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Climate change and health vulnerability in south Asia

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ABSTRACT: *The objective of the paper is to analyse the direct and indirect effects of climate change on human health through a complex set of interdependent interactions in South Asian Countries like India, Sri Lanka, Pakistan, Bangladesh, Nepal and Bhutan and to provide techniques of management and adaption of health related effects. The paper high lights changes in the pattern and distribution of disease spreading insects, virus, bacteria and increasing rate of deaths during last one decade due to greater frequency and severity of heat waves and other extreme weather events with the help of secondary data and information. Warmer and wetter conditions will lead to more vector-borne diseases like malaria, dengue and schistosmias is fever and deaths. The rise in temperature and increasing frequency of heat waves will increase the incidences of illness and death in all South Asian Countries. In India and Sri Lanka, the seasonal pattern of malarial transmission will change and area bordering the non-endemic wet zone are likely to become more vulnerable to malaria. The sub tropical and warm temperate regions of Nepal will be more vulnerable to kalaazar and malaria. In Pakistan, long warm spells are likely to become more frequent due to increase in carbon dioxide. The mountain regions of South Asia will be more affected by temperature rise and climate sensitive problems. The paper also provides health determinants and health outcomes with adaptive strategy.*

Keywords: *Bacterial Disease, Climate Change, Health, Malaria, Vulnerability*

I. INTRODUCTION

Global climate change has become one of the most visible environmental concerns of the 21st century. It is likely to threaten all life forms on earth with the extent of vulnerability varying across regions and populations within regions. Global climate change is expected to be accompanied by an increase in the frequency and intensity of heat waves as well as warmer summers and milder winters(Kolvata et al,1999)[1]. The impact of extreme summer heat on human health may be exacerbated temperatures, as well as the number and intensity of heat waves(IPCC,2007)[2]. The impact and incidence, however are likely to fall disproportionately upon developing countries, in particular, the poor living within them. Changes in temperature and precipitation patterns and numerous other factors will impact both natural and human systems. Climate sensitive sectors like agriculture, forestry, water resources and coastal regions, and, human systems including human health, human settlements, industry and energy sectors will be drastically affected (IPCC 2001)[3]. Global climate change would affect human health via pathways of varying complexity, scale and directness and with different timing. Similarly, impacts would vary geographically as a function both of environment and topography and of the vulnerability of the local population. Impacts would be both positive and negative (although expert scientific reviews anticipate predominantly negative). This is no surprise since climatic change would disrupt or otherwise alter a large range of natural ecological and physical systems that are an integral part of Earth’s life support system. The more direct impacts on health include those due to changes in exposure to weather extremes (heat waves, winter cold); increases in other extreme weather events (floods, cyclones, storm-surges, droughts); and increased production of certain air pollutants and aeroallergens (spores and moulds). Decreases in winter mortality due to milder winters may compensate for increases in summer mortality due to the increased frequency of heat waves. The consequences of climate change on human health can be categorized as follows: (i)Asthma, Respiratory Allergies, and Airway Diseases (ii)Cancer (iii)Cardiovascular Disease and Stroke (iv)Food borne Diseases and Nutrition (v)Heat-Related Morbidity and Mortality (vi)Human Developmental Effects (vii)Mental Health and Stress-Related Disorders (vii)Neurological Diseases and Disorders (ix)Vector borne and Zoonotic Diseases (x)Waterborne Diseases

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[2] IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth
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II. LITERATURE REVIEW

There is plethora of literature on impact of climate change but many of them are theoretical work. Checkley and co-workers(2000)[4] used time series analyses to correlate temperature, humidity and rainfall to daily hospital admissions in a paediatric diarrhoeal disease clinic in Lima, Peru. Correlations were controlled for seasonal variations and long-term trend. The analysis indicated an 8% (95% CI 7–9%) increase in admissions per 1°C increase in temperature across the whole year. There was no significant independent association with rainfall or humidity. While the study design gives high confidence in the results, its scope is limited to the more severe (i.e. hospitalizing) diarrhoeal diseases and to children.

