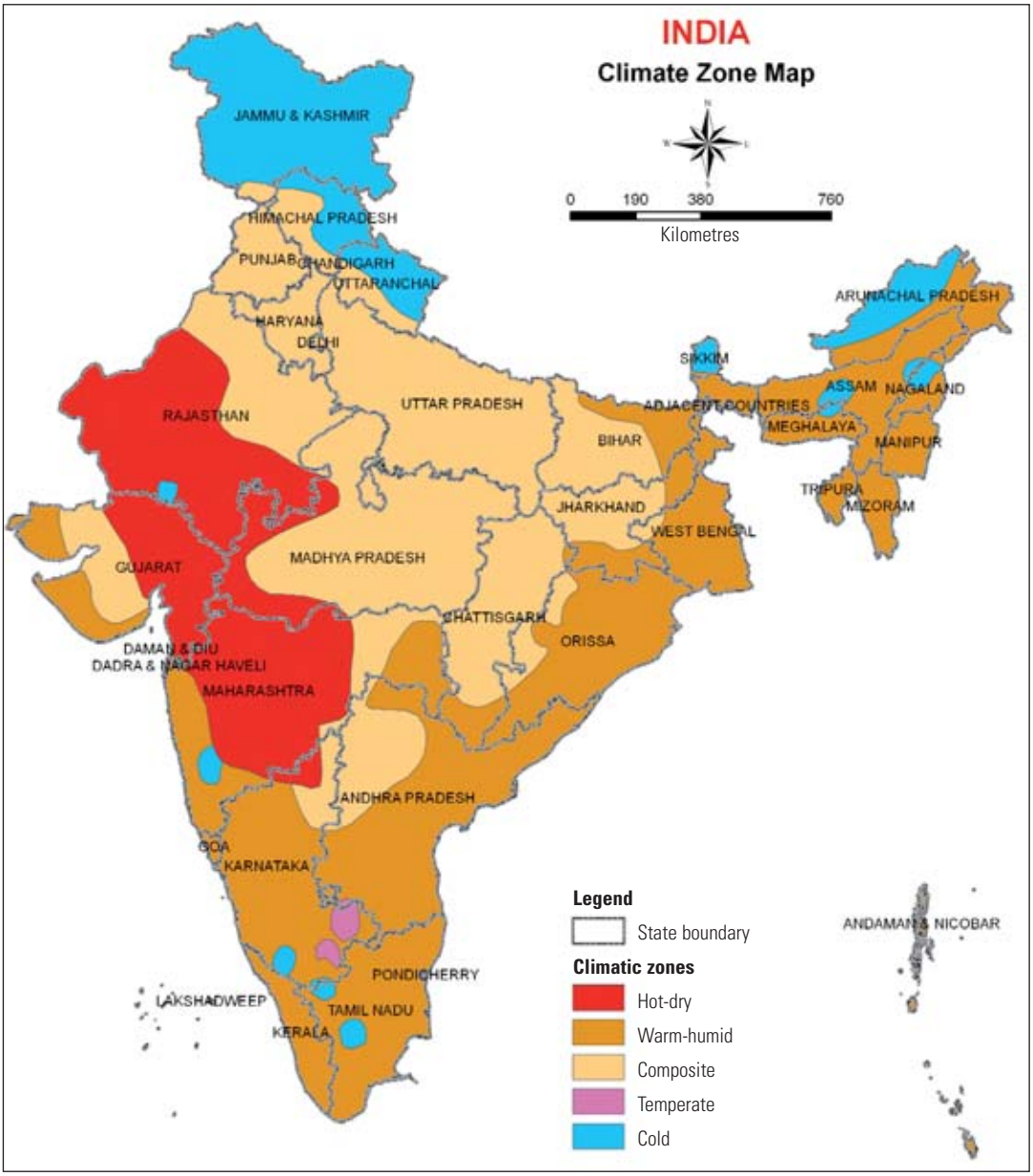

Fig. 2
Map showing climatic zones in India
Source: National Building Code of India, 2005

under stress due to socio-economic pressures. The world's farmers are finding it more difficult to keep up with the growth in population, climate change and soil erosion. Further, a build-up of CO_2, the principal heat-trapping gas, is further accentuating the problem (27, 48).

Zoonoses

Climate change is the most serious challenge facing human and animal populations, as it affects population dynamics of wild animals, reproductive success and population densities of some species. Moreover, climate variability may also expand the current limits of agricultural activities, increasing the chance of contact between species that have not normally interacted in that area. Livestock excrete many micro-organisms which have zoonotic potential. These pathogens can be transmitted by water and food and the risk of transmission to humans is increased if food crops are watered with contaminated water (2). Densely crowded urban environments, especially those without adequate sanitation, are of great public health concern because they are sources of disease epidemics (23).

