CLIMATE CHANGE and Disease Dynamics in India

Editors

Nitish Dogra • Sangeet Srivastava

Executive Summary

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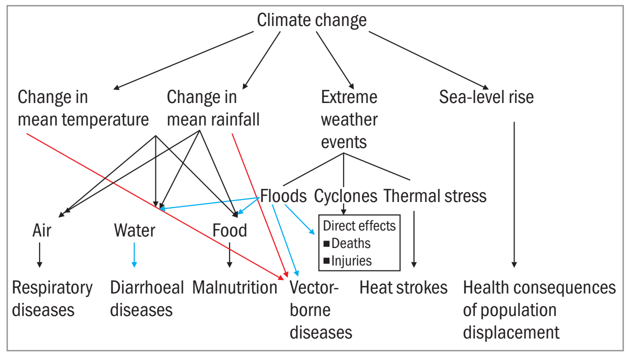
Preface

As editors of *Climate Change and Disease Dynamics in India*, we are pleased to present the technical summary of the edited volume, which has been placed in the public domain in the interest of the nation and the world community. The work represents perhaps the most comprehensive exercise conducted in this specific field of enquiry in a developing country context and involves 28 authors across India, Belgium, New Zealand as well as the USA. These include experts who have contributed to the 2007 Nobel Prize-winning, Intergovernmental Panel on Climate Change (IPCC).

The Lancet, one of the most reputed medical journals, has warned that climate change could be the biggest health threat of the twenty-first century. This mammoth challenge has the potential to cripple health systems in India just as in the rest of the world. It can also profoundly alter disease dynamics, thereby threatening the well-knit fabric and growth of society.

The core of the book relates to the climate-sensitive diseases, including but not limited to vector-borne diseases, diarrhoeal diseases, and malnutrition. However, it was felt that besides these "bedside" aspects, there was a need to cover supporting "basic" aspects such as modelling, climatology, and climate epidemiology. In addition, it was felt that "boardroom" aspects such as vulnerability and adaptation and economics required elaboration.

The relationships between climate change, mediating factors, and health outcomes are complex and maybe quite baffling for someone unfamiliar with the topic. An overall conceptual framework, such as the one shown in the figure, is extremely useful to understand the linkages. Although by no means exhaustive, it represents a simplified representation of reality.



Dogra–Srivastava Framework for Climate Change and Health Outcomes

Strengthening of health facilities is the core of the public health response to threats of climate-sensitive diseases and health conditions. Adaptation to climate change in the health sector can be effectively mainstreamed into the National Rural Health Mission, which is bringing about an architectural correction in the health system.

India's National Action Plan on Climate Change had several areas designated as missions to counter the challenges posed. Health, however, finds mention only as one of the other initiatives. Apparently, the sector has not been seen with the same seriousness as agriculture or water resources have been, and it needs urgent prioritization.

As evidence on climate change and health outcomes emerges, communication will become more important, with specific modules needed for health workers, programme managers, teachers, and students among others. Evidently, the pulse of the planet has got inextricably linked to the pulse of the population. Healing the planet will help us to heal ourselves.

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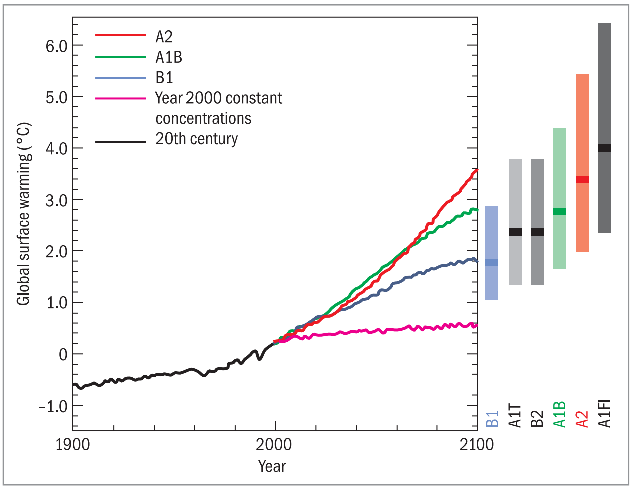
Global environmental change

Climate change is a worldwide problem because it is caused by disturbances in physical and biological systems that operate at a planetary scale. This makes it stand out from other wide-ranging, human-induced environmental problems such as massive forest fires or generation of black carbon soot. Under "business as usual" conditions, the concentration of CO_2 in the atmosphere will reach double the pre-industrial levels before 2100, and the global average temperature by the end of the century will be between 1 and 6 degrees higher than that of the present. This wide range results primarily from uncertainties over trajectories of future emissions. There are also differences between climate models, including a range of assumptions about feedback phenomena. The scenarios are depicted in the figure.

Average temperature is a convenient metric, but the changes in extreme events and the increase in variability that is projected for temperature and rainfall may be more important for human health.

Climate change is a global phenomenon, but the manifestations will vary from one part of the globe to another. Therefore, it is essential that countries conduct their own national assessments.

Climate change affects disease dynamics directly (for instance, impact of heat waves on cardiovascular mortality) and indirectly (for instance, crop failures or increased activity of disease vectors). It is expected that infectious diseases will alter their range, intensity, and timing. Unless public health programmes keep pace with the increased force, malaria and water-borne infections will also rise. It is possible that the impacts on other climate-related conditions will be even greater. These include consequences of food shortages, water insecurity and population displacement.



Global average warming relative to 2000 and projected to 2100 for three IPCC scenarios

Note Vertical bars on the right show best estimates and ranges for six emission scenarios for 2100

Source *IPCC Fourth Assessment Report*

Researchers and health-care providers have two major tasks. They have to understand and respond to the causes of vulnerability (some populations will be particularly susceptible) and formulate win-win strategies for mitigation (policies that stabilize the climate and bring health gains in the short term). For researchers, many of the questions posed by climate change are particularly difficult because they lie beyond the reach of conventional, experimental science. They have to employ new techniques, new uses of existing techniques, and broader applications of concepts such as risk, uncertainty, confidence, and likelihood.

A summit spokesperson at Copenhagen in March 2009 reported that "all of the signals from the earth system and the climate system show us we are on a path that will have enormous and unacceptable consequences". However, there are many possible low-carbon routes to social progress and ways of meeting local needs.

Climate epidemiology

The purpose of this chapter is to outline the key principles of environmental epidemiology—studying the distribution and determinants of diseases in population and indicating the methods of studies that link climate change phenomena to exposure with defined health outcomes.

Health policy planners are entrusted with the responsibility to frame evidence-based decisions and look for frameworks that will enable them to arrive at the best cost-optimized answers to the problems on the basis of best evidence. In case of studying climate change and health outcomes, observational environmental epidemiology studies are the mainstay of evidence. An understanding of these processes is essential to frame the best responses to pressing problems. Essentially, answers to two pressing questions are often searched for. First, how does one know that a valid association exists between environmental phenomena such as climate change and the specific health outcome, and second, the extent of the association searched for in framing these policy measures to mitigate health effects attributable to changes in climate and the downstream effect. Despite diversity of specific exposure variables (extreme climate events, temperature changes, emergent natural disasters, or indeed any other phenomenon attributable to changing global climate patterns) and health outcomes (infectious diseases, loss of lives due to disasters), the essential underlying principles of inquiry and methodology to understand the pattern of association remain the same and need a thorough discourse. These principles and the way to understand and extend these ideas are discussed in this chapter, while instances of how these are used in various climate–disease association contexts are discussed in other chapters.

An example of how the fundamental principles of epidemiology need to be examined through the prism of climate change is given the box.