Singh et al(2001)[5] used time series analyses to correlate temperature and rain fall to monthly reported diarrhoea incidence in Fiji. Reported overall incidence increased by 3% (95% CI 1.2–5.0%) per 1°C temperature increase, and a significant increase in diarrhoea rates if rainfall was either higher or lower than average conditions. The use of monthly averages of climate conditions, and the lack of a clear definition of diarrhea are likely to introduce a random effect and hence an underestimation of effects. Fussel, (2005) stated that there are two primary strategies in the face of a changing climate, mitigation and adaptation. This review focuses on climate change related adaptation and vulnerability. Typically before adaptation strategies can be developed and implemented the vulnerability of the system in question must be assessed. Initially the concept of vulnerability was based in two distinct areas of study The first of which was the human geography approach, used to describe the vulnerability of a system to adverse effects of a hazard (Fussel, 2005)[6]. The second approach was based in human ecology, seeking to understand who was vulnerable and why (Adger, 2006)[7]. As climate change research developed it integrated both understandings of vulnerability into its approach (Fussel, 2005). The range of vulnerabilities can vary dramatically from human health vulnerabilities to built infrastructure vulnerabilities. Vulnerability is explained in IPCC report(IPCC, 2007a, p.883) as the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. For a health perspective on methods for assessing climate change vulnerability, Health Canada has used a seven step guide (Berry, McBean, & Seguin, 2008)[8]. 1) Determine the scope of the assessment; 2) describe current distribution of climate-sensitive disorders; 3) identify current strategies/policies to decrease the number of climate-sensitive disorders; 4) review potential health impacts of climate change; 5) use future climate change scenarios to estimate future health impacts; 6) create an assessment report; 7) identify gaps and adaptation strategies to address them to further reduce health impacts, then evaluate the adaptation strategies (Berry et al., 2008).

Climate change is expected to impact the health of vulnerable populations such as seniors, children, those with underlying health conditions, or low socio-economic status, or Aboriginal peoples (Berry et al., 2008). These populations are vulnerable as they may have lower levels of mobility, less choice of where to live, inadequate infrastructure, or the need for steady medical care (Berry et al., 2008). In terms of health impacts from climate change things like increased air pollution or extreme heat can have an effect on individuals with respiratory difficulties (Lamy & Bouchet, 2008)[9]. A potential increase in heat and precipitation especially, might cause an increase in cases of water, vector and rodent borne diseases (Charron et al., 2008)[10]. The potential effects on human health are quite similar to the increase in extreme heat could exacerbate air pollution causing

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more respiratory disorders. Reiter P(2001)[11] stated that there are few instances in which effects of long-term climate change on human health have been observed directly. Where there have been substantial changes in rates of mosquito-borne disease in recent times, there is little evidence that climate has played a major part. This means that assessments of the impact of future climate change rely on expert judgment, informed by analogue studies, deduction from basic principles and modeling of health outcomes related to climate inputs. MacDonald(1957)[12]Vector-borne disease transmission is sensitive to temperature fluctuation also. Increases in temperature reduce the time taken for vector populations to breed. Increases in temperature also decrease the incubation period of the pathogen(e.g. malaria parasite, dengue or yellow fever virus) meaning that vectors become infectious more quickly. In a study, Jaenisch, T. & Patz, J(2002)[13] mentioned that relationships between year-to-year variations in climate and communicable diseases are most evident where these climate variations are marked, and in vulnerable populations in poor countries. Major scientific reviews agree that El Niño can provide a partial analogue for the effects of global climate change on communicable diseases. The Human Development Report(2007-08)[14] states that the greatest health impacts will be felt in developing countries because of high levels of poverty and the limited capacity of public health systems to respond. Major killer diseases could expand their coverage. For example, an additional 220–400 million people could be exposed to malaria—a disease that already claims around 1 million lives annually. Dengue fever is already in evidence at higher levels of elevation than has previously been the case, especially in Latin America and parts of East Asia. Climate change could further expand the reach of the disease.

