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International Journal Water Sciences and Environment Technologies
Vol. (vi), Issue. 4, December 2021, pp. 36-49
ISSN Online: 1737-9350; ISSN Print: 1737-6688, Open Access
www.jiste.org
Scientific Press International Limited
Received: 12 January 2022 / Revised: 25 January 2022 / Accepted: March 2022 / Published: March 2022

The health effects of global warming: developing countries are the most vulnerable

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Abstract

Detection and measurement of health effects of climate change are necessary to provide evidence on which to base national and international policies relating to control and mitigation measures.
Unequivocal evidence of health effects, and accurate measurements of their size, can come only from hard data. However, climate varies naturally as well as through human influences and in turn is only one of many determinants of health. There must be careful consideration of how best to collect and analyse information that will provide secure evidence of climate change impacts.
In this paper, we consider how monitoring may help provide evidence of early health impacts, examining the principles on which monitoring should be based, potential sources of monitoring data, and discussing issues in the analysis and interpretation of such data. There is a complex relationship between climatechange and health. Detecting and quantifying impacts on health will be gained only through broad scientific effort rather than individual monitoring studies.

Key Words*:* Water, Heatlth, Climate Change,

Les effets du réchauffement climatique sur la santé : Les pays en développement sont les plus vulnérables

Résumé

La détection et la mesure des effets du changement climatique sur la santé sont nécessaires pour fournir des preuves sur lesquelles fonder les politiques nationales et internationales relatives aux mesures de contrôle et d'atténuation.
Des preuves sans équivoque des effets sur la santé et des mesures précises de leur ampleur ne peuvent provenir que de données concrètes. Cependant, le climat varie naturellement ainsi que par les influences humaines et, à son tour, n'est qu'un des nombreux déterminants de la santé. Il faut examiner attentivement la meilleure façon de collecter et d'analyser les informations qui fourniront des preuves sûres des impacts du changement climatique.
Dans cet article, nous examinons comment la surveillance peut aider à fournir des preuves d'impacts précoces sur la santé, en examinant les principes sur lesquels la surveillance devrait être basée, les sources potentielles de données de surveillance et en discutant des problèmes d'analyse et d'interprétation de ces données. Il existe une relation complexe entre le changement climatique et la santé. La détection et la quantification des impacts sur la santé ne seront obtenues que par un effort scientifique général plutôt que par des études de suivi individuelles.

Mots clés : Eau, Santé, Changement Climatique, .

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INTRODUCTION

Climate change is now accepted as a reality and is being recognised as a serious environmental threat by international organizations, some governments, the policy makers and scientists. Scientists have improved their understanding of climate system and present us with evidence of creditable threat about such a change. Mathematical models have been used and these models have performed well in reproducing historical trends of the past, which creates confi dence in future projections in response to greenhouse gas emissions and concentrations. However, these climate projections on their own do not defi ne the potential risks of climate change. These risks are manifested through the exposure and tolerance of natural and human systems and their capacity to adapt to the change. Climate change impacts every aspect of human life, including economic (because of changes in natural systems and resources availability), long term prosperity. While climate change variability and disasters associated with it are an additional burden to sustainable development, particularly in developing countries. We also know that impact of climate change is regional based. Africa will be the worst hit continent, where the increase in temperature is expected to be more than global average inspite of the fact that their contribution of greenhouse gases is minimal. Most of the scientifi c community from the above-mentioned agencies and UNEP report that the latest data point towards the trend of global warming.

Effects of climate change on health will affect most populations in the next decades and put the lives and wellbeing of billions of people at increased risk. During this century, earth's average surface temperature rises are likely to exceed the safe threshold of 2°C above preindustrial average temperature. Rises will be greater at higher latitudes, with medium-risk scenarios predicting 2–3°C rises by 2090 and 4–5°C rises in northern Canada, Greenland, and Siberia. In this paper, we have outlined the major threats—both direct and indirect—to global health from climate change through changing patterns of disease, water and food insecurity, vulnerable shelter and human settlements, extreme climatic events, and population growth and migration. Although vector-borne diseases will expand their reach and death tolls, especially among elderly people, will increase because of heatwaves, the indirect effects of climate change on water, food security, and extreme climatic events are likely to have the biggest effect on global health.