Box: Criteria for causality in climate change and health studies

Kovats, Campbell-Lendrum, McMichael, et al (2001) suggested the following eight criteria that may be helpful in the detection and attribution of observed changes in vector-borne diseases to climate change:

1. Evidence of biological sensitivity to climate
2. Meteorological evidence of climate change
3. Evidence of entomological and/or epidemiological change in association with climate change
    - Maximizing sample size
    - Studies should extend across the full range or at least the extremes of the range to detect poleward or altitudinal shifts in vector or disease distributions. The authors argued that this was necessary to exclude simple expansions or contractions. This is highly relevant in the context of climate change and temperature-related studies, but can also be a more general case for other manifestations of climate change.
    - Need for long data series
4. Correspondence of year-to-year variability in climate series to health time series
5. Comparability of time slices when a continuous data series is not available. This is relevant for studies that are based on comparison of specific points in time
6. Adjustment for autocorrelations. While somewhat prescriptive and as a recommendation, an obvious point given the nature of climate data, this is nevertheless an important caveat that goes back to the point of redefining issues around confounding and biases in epidemiological studies.
7. Quoted statistically significant values for the association between temporal variation in climate and health outcomes should clearly distinguish between the effects of (in increasing order or relevance) seasonal variation, inter-annual variation, and long-term trends in climate.
8. Analyses should take into account, as far as possible, other changes that have occurred over the same time period, which could plausibly account for any observed association with climate.

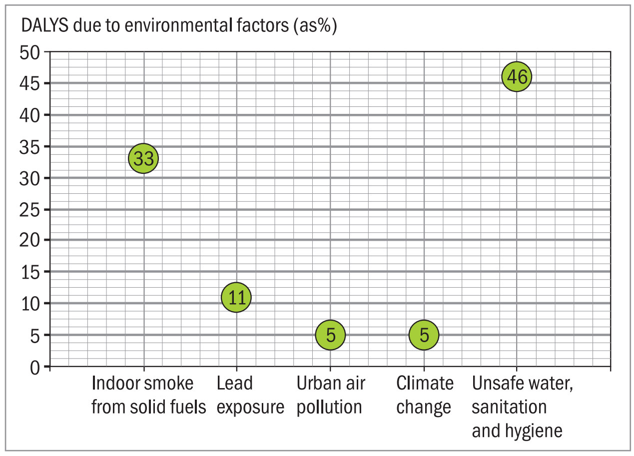
Kovats R S, Campbell-Lendrum D H, McMichael A J, Woodward A, Cox J St H. 2001. **Early effects of climate change: do they include changes in vector-borne disease?** *Philosophical Transactions of the Royal Society of London* **356**(1411): 1057

Climate change attributable burden of disease

One of the greatest challenges for researchers in the field of climate epidemiology is to quantify the impacts of climate change with regard to the repertoire of diseases and conditions associated with them. Quantification maybe done in terms of burden of disease, measured as disability-adjusted life years (DALYs).

The current burden of disease due to climate-sensitive health outcomes, including but not limited to diarrhoea, vector-borne diseases, malnutrition, deaths due to floods and landslides, and cardiovascular diseases in cold waves and heat waves, is considerable. It is essential to understand that certain health outcomes are already occurring at a high level. For example, according to the *NCHM Background Papers—Burden of Disease in India*, published by the National Commission on Macroeconomics and Health in September 2005, diarrhoea and malaria contribute almost 10% of total DALYs. Thus a risk factor for that outcome could be relevant even if the magnitude of the risk itself is small. This is particularly important in case of climate change when the risk is small but is incremental in character.

Globally, a comparative quantification of health risks has also been derived for physiological, behavioural, socio-economic, and environmental risk factors. The last among these factors accounts for approximately a quarter of the total disease burden. The figure shows the relative comparison of climate change with other environmental risk factors. Although the risk does not compare to unsafe water, sanitation and hygiene or indoor smoke from solid fuels, it should be noted that climate change is already leading to DALYs comparable to urban air pollution. These figures are further expected to rise with results from a new round of assessment expected soon.



Comparison of major environmental risk factors

Source Rodgers A, Ezzati M, Vander Hoorn S, et. al. 2004. Distribution of major health risks: findings from the Global Burden of Disease Study. PLOS Medicine (1): e27

The conceptual framework for burden of disease assessment is shown in the summary of Chapter 4. The assessment of increased burden due to climate change has been described as one of the two main components in the health sector initiatives of the National Action Plan on Climate Change. In a world of competing risks and compelling priorities, it is essential to have concrete evidence to make just and equitable allocation. On a more basic level, the estimates from a national assessment are required to know not just how climate change is affecting human suffering in India, but also to know how many people are dying due to it. Children are an especially vulnerable group in which the impacts of climate change need to be assessed to protect a new generation at risk.

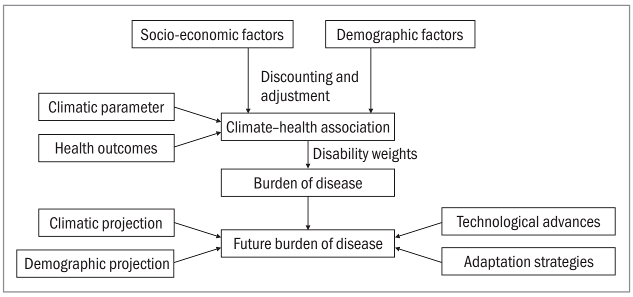
Modelling for future health impacts

Climate change entails unexpected changes for closely linked natural resources and biodiversity. Although humans can adapt to these direct and indirect changes, the adaptability is limited when it comes to extreme and frequent changes in the environment. This simply translates to human health impacts in terms of substantial increase in mortality and morbidity. This includes the occurrence and spread of climate-sensitive diseases, which are difficult to assess without a suitable model. The association between climate change and human health is very complex. To understand the dynamics of climate–health relationship and to quantify it, both for the present and future, it is essential to adopt suitable mathematical models related to various health determinants.

It is extremely difficult to make projections of the extent and direction of the potential impacts of climate variability and changes on human health because of various confounders, lack of downscaled models, and poorly understood factors associated with potential health outcomes, population vulnerability, and adaptation inter alia.

However, the modelling of health impacts is still in a nascent stage as climate change is a recently recognized risk factor. It is further limited by future technological advances and adaptive measures, for example, improved use of weather forecasting or newer vaccines, which might be developed in future to mitigate risks of adverse health outcomes. The framework for modelling future impacts is described in the figure.

With the ever-evolving modelling paradigms and epidemiological tools, it is possible to assess future impacts of health outcomes in relation to climate change scenarios. The measures of errors and uncertainties, both systematic and inherent,



Framework for modelling future health impacts

are essential in defining the acceptability of these projections for decision-making.

It is also imperative to develop measurable indicators of health impacts. Such assessments would not only augment our understanding of the climate and health linkages but also help in designing better adaptation strategies.

Another important aspect to be considered is the local scales of impacts. Detailed maps of such climate change-induced hot spots for all the sectors need to be developed, as health risks are linked with food, water, environment, and socio-economic conditions.

As health outcomes also depend on the location of the regions, it is difficult to implement a climate–health model developed and meant for a particular region in other regions having different characteristics. Since the climate–health linkages change according to the climatic conditions and other confounders, it is imperative to develop national as well as subregional burden of disease estimations. This also suggests developing integrated surveillance systems for collecting and collating necessary information critical to model climate–health relationship. Future burden of disease estimations would suggest the feasible developmental trajectories required to be followed to "climate-proof " our societies and safeguard our health.

Indian climatology in the context of human health

India has a unique climatic regime with two monsoon seasons (south-west and north-east), two cyclone seasons (pre- and post-monsoon), hot weather season characterized by severe thunderstorms and heat waves, and cold weather season characterized by violent snowstorms in the Himalayan regions and cold waves. Heavy to very heavy rainfall during the monsoon season (June–September) often cause floods over many parts of India. Similarly, strong winds, heavy torrential rains, storm surges and astronomical tides associated with tropical cyclone are also prevalent over the coastal belt of India mainly during the pre-monsoon (April–May), early monsoon (June), and post-monsoon (September–November) periods. After these disasters, various epidemics affect the area.