III. METHODOLOGY

The paper has used secondary information to analyse direct and indirect effects of climate change in South Asia. Some of the concepts and general methods for studing impact of climate change on human health are briefly outlined in this section. The burden of disease refers to the total amount of premature death and morbidity within the population. In order to make comparative measures it is necessary to use summary measures of population health. Estimation of attributable burdens, using a measure such as DALYs, thus enables comparative Risk Assessment: i.e. comparison of the disease burdens attributable to diverse risk factors. For each such factor, it is necessary to know the (i)burden of specific diseases(ii) increase in risk of each disease per unit increase in exposure (the“relative risk”) (iii) current population distribution of exposure, or future distribution as estimated by modelling exposure scenarios.

Since the mid 1990s, WHO[15] has published estimates of the global burden of specific diseases or groups of diseases in the annual World Health Report. The most recent updates of the measurements of these burdens constitute the total disease burden that can be attributed to the various risk factors. For calculating the attributable fraction for diarrhoeal disease, for example, the exposure distribution in the population is combined with the relative risk for each scenario with the following formula.

$$IF = \frac{\sum PiRRi-1}{\sum PiRRi}$$

Where IF= Impact Fraction

Pi = The proportion of the population in each exposure scenario

RRi = Relative Risk

Key input data for estimating the burden of disease caused by climate change are as follows.

(i) Risk factor levels or scenarios

• Current distributions

• Alternative and future distributions

(ii) Disease burden per disease in different years (Say 2010, 2020 and 2030)

(iii) Attributable burden in base year(say 2000)

(iv) Avoidable burden in different years(say 2010, 2020 and 2030)

Each exposure scenario is characterized by a relative risk (RRi) compared to the individuals that are not exposed to the risk factor, or that correspond to a base line “theoretical minimum” exposure scenario. The proportion of the population in each exposure scenario is Pi. The attributable burden is estimated by multiplying

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[14]HDI(2007-08),Fighting climate change: human solidarity in a divided world, PDF file

[15] World Health Organization Climate(2003), Change and Human Health, Risks and Responses, , Geneva,

the impact fraction by the disease burden for each considered disease outcome. In addition to the attributable burden, the avoidable burden at future time points can be estimated by defining an alternative distribution of the risk factor in the study population and comparing projected relative risks under the alternative scenarios. In this case, the relative risks that are calculated for each scenario are applied to future "climate-change independent" trends which attempt to take account of the most probable future changes due to climate-independent factors—e.g. improving socioeconomic and control conditions. Indicators of vulnerability to heat and cold can investigated using following variables.(i)age and disease profile (ii)socioeconomic status(iii)housing conditions(iv)prevalence of air conditioning (v)behaviour (e.g. clothing).These factors also have counterparts in individuals as risk factors for heat related mortality or morbidity, such as presence of air conditioning at time of death. Both individual and population level studies provide strong and consistent evidence that age is a risk factor for heat related mortality.

IV. CLIMATE CHANGE AND HEALTH RELATED IMPACTS

WHO and (IPCC) data identify risks to human health as a serious signal of the consequences of climatic disruption of this planet's natural processes which we depend on for food, water, and physical safety. Health hazards from climate change are diverse, global and difficult to reverse over human time scales. They range from increased risks of extreme weather events, to effects on infectious disease dynamics and sea level rise leading to salinization of land and water sources. Based on WHO estimates around 150,000 deaths now occur in low-income countries each year due to climate change from four climate-sensitive health outcomes(i) crop failure and malnutrition(ii) diarrhoeal disease(iii) malaria and (iv)flooding.