Vector-borne zoonoses

Vector-borne diseases are infections that are transmitted by the bite of infected arthropod species, such as mosquitoes,

ticks, triatomine bugs, sandflies, and blackflies (8). The projections on climate change indicate an increase in average temperature of between 2.5°C and 5°C, and an overall increase in the intensity of rainfall of between 1 mm and 4 mm/day, except for small areas in north-west India. It is thought that such changes in the climate may affect several characteristics of vector-borne disease, namely:

– their survival and reproduction rates

– the intensity and temporal pattern of vector activity

– the rates of development, survival and reproduction of pathogens within vectors (20, 21, 25).

In recent years, vector-borne diseases have emerged as a serious public health problem in countries of the South-East Asia region, including India. Many of these diseases, particularly dengue fever and Japanese encephalitis, now occur in epidemic form, almost on an annual basis, causing considerable morbidity and mortality. The risk factors that play a key role in the spread and transmission of dengue and other vector-borne diseases in India and across its borders include:

– globalisation

– unplanned and uncontrolled urbanisation

– developmental activities

– poor environmental sanitation

– poor household water-storage practices

– improper drainage of water

– widespread travelling

– human migration.

These issues are a cause of great concern and must be comprehensively addressed. The ability of vector-borne diseases to easily transcend boundaries is a challenge that must be faced in combating these diseases in India because these diseases are present in surrounding countries. For example, West Nile fever has been reported in Pakistan (neutralising antibodies against the virus have been recorded in India) (34) and Crimean-Congo haemorrhagic fever virus, the causative agent of Crimean-Congo haemorrhagic fever (CCHF), is endemic in Pakistan (41).

Prevalence of vectors

The damage caused by vector-borne zoonoses is enormous. In India, seven genera of hard ticks and three genera of soft ticks have been reported (1). The most important genera are *Hyalomma, Haemaphysalis, Rhipicephalus* and *Argas*. There is a significant lack of data on the tick distribution pattern in many states, e.g. Kerala, Goa and the north-eastern states. Soil in several villages was found to be infested with two species of sandflies, *Phlebotomus argentipes Annandale* and *Brunetti* and *P. papatasi* (55). The flea species *Xenopsylla cheopis* is prevalent in many parts of the country (45). The presence of *Leptotrombidium deliense*, the scrub typhus vector, in the Eastern Himalayas (59) has also been reported. In India, Japanese encephalitis virus has been isolated from 16 species of mosquitoes (18).

Mosquito-borne diseases

The first major outbreak of Japanese encephalitis occurred in the Bankura and Burdwan districts of West Bengal in 1973 and since then it has spread to many states and union territories of the country. Japanese encephalitis was first recognised in Tamil Nadu in 1955 on the basis of serological surveys. Subsequent surveys carried out by the National Institute of Virology in Pune have indicated that about half the population in South India has neutralising antibodies to the virus. In the last decade, there has been a major upsurge of Japanese encephalitis in many states, namely, Assam, Andhra Pradesh, Bihar, Goa, Karnataka, Manipur, Maharashtra, Madhya Pradesh, Tamil Nadu, Uttar Pradesh, Pondicherry and West Bengal (54). Japanese encephalitis is currently endemic in 135 districts in 15 states and union territories of India. A large outbreak in Uttar Pradesh took many lives, mostly of children. Presently, nearly 330 million people are considered to be at risk. Although the disease has not been reported from northern states of the Punjab region, the presence of vectors, a reservoir and a susceptible population indicates that the disease may occur in the near future. It is very likely that climate change will further extend the range of the mosquitoes to temperate zones such as Himachal Pradesh and other northern states.

Other mosquito-borne diseases that have been reported in India include zoonotic simian malaria (which emerged in the union territory of the Andaman and Nicobar islands) (53), and West Nile fever, which has spread into new regions as the virus has been introduced into competent vector habitats, possibly as a consequence of climate changes (44).

Fly-borne diseases

Leishmaniosis is a protozoan parasitic infection transmitted to humans through the bite of an infected female sandfly. Temperature influences the biting activity rate of the vector, the diapause, and the maturation of the protozoan parasite in the vector (3). Once conditions are favourable, imported cases can act as a rich source of infection and can consequently lead to the development of new endemic foci. Conversely, if climatic conditions become too hot and dry for vector survival, the disease may be contained.