During summer, most areas of India also experience episodes of heat waves every year causing sunstroke, dehydration and death. An analysis of daily climatological heat index (HI; combining temperature and humidity) over 41 districts well distributed over the country indicated that maximum HI exceeding 45°C characterizes many districts during March to May and also during June to September. On the other hand, the wind chill index (combining temperature and wind speed) is less than 10°C for a very few districts of northern India mainly in winter (January–Feb) and the post-monsoon season (October–December).

Different climatic conditions create favourable conditions for the transmission of vector-borne and enteric diseases. The two transmission windows TW_1 ($T_{max} \le 35°C$; $T_{min} \ge 20°C$; $RH \ge 55\%$) and TW_2 ($25°C \le T \le 30°C$; $60\% \le RH \le 80\%$), which are favourable for transmission of these diseases, are found to be satisfied for many days during the south-west monsoon (June–September) and the post-monsoon season (October–December) over different parts of India.

Air pollution and water pollution are other areas of concern as these also affect human health.

Climate change associated with global warming has already triggered weather changes (from flooding and storms to heat waves and droughts), which are taking a heavy toll on people's health around the world. Over the Indian region, the observed temperature during 1901 to 2008 indicated a rising trend at a rate of 0.52°C in 100 years. Significant rising trends in the frequency and magnitude of extreme rain events during the monsoon season have also been noticed by analysing the data over the Indian region. The regional model simulations under the scenarios of increasing greenhouse gas concentrations and sulphate aerosols indicate marked increase in both rainfall (including the frequency of extreme rainfall) and temperature over India during the twenty-first century. The projected changes in surface air temperature for sub-regions in Asia under the highest future emission trajectory pathway for the next 30 years (2010–39) are shown in the table.

Thus climate change is likely to continue to adversely affect human health in Asia, including India. The risk of climate-related diseases will depend on improved environmental sanitation, hygienic practice, and medical facilities among other factors.

Table: Projected changes in temperature and rainfall during two different scenarios (2010–39)

Subregion	Season	Projected changes during 2010–39			
		Temperature (°C)		Precipitation (%)	
		A1FI	B1	A1FI	B1
South Asia 5°N–30°N; 65°E–100°E	DJF	1.17	1.11	–3	+4
	MAM	1.18	1.07	+7	+8
	JJA	0.54	0.55	+5	+7
	SON	0.78	0.83	+1	+3

DJF – December, January, February; MAM – March, April, May; JJA – June, July, August; SON – September, October, November

Source IPCC (2007b)

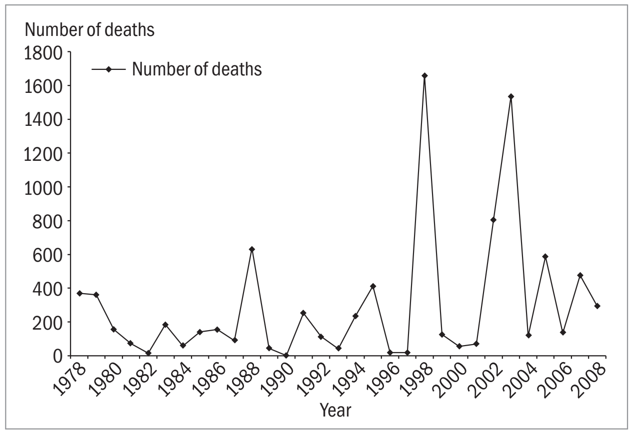
Thermal stress

Several researchers have asserted that global climate change is likely to be accompanied by an increase in the frequency and intensity of heat waves and cold waves. It is interesting to note that mortalities due to both heat waves and cold waves were highest in India in 2003 as compared to other years. Global climate change with extreme heat wave conditions has been seen not only in India but also in other countries like France. In the national context, a number of studies in India show that the country has been experiencing extreme weather events for the past few decades, particularly after the 1990s. The thermo-hygrometric index (THI) also showed that there was an increasing trend of discomfort seen from 20 April till June end. Heat wave and cold wave conditions and consequent deaths have been increasing in India. The trend for heat wave deaths is shown in the figure.

In 1998, major parts of north India and the northern parts of peninsular India experienced severe heat wave. During the second half of May, the heat wave was one of the severest ones seen in the last 50 years and led to the deaths of more than 2600 people.

The people residing at a place for a sufficiently long time get adapted to the weather conditions of that place. Hence, the maximum temperature neared 50°C in north-west India, especially Rajasthan, but the death toll was less compared to that in Odisha. The large number of deaths in Odisha was perhaps due to the lack of adaptability to such extreme conditions.

Cold wave events and consequent deaths have also been increasing in India. From 10 events and 22 deaths in 1994, it increased to 30 events and 425 deaths in 2000, and 42 events and 1156 deaths were officially reported by the India Meteorological Department in 2003.



Heat wave deaths in India (1978–2008)
Source Based on *IMD and NCC (Various years)*

Efforts should be made to increase awareness among the population to respond to symptoms of possible heat- and cold-related illnesses and to contact emergency medical services.

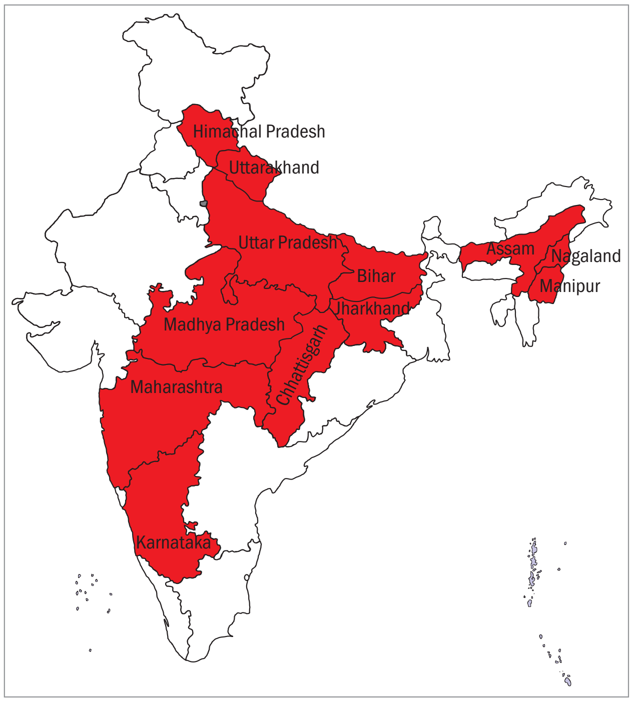
The following five-pronged adaptation policy framework for extreme climatic conditions is needed:

1. Increasing the robustness of infrastructure designs and provision of sheds for rest, particularly for homeless and slum dwellers.
2. Increasing the flexibility and resilience of managed natural systems and social systems.
3. Enhancing the adaptability of vulnerable natural systems.
4. Reversing trends increasing vulnerability (also termed maladaptation). Developing and implementing written heat illness prevention procedures.
5. Improving societal preparedness for future climate change. For cold wave conditions, these include snow and ice disaster control measures in mountainous areas. These include a focus on design and management of snow fences, snow-break forests and advancement of winter road management, while accounting for problems of landslides and stone shooting.

Climate disasters

The risk of disasters and the extent to which they impact human lives and livelihoods differ and depend on the exposure to hazards, frequency or severity of a hazard, and human vulnerability. As vulnerability is not evenly distributed across the world, societies, individuals, households or groups are likely to be unevenly affected.

Climate-related disasters represent the largest proportion of the total disaster count. Within this group, floods have been increasing in occurrence and intensity, with southern and south-eastern Asia displaying the highest vulnerability. Between 1960 and 2008, 183 countries were affected by floods. India occupies the first place, having suffered 208 floods that killed 57, 153 people between this time period. Asia, including India, was also heavily hit by droughts between 1960 and 2008. Recently, 2009 was declared a very heavy drought year for India with 50% of the districts affected by August 2009. Drought-prone states in India for that year are shown in the figure below.