Direct Impacts

The weather has a direct impact on our health. If the overall climate becomes warmer, there will be an increase in health problems. It is anticipated that there will be an increase in the number of deaths due to greater frequency and severity of heat waves and other extreme weather events. The elderly, the very young and those suffering from respiratory and cardiovascular disorders will probably be affected by such weather extremes as they have lesser coping capacity. An extreme rise in the temperature will affect people living in the urban areas more than those in the rural areas. This is due to the 'heat islands' that develop here owing to the presence of concrete constructions, paved and tarred roads. Higher temperatures in the cities would lead to an increase in the ground-level concentration of ozone thereby increasing air pollution problems.

Indirect Impacts

Indirectly, changes in weather pattern, can lead to ecological disturbances, changes in food production levels, increase in the distribution of malaria, and other vector-borne diseases. Fluctuation in the climate especially in the temperature, precipitation, and humidity can influence biological organisms and the processes linked to the spread of infectious diseases. These health related impacts are given in table-1.

Table-1 Health related impacts of climate change

Sl No	Impact	Outcome	Incidence
1	heat and cold	Cardiovascular disease Deaths	Rising
2	Food and water-borne disease	Diarrhea episodes	Rising(High)
3	Vector-borne disease	Malaria cases, dengue cases	Rising(High)
4	Natural disasters	injuries	Rising(Medium)
5	Risk of Malnutrition	Weak health, Low Productivity	Rising(Medium)

Source- Climate Change and Human Health, Risks and Responses, World Health Organization, Geneva, 2003,Table- 7.2, PP-140

Rise in temperature and cold due to climate change will cause cardiovascular disease deaths. The incidence of Food and water borne diseases are likely to increase substantially leading to more diarrhea and stomach related problems. Similarly vector borne diseases will spread through mosquitoes as they increase in warmer climate.

V. CLIMATE CHANGE AND VECTOR BORNE DISEASES

Climate change has direct impact on vector borne infections in different countries, particularly in South Asian countries. For vector-borne infections, the distribution and abundance of vector organisms and intermediate hosts are affected by various physical (temperature, precipitation, humidity, surface water and wind) and biotic factors (vegetation, host species, predators, competitors, parasites and human interventions). Various integrated

Table-2 Main vector-borne diseases, populations at risk and burden of diseases

Sl. No	**Disease**	**Vector**	**Population**	**% of World Population**	**Most Affected region**
1	Malaria	Mosquito	2400 million	40 %	Tropical/Sub Tropical(South Asia)
2	Schistosomiasis	Water snail	500–600 million	8 %-10 %	Tropical/Sub Tropical(South Asia)
3	Lymphatic filariasis	Mosquito	1000 million	16 %	Tropical (South Asia)
4	Dengue	Mosquito	3000 million	50%	Asia
5	Onchocerciasis	Black fly	120 million	1.8%	(South Asia)
6	Japanese encephalitis	Mosquito	300 million	5%	Asia

Source- Martens, W.J.M. et al.(1995),Climate change and vector-borne diseases: a global modeling perspective. Global Environmental Change 5: 195–209

Studies have predicted that an increase in ambient temperature would cause, worldwide, net increases in the geographical distribution of particular vector organisms (e.g. malarial mosquitoes). Further, temperature related changes in the life-cycle dynamics of both the vector species and the pathogenic organisms (flukes, protozoa, bacteria and viruses) would increase the potential transmission of many vector-borne diseases such as malaria (mosquito), dengue fever (mosquito) and leishmaniasis (sand-fly).

It is clear from table-2 that 40 % people in the world are at risk due to malaria and burden of malaria will increase due to climate change & rise in temperature. It will mainly affect tropical/ sub tropical region, particularly South Asian countries like India, Pakistan, Sri Lanka, Bangladesh and Nepal. Similarly 50 % people are vulnerable to deadly dengue fever which will increase due to rise in temperature. It will affect mostly South Asian countries. Filariasis will also increase in warmer climate & health in South Asia region will be worst affected. Recently, there has been considerable effort in developing mathematical models for making such projections. The models in current use have well recognised limitations—but have provided an important start. For example, from computer multiple modeling studies it seems likely that malaria will significantly extend its geographical range of potential transmission and its seasonality during the twenty first century as average temperatures rise.