Between 2030 and 2050, climate change is expected to generate nearly 300,000 additional deaths per year, increasing child malnutrition and undernutrition, insect-borne diseases, diarrhoea and heat-related stresses. The potential influences of these changes on health are therefore multiple and interrelated. To these damages, it is necessary to add the migration of populations fleeing profound changes in their living environment: decrease in agricultural yields, floods, sea level rise…. Nearly 250 million "climate refugees" are expected at the horizon of 2050. Everyone remembers the excess of mortality in Europe during the heat wave in the summer of 2003, whereas 70,000 deaths were recorded in August alone. The climatic effects on infectious diseases are more complex. But entomologists are convinced that the expansion of hot and humid areas on the surface of the globe would increase populations of virus-carrying insects tenfold. Finally, the economic impacts of climate change speak for themselves: the estimated cost of direct health damage is estimated at between $2 billion and $4 billion per year by 2030.

Management of the health effects of climate change will require inputs from all sectors of government and civil society, collaboration between many academic disciplines, and new ways of international cooperation that have hitherto eluded us. Involvement of local communities in monitoring, discussing, advocating, and assisting with the process of adaptation will be crucial. An integrated and multidisciplinary approach to reduce the adverse health effects of climate change requires at least three levels of action. First, policies must be adopted to reduce carbon emissions and to increase carbon biosequestration, and thereby slow down global warming and eventually stabilise temperatures. Second, action should be taken on the events linking climate change to disease. Third, appropriate public health systems should be put into place to deal with adverse outcomes.

Change in climate also has an impact on health and trends. This might change or prolong the pollen season impacting people with allergies, indoor environment due to more heating or cooling will have an impact on the health of the people, there might be change in UV radiations impacting health of people etc. Climate change will also have an impact on vector borne diseases as well as water and food borne diseases. With increase in temperature, mosquitoes and ticks are creeping up on latitude, change in precipitation is also changing the map of Malaria spread, also seasonal variation infl uences presence of pathogens such as Salmonella leading to increased incidences of water and food borne diseases. Change in precipitation patterns will also link into agriculture, food security and availability of nutritious food.

CLIMATE CHANGE EFFECTS ON HEALTH WILL EXACERBATE INEQUITIES BETWEEN RICH AND POOR

Global warming can result in many serious alterations to the environment, eventually impacting human health. It can also cause a rise in sea level, leading to the loss of coastal land, a change in precipitation patterns, increased risks of droughts and floods, and threats to biodiversity.

The effects are already evident in areas like Nunavut, Canada, where Inuit hunters are facing survival challenges due to the thinning of the ice. Explorer Will Steger gives an account of hunters in the Baffin Island, who are faced with the dilemma of unsafe hunting due to ice loss, risking their lives to get in contact with sea animals. Climate change will have its greatest effect on those who have the least access to the world's resources and who have contributed least to its cause. Without mitigation and adaptation, it will increase health inequity especially through negative effects on the social determinants of health in the poorest communities.

The effects of climate change on health are inextricably linked to global development policy and concerns for health equity. Climate change should catalyse the drive to achieve the Millennium Development Goals and to expedite development in the poorest countries. Climate change also raises the issue of intergenerational justice. The inequity of climate change—with the rich causing most of the problem and the poor initially suffering most of the consequences—will prove to be a source of historical shame to our generation if nothing is done to address it. Raising health status and reducing health inequity will only be reached by lifting billions out of poverty.

The World Health Organization (WHO) reports [1] that climate change is responsible for at least 150,000 deaths per year, a number that is expected to double by 2030. The effects of global warming will cause dire health consequences:

Infectious diseases: IPCC [2] predicts that global warming will worsen human health conditions, especially in tropical regions. In places like Africa, an increase in temperature signifies an increase in mosquito populations, thus escalating the risk of malaria, dengue and other insect-borne infections. Other regions are also affected. However, the ability to tolerate temperature changes differs from region to region. On the other hand, developing countries lack not only the technological know-how, but also the resources and public health systems, required to prevent such outbreaks.

Heatwaves: Prolonged periods of abnormally high temperatures can have serious health effects on vulnerable populations, such as the elderly and the sick. This was already seen during the 2003 heatwave in Europe, which claimed approximately 35,000 lives. In a study by Hadley Center for Climate Prediction and Research in the United Kingdom, scientists using computer models showed how greenhouse gas emissions have increased the likelihood of heatwaves. The most common health effect is hyperthermia or heatstroke that can be fatal if left untreated. IPCC predicts that global warming will lead to hot days, followed by nights of high temperatures.