Drought-prone states in India in 2009

Climate disasters such as floods and droughts have direct and indirect health effects and lead to social and economic disruption. They, more often than not, directly result in mortality and morbidity and may indirectly lead to an increase in the transmission of communicable diseases as well as damages to local infrastructure, displacement of population and ecological change.

The majority of disasters occur in regions of the world where infectious diseases such as malaria and dengue are either endemic or have a high endemic potential. The impact of communicable diseases is often presumed to be very high in the aftermath of disasters. However, the increase in endemic diseases and the risk of outbreaks are rather dependent on other different factors such as population movement and water as well as sanitation facilities that work synergistically to increase mortality resulting from communicable diseases.

Current evidence is not conclusive regarding the main causes for the increased risk of disasters. While climate-related factors, such as global warming, may be a contributor to the increase, a range of other social, behavioural and environmental factors such as urbanization, deforestation and land use also affect the health outcomes in question.

The past performance of climate may become a less reliable forecaster of future performance; thus, the future climate will be less familiar and more uncertain under climate change. Although the future risk may be largely unknown, it remains critical to make risk and impact estimates available to policymakers, along with a realistic representation of associated uncertainty. By learning from the past and considering today the uncertain risk of tomorrow, we will be able to adapt to the threat.

Sea level rise

Coastal regions offer several climatic and trade advantages, which result in a concentration of population and economic activities along the coasts. Coastal zones are also vulnerable to climate change as these are affected directly by climatic extremes. In light of climate change, extreme coastal events and accelerated sea level rise (SLR) can threaten human safety and shoreline development.

The coastal system is extremely dynamic owing to the changing nature of interactions between its components—the natural and human systems. Nearly a quarter of India's population living along its 7500 km coastline is at high risk due to SLR and its associated impacts.

The global mean SLR scenarios are obtained based on thermal expansion and ice melt projections, and the best estimate shows an increase of nearly 2.4 times as compared to the twentieth century. The Intergovernmental Panel on Climate Change (IPCC) mentions that thermal expansion is the largest contributor (70%–75%) to model projections for SLR, with the remaining being attributable to the melting of mountain glaciers. Higher temperatures are expected to further raise the sea level by expanding ocean water and melting mountain glaciers and ice caps. The IPCC estimates that the global average sea level will rise between 0.18 m and 0.59 m by 2100.

In India, model simulation studies indicate that SLR related to thermal expansion is expected to be between 15 cm and 38 cm by the middle of this century and between 46 cm and 59 cm by the end of the century. A 1 m SLR is projected to displace about 7.1 million people in India and cause a land loss of nearly 5764 km^2 with nearly 4200 km of roads being damaged/inundated. With a high likelihood of increase in the frequency and intensity of tropical cyclones, storm surges may give rise to extreme sea levels. At high risk are the western coast of India and areas along the Bay of Bengal that are likely to grow in terms of population, infrastructural investments and economic development. Along the western coast of India, Khambhat and Kachchh in Gujarat, Mumbai, parts of Konkan coast and south Kerala are at high risk due to SLR. The settlements and agricultural lands along Ganga, Krishna, Godavari, Cauvery and Mahanadi deltas on the east coast are expected to be impacted due to SLR.

SLR has multiple effects on human health which have been given in the table.

Table: Potential effects of SLR on health

	Effect
1	Morbidity and mortality associated with extreme coastal events such as flooding, cyclones, and storm surges
2	Effects on nutrition due to loss of agricultural land or decline in fish catch
3	Reduced freshwater availability by saltwater intrusion into groundwater aquifers
4	Changes in distribution of disease agents
5	Psychological trauma and stress
6	Population displacement associated with loss of land or other socio-economic and health impacts
7	Impacts on "sensitive" coastal ecosystems and loss of coastal livelihoods

To counter the impacts of SLR, regional adaptation strategies will be needed because the extent of damage caused would vary from region to region depending on the slope of land, extent and nature of coastal development, population density, local rate of SLR, existing coastal management policies, and local practices, among others.

There are two major challenges for adaptation activities. First, being a slow process, SLR often falls beyond the priority of short-term decision-making; second, the inherent uncertainty on SLR at the regional level makes it difficult to adopt any stringent adaptation measures.

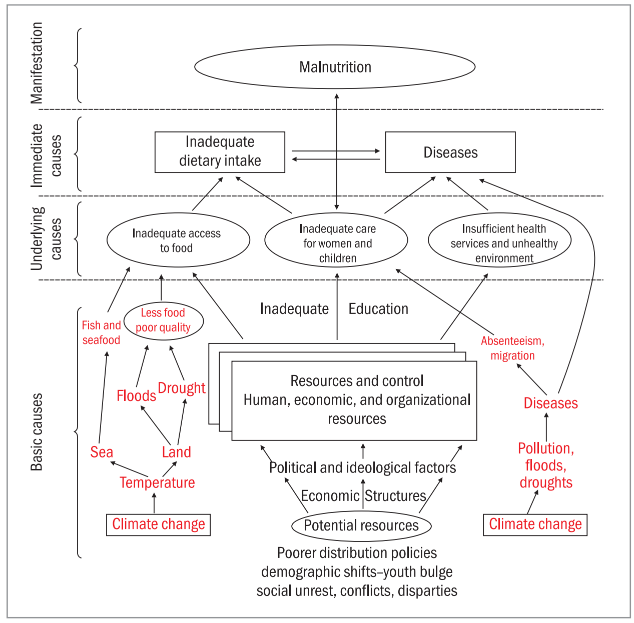
Malnutrition

India is home to major nutritional problems, both in terms of numbers and the proportion of population vulnerable. Climate change has major impacts on the progression of nutritional problems, and the future trends will be dictated by our adaptation to the epidemiologic shifts brought about by climate change.

Climate change affects access to food, health, and environment of the population—the critical determinants for health and nutrition of communities. This will particularly be so for children, women, and families from the worst off and vulnerable segments of the population. In such populations, in addition to decreased access to food, the increased morbidity and absenteeism as a result of environmental factors such as severe weather conditions, together with migration, seriously affect their nutritional status.

Poor families tend to lose their ability to earn enough, and decreased incomes result in coping mechanism with either shifts in dietary patterns or migrating to newer locations with corresponding adaptations. Often such shifts result in these families settling for either unhealthy or costly foods and progressively reduce the food intake resulting in malnutrition.

There will be both direct and indirect effects on food production and availability. Pressures on large-scale and small-scale farming and fishing will have consequences on nutrition. Research and evidence, as well as projections, suggest that with the expanding populations, the food and nutrients availability will be seriously compromised. As an agricultural economy predominantly dependent on nature, there are several real issues that have to be taken on board. India is already facing major challenges in terms of the widening of disparities with distribution and access to social services for children, women, and families who are poor and marginalized.



Conceptual framework of malnutrition (adapted from UNICEF)

Major causes of malnutrition in India include dietary practices, non-availability of fortified salts and fortified foods as well as food insecurity, especially among families that are economically vulnerable and unable to adequately meet basic needs. Disparities widen with rapid economic development, and larger number of families face both direct and indirect effects. India already has the dubious distinction of having the largest number and proportion of children under five who are malnourished. Effects of climate change will further compromise the ability of families who are poor, marginalized, and vulnerable to get adequate food and nutrition.

Investments need to be made on further improving surveillance and research activities, improved weather forecasting to help farmers and fishermen, and special action plans to protect the vulnerable. Strong measures are needed. That is the only way India can claim its place as an economic giant with the development of the full potential of the very rich and diverse human capital.

Vector-borne diseases

Vector-borne diseases have been documented to be affected the most by climate change. All vector-borne diseases are climate sensitive as the extrinsic incubation of pathogen takes place in cold-blooded insect vectors. In India, out of the six major vector-borne diseases, studies have been undertaken on malaria and dengue in the context of climate change. The projections for climate change and malaria are given in the table.