It is likely that climatic change over the past quarter-century has had various incremental impacts on at least some health outcomes. However, the time at which any such health impacts of climate change become detectable particularly depends upon (i) the sensitivity of response (how steep is the rate of increase) and (ii) whether there is a threshold that results in a "step function". Further, detectability is influenced by the availability of high-quality data and the extent of background variability in the health-related variable under investigation. The first detectable changes in human health may well be alterations in the geographical range (latitude and altitude) and seasonality of certain vector-born infectious diseases. Summer time food-borne infections (e.g. salmonellosis) may show longer-lasting annual peaks. There are several other categories of likely early impact. Hot weather would amplify the production of noxious photochemical smog in urban areas and warmer summers would categories of likely early impact. Hot weather would amplify the production of noxious photochemical smog in urban areas and warmer summers would increase the incidence of food poisoning. By contrast, the public health consequences of the disturbance of natural and managed food-producing ecosystems, rising sea levels and population displacement for reasons of physical hazard, land loss, economic disruption and civil strife, may not become evident for several decades.

EFFECTS OF SOLAR ULTRAVIOLET RADIATION ON HEALTH

Climate change results more ultraviolet radiation which has adverse effect on skin, eye, immunity and general behavior of people. These effects are summarized in table-3.

Table-3 Effects of solar ultraviolet radiation due to Climate Change on human health.

Sl No	Effects on skin	Effects on the eye	Effect on immunity and infection	Other Effects
1	Malignant melanoma	Acute photokeratitis and photo conjunctivitis	Suppression of cell mediated immunity	sleep/wake cycles
2	Non-melanocytic skin cancer	Climatic droplet keratopathy	Increased susceptibility to infection	seasonal affective disorder
3	Sunburn	Pterygium	Impairment of prophylactic immunization	mood
4	Chronic sun damage	Cancer of the cornea and conjunctiva	Activation of latent virus infection	------
5	Photodermatoses.	Acute solar retinopathy	--------	--------
6	------	A Macular degeneration.	--------	--------

Source- United Nations Environment Program (UNEP) Environmental effects of ozone depletion: 1998 assessment. Nairobi, Kenya,

In summer sunburn and chronic sun damage will increase in tropical region which will adversely affect the shin of people. Cancer on the cornea of eye and other eye diseases are likely to increase due to heat wave and solar radiation. The immunity power of people will reduce leading to frequent infection and diseases among people. Solar ultra violate ray has many adverse effects on human health.

IMPACT OF CLIMATE CHANGE ON HUMAN HEALTH IN SOUTH ASIA

In Asia, the main health concerns under climate change and variability are malaria and cholera, but thermal stress and air-pollution related illnesses are also important. Malaria still is one of the most important vector-borne diseases in India, Bangladesh, Sri Lanka, Thailand, Malaysia, Cambodia, the Lao People's Democratic Republic, Viet Nam, Indonesia, Papua New Guinea and parts of China. Vector resistance to insecticides, and parasites' to chloroquine, compound the problem of malaria control. The IPCC concluded that changes in environmental temperature and precipitation could expand the geographical range of malaria in the temperate and arid parts of Asia.

Water-borne diseases such as cholera, and various diarrhoeal diseases such as giardiasis, salmonellosis and cryptosporidiosis, occur commonly with contamination of drinking water in many south Asian countries. These diseases could become more frequent in many parts of south Asia in a warmer climate. The direct effects of heat are important public health issues in this region. Changes in climate may alter the distribution of important vector species (for example, mosquitoes) and may increase the spread of disease to new areas that lack a strong public health infrastructure. The specific impact of climate change in important South Asian countries are analysed below.