The present foci of visceral leishmaniosis (VL) in India are Bihar, West Bengal, Uttar Pradesh and Jharkhand (57). Sporadic cases have also been reported from Gujarat, Tamil Nadu, Kerala and sub-Himalayan parts of north India,

including Uttar Pradesh, Himachal Pradesh and Jammu and Kashmir (24). It had been conjectured that western India had become a VL-free zone, but recent studies (52) have shown that the populace of Gujarat State is again at risk from the disease, after about 20 years.

Cutaneous leishmaniosis (CL), which is endemic in the western desert area of Rajasthan (32), used to be confined to hot dry north-western region(s), with sporadic cases reported from Punjab, Delhi, Haryana and Gujarat states. Since 2003, however, new foci of infection have been reported from various parts of India (51). Cutaneous leishmaniosis was not reported from southern India (Kerala State) before 1988. However, many cases have been recorded since then (28). This is of considerable public health interest in view of newly recognised reservoir areas of CL in South India (28). Detailed studies with specific emphasis on climate change are required to study the re-emergence of the disease in certain parts of the country.

Tick-borne diseases

As it does in the case of other vectors, temperature accelerates the development cycle, egg production, population density, and distribution of ticks (50). For example, the distribution of the bacterial spirochete *Borrelia burgdorferi*, the causative agent of Lyme borreliosis, may extend into the Himalayan region as climate change causes a shift to milder temperatures. The disease is transmitted to humans during blood feeding by hard ticks of the genus *Ixodes*, and in a survey carried out in north-east India, 65 out of 500 people (13%) were positive for *B. burgdorferi*-specific immunoglobulin G. Seropositivity to *B. burgdorferi* suggests infection by the organism and the presence of Lyme disease in these areas. Population and vector biology studies are required to find out the exact species involved in transmission of the organism (40). It is worth noting that, although rising temperatures will increase tick distribution, droughts and severe floods will negatively affect their distribution, at least temporarily (50).

Crimean-Congo haemorrhagic fever is caused by an RNA virus of the *Bunyaviridae* family and transmitted to humans from domestic and wild animals by *Hyalomma* spp. ticks. Milder weather conditions, which favour tick reproduction, may influence CCHF distribution (10). For example, an outbreak in Turkey was linked to a milder spring season (a substantial number of days in April with a mean temperature higher than 5°C) in the year before the outbreak (50). The disease has not been reported from India, but does occur in Pakistan (41).

Flea-borne zoonoses

In August 1994, an outbreak of bubonic plague was reported from the Beed district, a known plague-enzootic region in Maharashtra State in western India. In late September, news came of an explosive epidemic of suspected primary pneumonic plague in the city of Surat in neighbouring Gujarat State (6). Hundreds of suspected cases and more than 50 deaths were reported from Surat. Press accounts reported a mass exodus of hundreds of thousands of people from this industrialised port city of nearly two million inhabitants (11). By early October 1994, more than 6,300 suspected cases of plague had been reported from 12 Indian states, including Delhi (61).

Rickettsiosis was believed to have disappeared from many parts of India. However, the serological testing of 37 residents of southern India who presented with fever of unknown aetiology between 1996 and 1998 confirmed that spotted fever, epidemic/endemic typhus and scrub typhus were prevalent in southern India. The epidemiology and magnitude of the problem need to be evaluated (31).

Waterborne zoonoses

Water contamination events are affected by the rates and timing of precipitation, among other factors (9). When drought is followed by heavy rain, faecal matter containing human pathogens may be flushed into the surface water and contaminate the drinking water, which can result in a greater probability of disease outbreaks. Faecal contamination of water in extreme events (droughts, floods) could result in increased prevalence of diseases such as echinococcosis, taeniosis, and toxoplasmosis (53). A study from England and Wales found that 20% of waterborne outbreaks in the past century were associated with a sustained period of low rainfall, compared with 10% associated with heavy rainfall (33).

Waterborne and foodborne diseases are a major cause of mortality worldwide. The association between warmer temperatures and the occurrence of disease suggests that rates of waterborne and foodborne illnesses are likely to increase with rising temperatures (14). The close relationship between climate, environment and infectious diseases in the developing world is well recognised. For example, the importance of warm ocean waters in disseminating cholera in the Ganges river delta and elsewhere in Asia (35) has been well described. Indeed, there is widespread concern about the potential impact of global climate change on the distribution and burden of cholera and other infectious threats in the developing world (20, 26). In September 1992, *Vibrio cholerae* O139 Bengal (the first non-O1 strain) appeared in South India. It later spread to the rest of India and Bangladesh (7). Cholera is a diarrhoeal disease with a high case-fatality rate caused by infection with toxigenic strains of *V. cholerae*. It remains an important cause of death in the developing world and is the waterborne

enteric disease most likely to increase in the face of global climate change. Risk increases with warmer water temperatures, suggesting that global cholera activity may increase sharply in the face of climate change (46). *Vibrio cholerae* outbreaks are closely associated with climatic cycles (e.g. El Niño Southern Oscillation) and ocean plankton blooms.