Loss of agricultural productivity: Global warming can result in droughts that can worsen living conditions, particularly in Africa. The World Wild Fund has reported that climate change can drastically alter rainfall pattern, and risk water and food supplies for millions. The IPCC report estimates that approximately 75 million to 250 million people in Africa will be without adequate water and will face food shortages by 2020, as crop productivity will decline by about 50 per cent. Rising temperatures could also result in food shortages for 130 million people in Asia.

Asthma and other respiratory diseases: People suffering from heart problems are more vulnerable to increased temperatures, especially those living in already warm areas, as their cardiovascular system must work harder to keep their body cool. Hot temperatures increase the ozone concentration, which can damage people's lung tissue and cause complications for asthma patients and those with lung diseases. Increased global warming can also pose a threat to national security, affecting food security, which, in turn, can lead to resource conflicts. At the UN Security Council debate on energy, security and climate, British Foreign Secretary Margaret Beckett introduced global warming as a security risk.

On a positive note, many countries have now realized the grave consequences of global warming. However, the major impact on reducing the effects of global warming cannot be made without the commitment of those countries that account for the greatest production of greenhouse gases.

CLIMATE-SENSITIVE HEALTH RISKS

Climate change is already impacting health in a myriad of ways, including by leading to death and illness from increasingly frequent extreme weather events, such as heatwaves, storms and floods, the disruption of food systems, increases in zoonoses and food-, water- and vector-borne diseases, and mental health issues. Furthermore, climate change is undermining many of the social determinants for good health, such as livelihoods, equality and access to health care and social support structures. These climate-sensitive health risks are disproportionately felt by the most vulnerable and disadvantaged, including women, children, ethnic minorities, poor communities, migrants or displaced persons, older populations, and those with underlying health conditions (Figure 1).