India

India is a vast country with more than 121 crore population with lot of diversities which will be affected more by climate change. The mosquito borne disease, malaria is endemic in all parts of India, except at elevations above 1,800 meters and in some coastal areas. The spatial distribution, intensity of transmission, and seasonality of malaria is influenced by climate in sub-Saharan Africa; socio-economic development has had only limited impact on curtailing the disease distribution. The principal malaria prone areas are tribal dominated area of Orissa, Madhya Pradesh, Chhattisgarh, and the north-eastern parts of the country. According to the World Bank, about 577,000 Disability- Adjusted Life Years (DALYs) were lost due to malaria. Presently, the transmission window (based on minimum required conditions for ensuing malaria transmission) is open for 12 months in eight states (Andhra Pradesh, Chhattisgarh, Karnataka, Kerala, Maharashtra, Orissa, Tamil Nadu and West Bengal), nine to 11 months in the north-eastern states (Gujarat, Haryana, Madhya Pradesh, Punjab, Rajasthan, Uttar Pradesh and Uttaranchal). The northern states of Himachal Pradesh and Jammu and Kashmir have transmission windows open for five to seven months, respectively. If there will be a 3.8°C increase in temperature and a seven per cent increase in relative humidity by the 2050s , nine states of India may have transmission windows open for all 12 months. The transmission windows in the states of Jammu and Kashmir and Rajasthan may increase by three to five months as compared to the base year. States like Orissa and some southern states, where the mean temperature is more than 32°C in four to five months, a further increase in temperature is likely to cut the transmission window by two to three months (GoI 2004). Other health related impacts are more injuries, skin burning, cancer, Diarrhea etc.

Nepal

Nepal is a country with hills and mountains where transport system, sanitation and other infrastructure is very weak. There is greater risk of Malaria, kalaazar and Japanese encephalitis which is highlighted in the Nepalese National Communication (DHM 2004). The subtropical and warm temperate regions are predicted to be particularly vulnerable to malaria and kalaazar. There will be higher risk of water-borne diseases due to poor sanitation and higher rainfall. Increased flooding could damage municipal treatment facilities or land-fills, increasing the risk of contamination.

Sri Lanka

Sri Lanka has relatively warmer climate among all south Asian Countries. Expansion and shift in malarial transmission zones is expected due to climate change. Moreover, the seasonal pattern of malaria transmission is likely to undergo a change, from the high transmission season which now occurs from November to February being curtailed, and the minor mid-year peak being enhanced with high rates of transmission occurring in September. Areas bordering the non-endemic wet zone of the country are likely to become highly vulnerable to malaria (MENR 2000).

Pakistan

A recent study for Pakistan also points out that long warm spells are likely to become more frequent under a doubled CO_2 climate change scenario (Islam and Rehman 2006). The mountainous regions of South Asia are particularly vulnerable to temperature rise and associated climate changes. High altitude populations that fall outside areas of stable endemic malaria transmission may be particularly vulnerable to increases in malaria, due to climate warming.

Maldives

Although malaria has been eradicated from the Maldives, climate change is likely to induce a threat of malaria outbreaks. Poor sanitation in the islands of Maldives along with conducive environment for the spread of diseases might lead to the outbreak of water related and waterborne diseases such as diarrhoea (Ministry of Environment and Construction 2005).

The existing health outcomes in south Asian countries are shown in Table-4.

Table-4 Health determinants and health outcomes currently exist in South Asian Countries

Sl No	Events of Climate Change	Bangladesh	Bhutan	Nepal	India	Sri Lanka
1	Heat waves	Y(T)	N	Y(T)	Y(T)	Y (T)
2	Glacial lake floods	N	Y	Y	Y(T)	N
3	Flash floods	N	Y	Y	Y	N
4	Riverine floods	Y (NM)	No	Y(NM)	Y(NM)	Y (NM)
5	Malaria	Y (NM)	Y (NM)	Y(T)	Y(NM)	Y (NM)
6	Japanese encephalitis	Y (NM)	No	Y(NM)	Y(NM)	Y (NM)
7	Kalaazar	No	No	Y(NM)	Y(NM)	Y NM)
8	Dengue	Y (NM)	Y(NM)	NO	Y(NM)	Y (NM)
9	Water-borne diseases	Y (NM)	Y(T)	Y(T)	Y(T)	Y (T)
10	Water scarcity, quality	Y (NM)	Y (NM)	Y(M)	Y(M)	Y (M)
11	Drought-related food insecurity	Y (NM)	No	No	Y(M)	Y (NM)