Other waterborne diseases are also present in India. For example, melioidosis has been documented in South India (Tamil Nadu and Karnataka) and leptospirosis is an important emerging waterborne disease which is also prevalent in the southern states and in the Andaman Islands (7). Hepatitis E virus infection (HEV) is another important new waterborne emerging pathogen with a zoonotic potential (60). In India, the lifetime infection risk is more than 60%, which translates into hundreds of thousands of cases annually (62). More molecular phylogenic analysis of HEV genotypes circulating in human and swine populations in India is thus required to delineate the mode of HEV transmission and the evolution of new emerging HEV genotype subgroups (56).

There have been several reports of parasitic zoonoses in India. For example, cryptosporidiosis has been reported throughout the country (53) and human infection with *Entamoeba histolytica* has been reported (and many other animals are potential reservoirs of infection). The occurrence of the zoonotic genotypes of *Giardia intestinalis* among animals is of public health significance; epidemiological studies have revealed the presence of the parasite among children and HIV-seropositive individuals (53). In addition, most of the trematode zoonoses, namely, paragonimosis, gnathostomosis, schistosomosis, dracunculosis, fasciolopsiosis and diphyllobothriosis have been reported in India (53). The prevalence of these waterborne diseases is likely to increase if extreme weather events occur. Climate change has the potential to shift boundaries for spatial distributions, host–parasite assemblages, demographic rates, life-cycle phenologies, associations within ecosystems, virulence, and patterns of infection and disease (38). For example, an increase of a few degrees in environmental temperatures may lead to marked increases in cercarial emergence from snails (first intermediate host), with little if any reduction in their transmission efficiency (30). Thus, global warming may also enhance the local impact of trematodes (39). Trematodes and helminths whose life cycles include a larval stage in the environment or in an invertebrate host may be more susceptible to climate change impact (29) than trematodes and helminths in whose life cycle such phases are absent or reduced to a minimum.

Foodborne zoonoses

Many foodborne pathogens are prevalent in India. Enterohaemorrhagic *Escherichia coli* (EHEC) O157 sorbitol phenotype has been isolated from the Ganges river in Varanasi (15). Brucellosis, listeriosis, and infections due to drug-resistant *Staphylococcus aureus*, *Salmonella typhi*, *S. paratyphi*, and *Shigella* species are other important emerging foodborne zoonoses (7). Outbreaks caused by foodborne viruses have been reported in India (12). Climate change may cause increased risk of food contamination, increased environmental survival of pathogens, changes in prevalence of pathogens in animal reservoirs and changes in host–parasite ecology, which may enhance the risk of foodborne disease (14). Changes in the ecology of enteric pathogens internationally may increase the risk of outbreaks linked to imported foods (14).

Airborne zoonoses

Many important zoonoses are airborne in nature. A number of these zoonoses, such as influenza virus infections, anthrax and plague, have been recorded in India (4, 5, 36). Aspergillosis has been reported in animals, birds and humans (58). While warm and humid conditions may increase the risk of transmission of airborne zoonoses, hot and drier conditions may reduce their incidence in certain parts of the country. Many respiratory pathogens, including influenza viruses, exhibit winter seasonality that is often attributed to seasonal changes in temperature or population behaviour (e.g. indoor crowding) (14). If cold temperatures are an important driver of respiratory disease, climate change might be expected to attenuate the impact of influenza epidemics in the country. Climate change also has the potential to indirectly affect the transmission of communicable diseases (14). Forced migration of people because of drought or flooding could increase the transmission of many communicable diseases because of enhanced intermingling of populations that have previously been isolated from one another (14).

Other important zoonoses

The fungal infections histoplasmosis, cryptococcosis and aspergillosis have all been reported (58) across the country. Conditions promoting the release of spores include high humidity and the disturbance of colonised soil through excavation or similar activities (14). Any changes in rainfall and temperature patterns could, therefore, affect the occurrence of these diseases. Climate variability affects the population dynamics of wild animals, and these dynamics affect the transmission of diseases (22). Outbreaks of *Hantavirus* infections in the south-western United States have clearly been linked to El Niño impacts on rodent populations (13, 16). Climate variability may also lead to a change in the range of area over which wildlife can live, as well as expand the current limits of agricultural activities,

thereby increasing the chance of contact between species that have not interacted before (17). Such changes may increase the risk of rabies, plague, trichinellosis, and Kyasanur forest disease, all of which are already prevalent in different parts of the country (37, 47, 49).