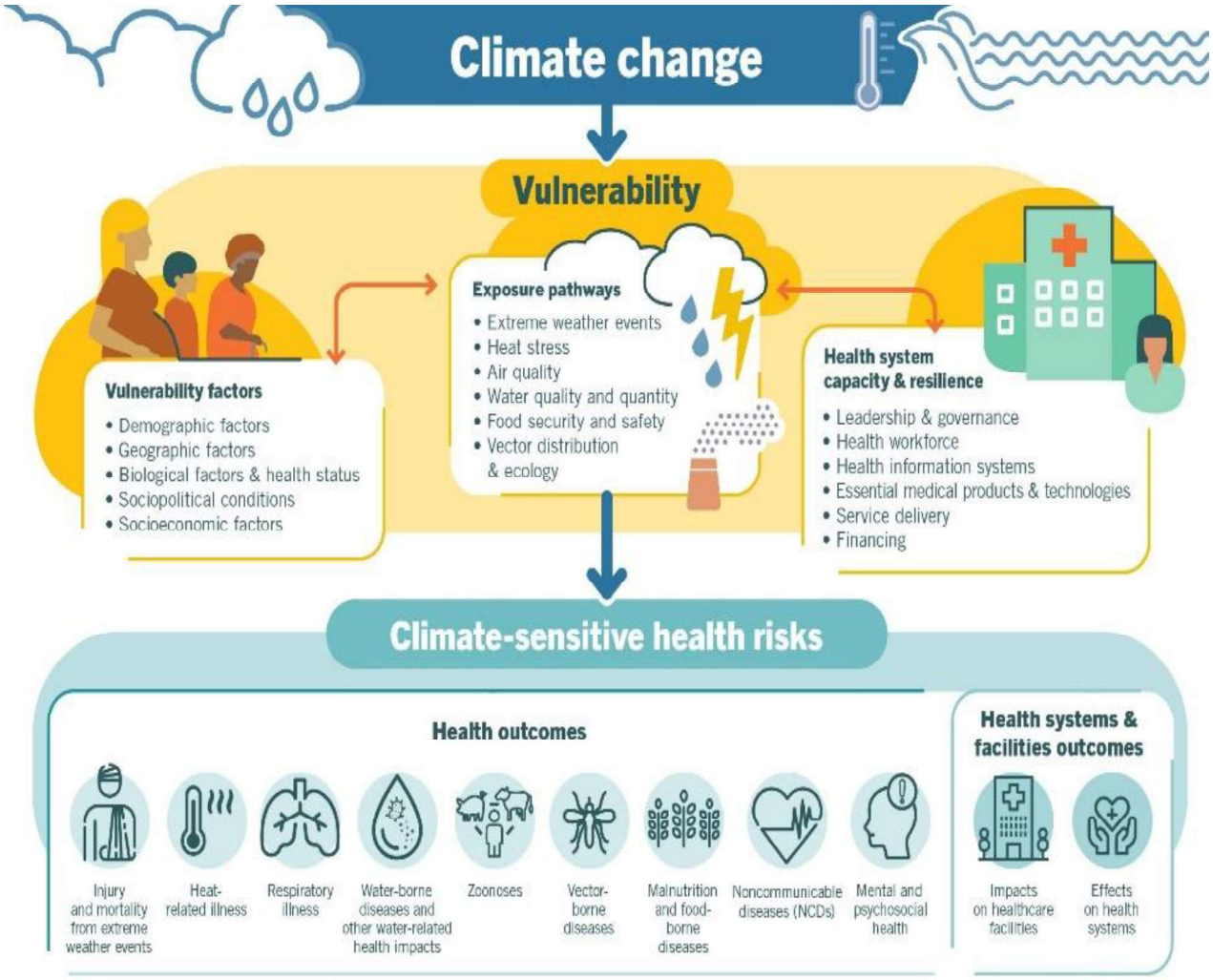

Figure 1. An overview of climate-sensitive health risks, their exposure pathways and vulnerability factors. Climate change impacts health both directly and indirectly, and is strongly mediated by environmental, social and public health determinants. [3]

Although it is unequivocal that climate change affects human health, it remains challenging to accurately estimate the scale and impact of many climate-sensitive health risks. However, scientific advances progressively allow us to attribute an increase in morbidity and mortality to human-induced warming, and more accurately determine the risks and scale of these health threats. In the short- to medium-term, the health impacts of climate change will be determined mainly by the vulnerability of populations, their resilience to the current rate of climate change and the extent and pace of adaptation. In the longer-term, the effects will increasingly depend on the extent to which transformational action is taken now to reduce emissions and avoid the breaching of dangerous temperature thresholds and potential irreversible tipping points.

DIRECT EFFECTS ON HUMAN HEALTH

Heat Stress: An increase in average temperature would probably be accompanied by an increase in the number and severity of extreme heatwaves in some areas. This would cause an increase in illness and death, particularly among the young, the elderly, the frail, and the ill, especially in large urban areas. Climate change would exacerbate an already large urban heat island effect that exists in many large cities. In fact, heat-related mortality may prove to be the largest direct health threat from global climate change. However, much of the research points to a substantial increase in weather-related mortality under climate change conditions. Despite these uncertainties, there is a clear need to develop an adequate warning system to alert the public and government agencies when oppressive air masses are expected—extended periods of extreme high temperature, light winds, high humidity, and intense solar radiation [4].

Skin Cancer, Cataracts, and Immune Suppression: Ozone depletion can have both direct and indirect effects on ecological systems and human health. Increased exposure to ultraviolet radiation (especially UV-B) can have harmful effects on photosynthesis (on land and sea), with potentially disruptive impacts on food production and the stability of ecosystems. The most important direct human health effect would be an increase in nonmelanoma skin cancers, especially in fair-skinned populations. Such cancers are already a major problem in the United States, with about 1 million new cases per year. Furthermore, current models suggest a two percent increase in incidence for every one percent decrease in stratospheric ozone. The current scenario for phaseout of CFCs predicts a 25 percent increase in skin cancer by 2050 at 50°N latitude, relative to the 1980 incidence. Melanoma is a less frequent but far more deadly skin cancer, whose relationship to UV-B exposure remains uncertain. Both types of skin cancer have a long lag time between exposure and disease; the effects of increased UV-B may not be seen until after 2050. Increased UV-B can also be expected to increase the frequency of cataracts, which can lead to blindness in all populations. Current estimates indicate a 0.3 to 0.6 percent increase in new cataract cases for every 1 percent decrease in stratospheric ozone. Ozone depletion may also contribute to the frequency, severity, and duration of some infectious diseases due to ultraviolet's ability to suppress the immune system. There are many uncertainties about the effect of UV-B on immune responses, although it appears that neither pigmentation nor sunscreens offer effective protection [5].