Source: WHO (2005)

Y=Present, N= Absent, M=Mountainous Region NM= Non Mountainous region, T=Every where

India and Sri Lanka will be more affected by vector borne diseases due to climate change where as kalaazar has no effect in Bangladesh. Drought & heat Waves have no effect in Bhutan & drought has no effect in Nepal.

ADAPTING STRATEGY

Since mitigation of adverse impact of climate on human health is not possible, it is necessary to strengthen adaptive capacity of people. Adaptation refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Adoption depends on adaptive Capacity that refers to the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. In fact, the IPCC identified rebuilding public health infrastructure as “the most important, cost-effective and urgently needed” adaptation strategy . Other measures include public health training programmes, more effective surveillance and emergency response systems and sustainable prevention and control programmes. These measures are familiar to the public health community and needed regardless of whether or not climate changes. They constitute the basis of a “no-regrets” adaptation strategy. Adaptive actions to reduce health impacts can be considered in terms of the conventional public health categories of primary, secondary, and tertiary prevention.

(i) Primary prevention refers to an intervention implemented before there is evidence of disease or injury: avoiding hazardous exposure, removing causative risk factors or protecting individuals so that exposure to the hazard is of no consequence. For example, bed nets can be supplied to populations at risk of exposure to malaria and early warning systems (e.g. extreme heat health warnings, famine early warning) established to provide information on hazards and recommended actions to avoid or reduce risks. Primary prevention largely corresponds to anticipatory adaptation.

(ii) Secondary prevention involves intervention implemented after disease has begun, but before it is symptomatic (e.g. early detection or screening), and sub sequent treatment that averts full progression to disease. Examples include enhancing monitoring and surveillance; improving disaster response and recovery; and strengthening the public health system’s ability to respond quickly to disease outbreaks. Secondary prevention is analogous to reactive adaptation.

(iii) Finally, tertiary prevention attempts to minimize the adverse effects of an already present disease or injury (e.g. better treatment of heat stroke, improved diagnosis of vector-borne diseases). As the adverse health outcome is not prevented, tertiary prevention is inherently reactive.

Climate-related adaptation strategies should not be considered in isolation of broader public health concerns such as population growth and demographic change; poverty; public health infrastructure; sanitation, availability of health care; nutrition; dangerous personal behaviours; misuse of antibiotics; pesticide resistance; and environmental degradation. All of these factors will influence the vulnerability of population and the health impacts they experience, as well as possible adaptation strategies. Sanitation and water treatment, may have a profound influence on health consequences associated with climate change.

VI. CONCLUSION

The impacts of climate change on food security, access to water, human health, ecosystems, urban areas, and frequency of disasters will have severe implications for the achievement of sustainable development. Present coping capacity is very limited particularly for small farmers, rural communities eking out precarious livelihoods dependent on natural resources, urban poor living in marginalised conditions, women and children. There are several good practices and policies, but these need to be scaled up. While government programmes in these sectors address issues relevant for strengthening adaptive capacity to climate change, they do not as yet explicitly incorporate the increased risks due to climate change. Adapting to the changing conditions of climate would form an integral part of sustainable development. Inclusion of climatic risks in the design and implementation of development initiatives is vital to reduce vulnerability and enhance sustainability. Large areas of uncertainty remain. What is certain is that dangerous climate change has the potential to deliver powerful systemic shocks to human development across a large group of countries. Avoiding the unprecedented threats posed by dangerous climate change will require an unparalleled collective exercise in international cooperation.

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