Conclusions

Keeping track of the changing global disease situation is very important, as climate change increases the risk of zoonoses by expanding the host, reservoir, and vector base. Public health infrastructure for disease surveillance, food and water safety, control of vectors and disease reservoirs, and public health outbreak response needs to be strengthened. The provision of safe food and water and the control of zoonoses and associated outbreaks are important challenges to be faced. Multinational and collaborative scientific efforts to minimise the effects of climate change on zoonotic diseases must be given renewed impetus if the spread of these diseases is to be controlled.

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Le changement climatique et les zoonoses en Inde

B.B. Singh, R. Sharma, J.P.S. Gill, R.S. Aulakh & H.S. Banga

Résumé

Jusqu'à une période récente, la croissance et le développement du secteur de l'élevage étaient déterminés par les orientations économiques, au prix d'une modification des ressources naturelles et des écosystèmes qui ne va pas toujours de soi. À l'heure actuelle, la situation tend à s'inverser puisque ce sont les orientations environnementales qui commencent désormais à influencer notre économie et notre situation sanitaire. Les animaux, les oiseaux, mais aussi l'eau, l'air et les denrées alimentaires jouent un rôle déterminant dans la persistance et dans la transmission d'importantes maladies zoonotiques dans le milieu naturel. On estime que l'Inde connaîtra une prévalence accrue des zoonoses d'origine vectorielle et hydrique dans les prochaines années, en raison des effets du réchauffement climatique mondial. Depuis quelques années, l'émergence des maladies à transmission vectorielle constitue un grave problème de santé publique en Asie du Sud-Est et notamment en Inde. Les zoonoses à transmission vectorielle surviennent désormais pratiquement chaque année sous forme épidémique en entraînant une morbidité et une mortalité importantes. Il a été constaté que de nouvelles zones font office de réservoirs pour la leishmaniose cutanée dans le Sud de l'Inde ; il convient donc d'approfondir les recherches sur le rôle du changement climatique dans la réémergence de cette maladie, ainsi que dans l'essor des maladies d'origine hydrique et alimentaire. Ainsi, lorsque le changement climatique entraîne une hausse des températures et de l'hygrométrie, le risque de transmission des zoonoses aérogènes peut augmenter, alors que dans des conditions climatiques chaudes mais plus sèches, l'incidence des maladies tend à diminuer. Les auteurs examinent la prévalence de ces zoonoses et de leurs vecteurs, ainsi que les effets des changements climatiques sur les principales zoonoses présentes en Inde.

Mots-clés

Changement climatique – Inde – Zoonoses.

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Cambio climático y zoonosis en la India

B.B. Singh, R. Sharma, J.P.S. Gill, R.S. Aulakh & H.S. Banga

Resumen

Las tendencias económicas han determinado nuestro crecimiento y el del sector pecuario, pero a costa de alterar recursos y sistemas naturales de un modo que no siempre resulta obvio. Ahora, sin embargo, empieza a ocurrir lo contrario: la situación ambiental empieza a repercutir en nuestra economía y nuestro estado de salud. En la naturaleza, los animales y las aves, al igual que el agua, el aire y los alimentos, tienen una función básica en el mantenimiento y la transmisión de importantes enfermedades zoonóticas. En general se pronostica para los próximos años un probable aumento de la prevalencia de zoonosis transmitidas por vectores o por el agua debido a los efectos del calentamiento planetario en la India. De unos años a esta parte, las enfermedades transmitidas por vectores se han erigido en un grave problema de salud pública en los países del Asia sudoriental, entre ellos la India. Ahora esas zoonosis pueden surgir en forma de epidemia prácticamente cada año, provocando importantes tasas de morbilidad y mortalidad. En el sur de la India se han detectado nuevas zonas de reservorio de la leishmaniosis cutánea, y merece la pena investigar más a fondo la influencia que ha tenido el cambio climático en su reaparición y en la pujanza de enfermedades transmitidas por el agua o los alimentos. En el mismo orden de ideas, el cambio climático, cuando se traduce en condiciones más húmedas y calurosas, puede incrementar el riesgo de transmisión de zoonosis por vía aérea, y cuando genera condiciones de calor y mayor sequedad, al contrario, inducir una menor incidencia de enfermedades. Los autores examinan la prevalencia de estas enfermedades zoonóticas y sus vectores y los efectos del cambio climático sobre zoonosis importantes en la India.

Palabras clave

Cambio climático – India – Zoonosis.

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