Table: Projected impacts of climate change on malaria

Global	Greater than 220–400 million additional population at risk with A2 scenario by 2020 to 2080.
Africa	Increase in person–months of exposure by 16%–28%, including 5%–7% increase by 2020–80. Latitudinal expansion limited.
Australia	Receptive zone expands southwards by 2050.
Britain	Increase in the risk by 8%–15% with 1–2.5°C average temperature rise by 2050. Indigenous transmission unlikely.
Portugal	Increase in the number of days suitable for survival of malaria vectors.
Zimbabwe	With 1.4°C to 4.5°C temperature increase, highlands become more suitable for transmission.
India	Projected shift to south-western and northern states. Transmission windows widen in northern and western states; shorten in southern states by 2050.Using A1B Scenario, new foci in Himalayan regions and increased intensity in north-eastern states projected by 2030.

The Government of India has recently carried out some studies. The projections for malaria by 2030 have been made using the PRECIS model (A1B scenario) for the Himalayan region, north-eastern states, Western Ghats, and coastal regions. The findings project an increase in new foci and intensity of transmission months in the Himalayan region, covering north-eastern states. A reduction in coastal areas has been projected. Preparedness plan to meet the challenges has also been discussed.

The role of temperature, rainfall, and relative humidity in the biology of *Aedes* mosquito and epidemiology has been well established. Several studies have reported associations between spatial, temporal and spatio-temporal patterns of dengue and climate. The projections of dengue in Delhi and Kolkata showed initial rise in transmission weeks and thereafter reduction as temperature increased.

In view of the complexity of determinants of vector-borne diseases, projections based on climatic parameters should take into account future preparedness also. The projections should not be taken with certainty as malaria transmission dynamics depends on various factors like agricultural practices, ecological changes, deforestation, socio-economic conditions, pre-existing health status, quality and availability of public health care as well as types of intervention measures.

Except malaria and dengue, impact assessments on vector-borne diseases are generally lacking. Therefore, regional studies are required. Situation analysis regarding the reasons for persistence of vector-borne diseases and priority-based preparedness plans need to be developed giving emphasis on capacity building, review mechanism, strengthening health systems, and facilitation of action plans implementation.

Diarrhoeal diseases

Change in climate is not a mere environmental or developmental issue. A greater appreciation of the human health dimensions of climate change is necessary for both the development of effective policy and the mobilization of public engagement. It is known that environmental factors can directly or indirectly affect survival, persistence, and ability to produce disease.

The major diseases that are attributed to poor environmental conditions and sanitation are diarrhoeal diseases like cholera, shigellosis, *Escherichia coli* diarrhoea, poliomyelitis, typhoid fever, water-borne viral hepatitis, protozoan and helminthic diseases. Diarrhoeal diseases alone can cause more than two million deaths annually globally and account for 4.8% of disability-adjusted life years (DALYs) of the total global burden of disease.

Acute diarrhoeal disease is one of the most important health-related impacts linked to short-term and long-term changes in climate. With climatic variations, non-climatic factors also contribute to the global burden of diarrhoeal diseases. Water shortage causes diarrhoea due to perpetuation of unhygienic and poor sanitary conditions, and flooding contaminates drinking water supplies. Thus, although there is strong suspicion that global climate change influences infectious disease transmission dynamics, the extent of the influence is uncertain due to non-availability of data on these non-climatic factors that may also positively or negatively contribute to the occurrence of diarrhoeal diseases.

Previously, it was difficult to quantify climate change and its impact on diseases like cholera, but with the advent and use of sophisticated modern technologies like remote sensing, a new horizon has opened up. Researchers are able to quantify the burden due to climate change as well as forecast impending epidemics of cholera.

Perhaps the best examples of relation between climate change and diarrhoea include the pathogenic *Vibrio spp., which are ubiquitous in estuarine ecosystems. Vibrio cholerae*, which causes cholera, resides in the microflora and microfauna of aquatic environs. It has the ability to spread as worldwide pandemics. Almost every developing country faces a cholera outbreak or the threat of an epidemic. The number of cholera cases reported to the World Health Organization (WHO) during 2006 rose dramatically, reaching the level of that of late 1990s. As many as 18 states are endemic as per WHO definition, with 68 outbreaks in 10 years (1997–2006).

Freshwater sources are a must for the prevention of diarrhoeal diseases. Evidence shows that the more the temperature and the lower the potential of water availability, the higher is the diarrhoea.

The changes in global climate are getting reflected on the whole planet. Due to the lack of robust data, the magnitude of the effects of climate change on human health is difficult to quantify and, as a result, difficult to predict. Consequently, adaptive strategies must be reviewed and adjusted as new information and improved climate models are available. Developing effective strategies require a multi-sectoral approach, involving different government agencies, academia, and general public. The strategies are mentioned in the table.

Table: Strategies for reliable data generation, analysis, and action

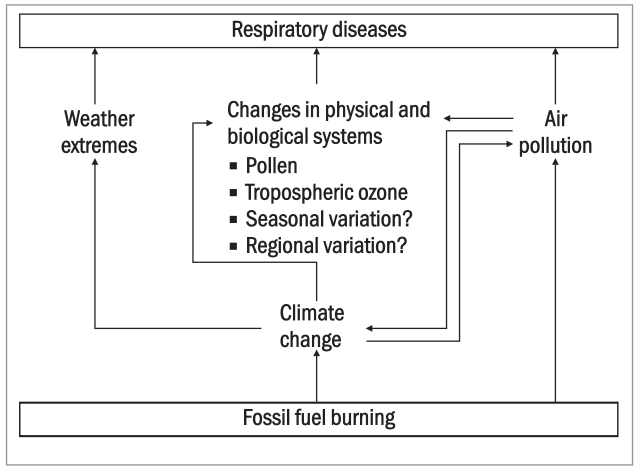
Enhanced surveillance
Appropriate research and development
Advocacy for public and health professional awareness
Integrated and adaptive policy development

Respiratory diseases

Humans affect the environment and vice versa. Burning of fossil fuels leads to the accumulation of greenhouse gases, which have very likely (>90% probability) warmed earth's climate. This "global warming" has likely (>66% probability) changed physical and biological systems. There is emerging evidence and considerable speculation that this man-made or "anthropogenic" climate change affects respiratory health.

Climate change has been associated with increased respiratory morbidity and mortality in essentially three ways: first, "extreme weather events" like heat waves, cold waves, extreme precipitation and forest fires; second, indirect mechanisms mediated via changes in "physical and biological systems"; and third, direct damage through "air pollution".

Changes in physical and biological systems are multifaceted. Allergic rhinitis and bronchial asthma are mediated in part through pollen. Changes in temporal and regional patterns of flowering and allergenicity of pollen particles have been documented in the Americas and Europe. It is postulated that air pollution has led to an increase in ground-level ozone, which contributes to cardiorespiratory mortality. Seasonal variation in viral and bacterial respiratory infections, including tuberculosis, is well recognized in India and abroad. Likewise, regional variation has been observed in bronchial asthma and chronic obstructive pulmonary disease (COPD). How climate change alters regional or seasonal variation in respiratory diseases is open to investigation.



Conceptual framework for climate change and respiratory diseases

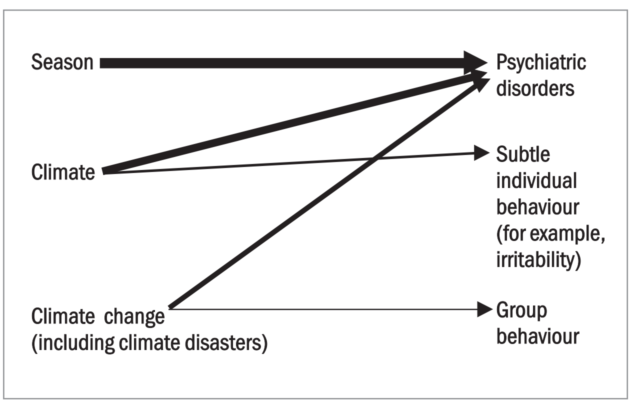
Particulate matter is one of the six "criteria air pollutants" and leads to increased nasal and bronchial airway inflammation. Various oxides of nitrogen and sulphur have been associated with increased allergic rhinitis and poorer asthma control. Associations of indoor air pollution have been documented with COPD, lower respiratory tract infections, and even lung cancer, especially among women in developing countries. In India, the Central Pollution Control Board monitors air pollution in 342 sites countrywide.

India is one of the few countries in the world to be committed to a National Action Plan on Climate Change. The plan recognizes that the health-related database needs expansion and improvement. Overall, the evidence for the multifarious relationship between climate change and respiratory health is suggestive.

Mental health

This chapter seeks to provide the reader with a broad understanding of potential and observed effects of climate change on mental health at the population level. These include the areas of psychiatric disorder, climate disaster related outcomes, urbanization and mental health, environmental refugees and conflict as well as resource constrains. While focusing on mental health in India, examples are also drawn from excellent work conducted in other parts of the world.

There is considerable evidence from the literature including studies from India which relate to season and psychiatric disorders, such as linkages with reverse (summer) seasonal affective disorder and schizophrenia. Also, research linking climate with bipolar disorder and psychosis exists. As an example, climate will affect malaria transmission in India, as mentioned elsewhere. It has also been demonstrated conclusively that individuals affected with cerebral malaria are at risk of cognitive and psychiatric disturbances, thus increasing the mental health burden. However the evidence of a relationship between climate change and mental health is only putative as of this stage. These and related aspects are captured in the figure given below.



Conceptual framework for climate change and mental health

Note Thickness of the arrows reflects the relative level of evidence (approximately)

One postulated outcome of climate change is an increase in the risk of catastrophic weather events. Disasters affect not only the psychosocial well-being but may also lead to a significant increase in psychiatric disorders in the affected population. The majority of affected individuals are best served if community-level interventions are made immediately after an event.

Increases in global and regional urbanization have been postulated as likely outcomes of the effects of climate change on rural landscapes. Urban living has been associated with higher levels of stress. In susceptible individuals, increased levels of stress can increase the risk of psychiatric illness.

Climate change results in the phenomenon of environmental refugees. Thus a competition for natural resources is created with a potential for conflict. Detailed studies are needed to explore the impact of these situations on mental health outcomes.

Climate change is likely to result in resource constrains in the country. As an example, the farmer suicides in the Vidharbha region of Maharashtra, India are a mental health outcome of grave concern resulting from reduced farm productivity due to a variety of reasons including a changing climate.

Lastly, while we lay stress on the possible links between climate change and mental health, it is also essential to bear in mind that the promotion of mental health is essential to play a critical role in the mitigation of climate change. Studying mental disorders in the context of climate change will greatly increase the knowledge of psychiatric illness in the population as a whole. In this way, changes in India's physical climate may represent an opportunity to work towards changing the social climate of stigma and denial that currently surrounds mental illness in India and other parts of the developing world.

Emerging and re-emerging diseases

Mankind's fight with diseases has been a mixed fortune. Some diseases have been eradicated, eliminated or brought under control, while a few others have emerged. Diseases that have newly appeared in a population are termed emerging infectious diseases and diseases whose incidence has increased during the last few decades or threaten to increase in the near future are termed as re-emerging infectious diseases. Various diseases and viruses posing a serious public health challenge have emerged since 1973, including Legionnaire's disease, HIV/AIDS, West Nile Fever, human "mad cow disease", severe acute respiratory syndrome (SARS), Ebola virus, Nipah virus, and the new H1N1 influenza A virus. Geographically, such infections have emerged the world over. And temporally, these diseases are emerging and spreading more freely in the recent decades.

The emergence of a new infectious disease agent in humans is a two-step process: introduction of a potential "new" pathogen into the human host, followed by establishment and further spread of the agent. Greater environmental intervention via deforestation, irrigation, infrastructural projects, urbanization, pollution, and their impact such as climate change is leading to the emergence of new infectious diseases. In 2002, a *Working Group on Land Use Change and Infectious Disease Emergence* ranked top 12 environmental changes with the most "public health impact" on emerging diseases in descending order (see table). The changes are given in the table.

Climate change affects all three components of the epidemiological triad—humans (the host), pathogens (the agent), and their vectors (the environment)—by way of changed climatic conditions, especially temperature, humidity, and availability of water and food.

Table: Environmental changes with most public health impact on emerging diseases

1	Agricultural development
2	Urbanization
3	Deforestation
4	Population movement
5	Introduced species/pathogens
6	Biodiversity loss
7	Habitat fragmentation
8	Water and air pollution, including heightened respiratory susceptibility
9	Road building
10	Impact of HIV/AIDS
11	Climatic changes
12	Hydrologic changes, including dams

It is often difficult to establish the cause–effect relationship between climate change and infectious diseases because it entails interplay of many genetic, biological, demographic, socio-economic, political, and technological determinants, which make it immensely cumbersome to attribute these diseases to clear-cut climate change impact. Nevertheless, there is suggestive evidence of recent climate change influencing tick-borne encephalitis in Sweden, malaria in parts of eastern Africa, cholera in Bangladesh, and West Nile Fever in the USA. The impact of climate change and long-distance trade and travel is very well illustrated by the emergence of West Nile virus.

Improved surveillance, including epidemiological, laboratory, entomological, and weather surveillance, coupled with intensified research on various related aspects, is needed for a better understanding of the relationship between climate change and infectious diseases.

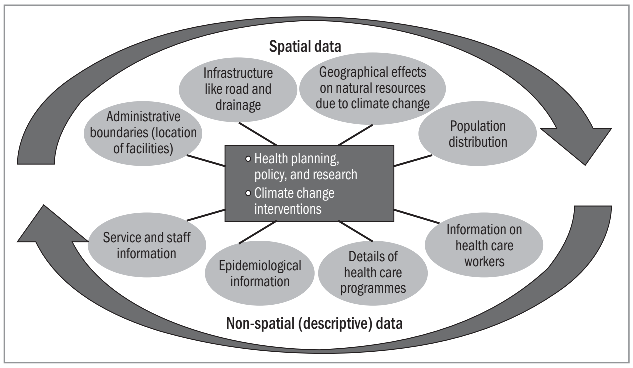
To sum up, climate change, perhaps the greatest human-induced environmental change, will have diverse, mostly negative impact on the patterns of infectious disease occurrence.

Geographic information systems

Rapid environmental changes are threatening global public health security today. Climatic drivers like catastrophic weather events and variations in the normative weather conditions that affect natural resources and trigger new patterns of infectious disease outbreaks are adding stressors to the challenges faced by health administrators around the world. Climate change is a major public health concern, especially for developing countries because of the existing dismal condition of health infrastructure and resources.

John Snow demonstrated long ago that health is a geographic issue, and in light of current environmental changes, the concept of "location matters" assumes even greater value. The answer to the question of "where" can lead to improved resource planning and intervention management. Where are the risk factors located? Where is the population at risk? What are the health outcomes in the region? Are there any associations between risk factors and outcomes in a particular area? What are the types and locations of relevant health interventions required? Geographic information systems (GIS) can help in finding solution to many such questions.

With GIS and similar technologies, it has become possible to integrate different sets of social and climatic drivers together with geographically referenced information and display it on a single map. By analyzing complex relationships between underlying health-related factors, GIS not only enables informed decision-making but also multiplies the effectiveness of health intervention manifolds. GIS can be used for health services mapping at national, state, district, and block levels. These maps can further be overlaid with other vital information like health statistics, climate vulnerability indicators, demographic indicators, epidemiological information, inter alia, to do effective risk mapping. The application of GIS for climate change and disease dynamics is depicted in the figure.



Analysis of spatial and non-spatial data using GIS

It is evident that GIS provides workable and technologically sound solutions to numerous challenges faced by public health planners and policymakers. In particular, climate-sensitive diseases can occur in smaller regions; thus, GIS can be an effective tool to identify such hot spots. However, the road to full-scale GIS implementation in the health sector, especially to tackle the unfavourable effects of climate on health, is still mired with many infrastructural and technological limitations as mentioned above. Therefore, the way forward should be a two-step approach.

Resource development: Centralized data facility should be maintained and made available at nominal cost to professionals and researchers working in this sector. Since an advanced database is the foundation of GIS technology, it will strengthen the development of resource base.

Technology development: A consortium of GIS users in health sector at the national level should be formed to strengthen its uses and applications.

Resources and infrastructure

Climate changes will have a direct impact on all environmental factors such as water, soil, and air, thereby affecting agricultural production through direct and indirect effects on crops, soil, livestock and pests. Climate change, in general, will affect the total amount of precipitation, both in terms of frequency and intensity. This in turn will affect the magnitude of run-off and soil moisture status. Climate change might affect the soil fertility also. It can lead to drought in already arid regions and flood in wet regions. Fertile soil could be eroded due to frequent floods or high-intensity rain in the region. Drought and flood decrease the food production capacity of the land.

Since there is average increase in temperature, its impacts on sea level and snow covers have also been observed. An increase in frequency of droughts and heavy precipitation over most land areas has been seen. Events are, however, concentrated in some selected pockets creating hot spots for droughts and floods. There is an increased frequency of tropical cyclones. All these have got direct and indirect impact on the quality and quantity of water availability, thereby having direct impact on human health.

The demand for groundwater is likely to increase in the future. The main reason for this is increased water use. Another reason may be the need to offset declining water availability due to increasing variability in precipitation in general and reduced summer low flows in snow-dominated basins. Future decreases in groundwater recharge and levels have been projected for various climate scenarios. Problems in groundwater management in India have potentially huge implications for climate change. An assumption suggests that an average drop in groundwater level by 1 m will increase India's total carbon emission by over 1%. The following table gives some indication of India's water crisis.

Table: Per capita availability of water in India

Year	Availability per capita (m^3)
1947	5150
2000	2200
2017	1600

Note: Figures provided were computed under water-stressed conditions
Source: Ministry of Water Resources

Trace gas emissions from biosphere and human activities like burning of biomass govern the concentration of trace species in the atmosphere, affecting the temperature and the weather system. These processes change air circulation and quality appreciably. As indoor air pollution is affecting both human health and ecosystem and also climate, a number of suitable measures can be undertaken.

It is important to remember that mitigation measures aiming at reducing greenhouse gas emissions can help avoid, reduce or delay the impacts of climate change and resulting health problems. All sectors, including buildings, industry, energy production, transport, forestry and waste management can contribute to overall efforts.

Climate change disproportionately impacts the poorest in the society. It also gives rise to health inequities in terms of access to adequate food, clean water and health and results in overall decelerated progress. Thus climate change is closely linked to other environmental issues and the challenge of sustainable development.

Lifestyle

Apart from urbanization and changing lifestyle due to technological advancements, climate change has been cited as a major non-social driver for human health. The health and risk transition has given rise to an increasing contribution of non-communicable diseases (NCDs) to deaths, disabilities, and socio-economic losses in India. These comprise a large number of diseases, and the major ones among them include cardiovascular diseases (coronary artery disease, stroke and hypertension), diabetes mellitus, cancers, chronic obstructive pulmonary disease and asthma. This group of diseases and their risk factors can be effectively prevented and controlled with existing knowledge by integrated and inter-sectoral approaches using cost-effective interventions. The distribution of death and disability-adjusted life years (DALYs) due to NCDs in India is also noteworthy.

Lifestyle, in general, is linked with the economic growth of a region or country. With changing economy, resources and diversity in socio-economic conditions, lifestyle in developing countries is more variable. Due to diversity in scales and complexity in the causal pathways, it will be difficult to assess the impacts of these conditions on lifestyle and hence their cascaded impacts on climate as a whole.

Dietary practices and physical activities (including commuting practices) are well-known modifiable NCD risk factors. Thus it is possible to ensure dual benefits in relation to both climate protection and NCD risk-factor prevention. This is referred to as the concept of co-benefits. As an example, avoiding non-vegetarian food reduces greenhouse gas emissions and the risk of NCDs. This intervention in developing countries like India would be justified for a select population subgroup where meat consumption exceeds the recommended intake.

There is an urgent need to address key risk factors and incorporate health concerns into the decision model and multi-sectoral approaches while planning to mitigate and adapt to climate change. These are enunciated in the table.

NCDs result in significant economic losses to every country. NCD prevention and control is becoming an area of importance for national governments in recent years. It is thus essential that we change our lifestyles to benefit both climate and health.

Table: Potential interventions and co-benefits

Risk factor	Potential intervention	Health co-benefit	Multi-sectoral approach
Diet	Healthy balanced diet with low fat, moderation	Prevention and control of major NCDs (diabetes, CVDs, COPD, cancer)	Health and non-health sectors like education, industry, transport, agriculture, urban and rural development, finance, environment
Physical inactivity	Non-motor transport, cycling		
Outdoor and indoor air pollution	Strict pollution and emission norms, lower emission motor vehicles, improved green energy solutions		

COPD – chronic obstructive pulmonary disease;
CVD – cardiovascular disease;
NCD – non-communicable disease

Vulnerability and adaptation

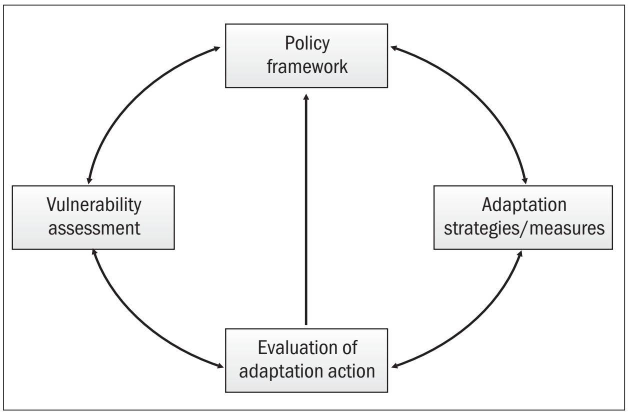
The assessment of potential health impacts of climate change entails the understanding of two related concepts: vulnerability of population to risks or hazards and its capacity to respond to them. Communities and countries differ in the degree of vulnerability to certain health outcomes attributable to climate change. Differential vulnerabilities may partly arise from geographical or environmental factors and partly from inequitable access to resources and uneven pattern of development.

Adaptation includes strategies, policies, and actions undertaken to lessen the impact of climate-sensitive health determinants and outcomes. In terms of the public health concepts of primary, secondary, and tertiary prevention, illustrative measures are as follows:

- Primary prevention includes adaptation responses (like bed nets for preventing malaria) in anticipation of disease or injury induced by climate-sensitive factors.
- Secondary prevention involves interventions (like strengthening rapid response to a disease outbreak) put in place after the effect of climate-related hazards has been felt or observed.
- Tertiary prevention measures (like better treatment of heat strokes) seek to ameliorate the adverse effects of a disease or injury caused by climate-related extreme or adverse events.

Vulnerability and adaptation assessment is an iterative process as illustrated in the figure.

Considering the prevailing socio-economic conditions in India, people living in resource poor settings as well as those with poor access to health-care facilities are at a higher risk of being affected by climate change. In a vast and diverse country like India, it will be imperative to carry out regional studies to arrive at realistic assessments of vulnerabilities and to help evolve strategies suited for given geographical locations.



Vulnerability and adaptation in policy and implementation context

Adaptation measures recommended for India include, among other aspects, the following: awareness; capacity building of individuals, communities, and institutions; disease and vector surveillance; preparedness for disaster management, development of early warning systems as well as strengthening of primary and secondary health-care facilities.

As public health response to climate change evolves in India, public health professionals and researchers should gather and disseminate convincing evidence. Enlightened and committed leadership at political, institutional and community levels should support and guide the development and implementation of comprehensive adaptation strategies to combat public health challenges emanating from climate change. Finally, the goal of sustainable and equitable development in the face of climate change should underpin all efforts at vulnerability assessment and adaptation in the health sector.

Economics of scaling up

Assessing the social and economic impacts of climate change is important to effectively respond to the health concerns of climate change. Globally, these studies are currently limited because of lack of data on the various dimensions of climate change as well as the covariants that directly or indirectly determine the extent of impact. There are also tremendous geographical variations that make the task of data gathering and generalization based on a few studies extremely difficult. Currently, economic studies are also constrained by somewhat mixed evidence on the impact on health.

A study that attempted to quantify the health impact of climate change in different parts of the world indicated that climate change-related consequences of diarrhoea, malnutrition, and malaria are projected to pose the largest risks to future populations.

The study also indicated that in most countries of the South-East Asian region including India, malnutrition is the real cause of concern. Global results of the study are given in the table.

Table: Comparison of estimated cases and costs attributable to climate change for major climate-sensitive diseases in 2030

Total cases	4 513 981	46 352	408 227
Cases due to climate change impacts	131 980	4 673	21 787
Increase in cases (%)	3	10	5
Total investment	$67 billion	$2 billion	$50 billion

Note: Assuming 750 ppm of CO_2 scenario

Source: Ebi K L. 2008. Adaptation costs for climate change-related cases of diarrhoeal disease, malnutrition and malaria in 2030. *Globalization and Health* 4(9): 1–9

In these circumstances, the estimated 2.6% of gross domestic product (GDP) allocated for adaptation to climate variability mentioned in the prime minister's National Action Plan on Climate Change seems insufficient, considering this percentage includes mitigating health expenditures as well. The current strategies of prevention and control are inadequate to meet the full need. Any additional burden due to climate change will challenge both financial and non-financial operations for these diseases.

Moreover, since climate change impacts the most vulnerable, any development programme for alleviating poverty and hunger will also go a long way to cushion the health impacts of climate change. Additionally, strengthening of health systems is an important concern. Currently, many of the interventions do not reach their potential target due to inefficiencies and bottlenecks in the health system of the country. Mere scaling up without addressing the existing inefficiencies of the health system will be more expensive.

The number of studies related to the health impacts of climate change in India is negligible. Clearly, the uncertainty around data, methodology, and confounding factors makes it extremely difficult to assess the additional cases of these diseases that can be attributed to climate change alone. This is the reason for the paucity of economic impact studies. Unfortunately, while India is gearing up to gather more evidence on climate change, it is yet to seriously work on understanding what works, why, and for how much, for basic health sector interventions. While one awaits results of the study on the health impact of climate change, there is an urgent need to start gathering more evidence on how to combat diseases like malaria and diarrhoea and hunger in a fast and cost-effective manner.

Health communication

The challenge of effectively communicating the health impacts of climate change is unique. The focus of the message is on long-term benefits that lie in an unseen future. However, the recipients of the message—ordinary people and a variety of stakeholders—are required to make near-term lifestyle changes and sacrifices, sometimes at an economic cost.

It is critical to design appropriate communication strategies to convey and address the health impacts of climate change. This could range from heatstrokes to malaria to the mental health of farmers whose cropping patterns and expectations are damaged by erratic weather patterns.

At the outset it is important to get the message right. This means ensuring that it conforms to four key parameters: single (focusing on one theme or issue); simple (avoiding jargon and being intelligible to the widest possible audience); clear (a sharp and trenchant message); and interesting/relevant (making the message relevant to people's lives and weaving this quality into the content of the message).

The vital aspects of communication are mentioned in the box.

Box: The seven C's of communication
1. Command attention
2. Clarify message
3. Communicate a benefit
4. Consistency
5. Cater to the "heart" and "head"
6. Create trust
7. Call to action

A multiplicity of media can be used to transmit the message. These include radio, television, newspapers, social media, the Internet, community media (street theatre), posters, and social and religious leaders to champion the message.

It is also vital for government officials and development/public agencies to understand how the media can be used as a force multiplier and to synergize their relationship with different elements of the media and communication industry. Responding to the media at a time of crisis or calamity cannot be left to chance and must be the product of long-term planning. Designing correct messages, training chosen technical specialists for communication duties, and drawing up hypothetical scenarios to test an organization's communication-response preparedness are important. In the end, public health communication, like all communication, must convey a compelling attribute: trust and credibility.

To be effective in convincing multiple stakeholders of the seriousness of the health threats due to climate change, it is imperative to plan ahead according to the following four-fold path:

1. Have a communication strategy in place.
2. Train technical specialists as communicators. Professional communicators should also be a part of decision-making.
3. Use hypothetical scenarios. All messages should undergo a dry run.
4. Formulate standard answers and talking points for frequently asked questions so that all experts speak with "one voice".

Conclusion

The risks of accelerated climate change are global and substantial. The linkages between such changes and specific health outcomes are important to study and address from a public health perspective. This poses unique methodological challenges to epidemiologists and requires innovative approaches. Individual-level exposure assessment and health outcome measurement are not feasible for studying the impacts of climate change and disease dynamics. Thus, it is imperative to have appropriate models to understand the linkages.

A national-level assessment of increased burden of disease due to climate change is critical from the point of view of decision-makers and programme managers. As health is vulnerable not only to climate risk factors but also to non-climatic risk factors, it is essential to estimate the impacts due to these factors too, in order to arrive at accurate results.

It is also essential to develop integrated surveillance systems for collecting and collating necessary information critical to model climate–health linkages. Future burden of disease projections could further suggest the feasible developmental trajectories to "climate-proof" our societies and safeguard our health. These trajectories would depend on improved environmental sanitation, hygienic practices, and medical treatment facilities among other aspects.

The risk of more complex, frequent, and intense weather events, also referred to as climate extremes, and the resulting impacts is projected to become a major contributing factor to morbidity, mortality, and poverty.

Climate change can further weaken the Millennium Development Goals (MDGs). In particular, the MDG related to child health is at risk since many of the climate-sensitive diseases are known to disproportionately affect children. Vector-borne diseases, diarrhoeal diseases, and malnutrition represent the greatest challenges in relation to climate change, with malnutrition being the most critical, considering the gravity of the situation existing today.

The dearth of studies related to climate change and disease dynamics in India is a real concern, with vector-borne diseases being the only area in which a considerable body of evidence exists. The relationship of climate change with diseases like asthma and depression in the Indian context, if and when established, could have substantial public health implications since these outcomes account for a significant burden of disease. Emerging and re-emerging diseases are also relevant, especially because of the potentially global ramifications in an inter-connected world.

Various state-of-the-art tools like geographic information system (GIS) mapping can be used to identify hot spots for decision-makers and programme managers. Appropriately managed resources and infrastructure could further help tackle the health risks of climate change as well as reduce greenhouse gas emissions. Similarly, a suitable lifestyle including appropriate dietary habits could not only further reduce the risks of non-communicable diseases but also contribute to protecting the climate. Developing a climate vulnerability index for the health sector in India would identify and prioritize the programmes for vulnerable regions. Despite the challenges in estimating the cost of adaptation, funding will remain at the core of health impacts of climate change. Lastly, the communication system is vital for effectively spreading awareness and educating stakeholders.

CLIMATE CHANGE

and Disease Dynamics in India

Editors

Nitish Dogra • Sangeet Srivastava

Climate change will have a major influence on the dynamics of human diseases in the years to come. Today, the topic is of global concern and in-depth research. Ironically, little is known about this subject in the Indian context. This book brings together specialists from the field of climate, public health, medicine, environment, and social science. The contributors, in a refreshing interdisciplinary spirit, have synthesized the evidence to date, analysed policy, and suggested a way forward. This edited compilation is expected to provide a beacon for the looming climate epidemic, especially as it will play out in developing countries.

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The Energy and Resources Institute