INDIRECT EFFECTS ON HUMAN HEALTH

Food Production and Nutritional Health: Global climate change would have mixed effects on the productivity of agriculture, livestock, and fisheries. In tropical and subtropical areas, global climate change may lead to droughts, flooding, and the emergence of new plant diseases, decreasing food production in many areas where food supplies are already insecure. Meanwhile, crop productivity may increase in other regions, mostly in the higher temperate latitudes such as Canada, Siberia, and Patagonia. However, agricultural projections are strongly dependent on assumptions about technological advances and patterns of consumption. Over 800 million people are chronically undernourished today, particularly in the developing world, and malnutrition is an underlying cause of childhood mortality. With further population growth, malnutrition may increase the vulnerability of these populations to endemic diseases and epidemics. Some areas may need to change crops, planting practices, and diet, further increasing vulnerability during the period of transition. Such regions might be helped by advance warning of conditions that might cause crop failures. Overall, models project the world may be able to produce enough food to feed future populations. However, changes in regional patterns of production could be significant, and in the long term, nutritional security can only be ensured through education and training, higher incomes, favorable market mechanisms, political stability, and population controls [6].

Fresh Water Quality and Quantity: Great spatial and temporal variability characterize water availablility. Climate change may exacerbate such variations. Today 1 billion people lack access to clean and abundant drinking water, and even more are without adequate sanitation. Adjustments to water shortages can be managed where physical infrastructure (reservoirs, pipelines, and canals) and water management institutions exist. Increasing populations dependent on limited sources served by isolated systems are at more risk. Landscapes may erode or stabilize as precipitation alters vegetative cover, thus affecting runoff and transport of sediment and pollutants [7].

Air Pollution and Allergens: The same industrial processes that produce greenhouse gases will also produce increased urban air pollutants, and they too can pose major health risks. Levels of fine particulates (from fossil fuels and wood smoke) and ozone (from photochemical reactions) are known to be associated with higher levels of hospital admissions for respiratory diseases. Fine particulates also appear to be associated with admissions for heart disease and with general mortality. In the United States, where air pollution is relatively low compared with

Mexico City and some Asian cities, it nevertheless contributes to 70,000 excess deaths and 1 million additional hospitalizations annually. In the future, as global increases in energy production lead to higher levels of particulates, and increases in temperature and ultraviolet radiation accelerate the reactions that produce ozone and other secondary pollutants, the health effects of air pollution on a global scale could be staggering. Higher temperatures and humidity may also lead to higher concentrations of plant pollen and fungal spores that cause allergic disorders such as asthma and hay fever [8].

Weather Disasters and Rising Sea Level: El Niño is associated with increased rainfall and floods in some regions. Long-term climate change over the entire planet may result in an increase in extreme weather events, such as droughts, floods, and cyclones. These events could increase the number of deaths and injuries and the incidence of infectious diseases and psychological disorders, as well as causing indirect effects through food shortages and the proliferation of disease vectors. A 40-centimeter rise in sea level would approximately double the number of people who are currently exposed to flooding each year in areas like Bangladesh. It could also contribute to the loss of coastal and delta farmland, as in Egypt, and to the destruction of food supplies. Rising sea level also increases the vulnerability of costal cities, low-lying areas, and small islands to damage during storms [9].

Social and Demographic Dislocations: Global climate change would alter patterns of employment, wealth distribution, and population settlement throughout the world. Physical conflicts might also arise over depleted environmental resources such as farmland, surface water, and coastal fisheries. Biodiversity would also be affected. The greatest destabilizing effects would likely be experienced in areas of Africa which are already highly vulnerable. At the same time, populations may be moving out of tropical and coastal areas and into cooler wilderness areas where they will be exposed to new and unfamiliar health threats. From another point of view, the difficulty of responding to global climate change lies in the rapid pace of the change—the projected rate of change is greater than has occurred on earth in the past 10,000 years. Although it appears that some of the global climate changes may be dealt with by the industrial world, adaptation will be more difficult in the developing world. The pace of global climate change may be complicated by an inadequate pace of institutional change [10].

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IMPACT OF CLIMATE CHANGE ON WATER CYCLE AND HEALTH

Climate change is happening; no one is debating that fact anymore even though the reasons for change in climate (i.e. natural or anthropogenic) might be still debatable! Natural hazards are increasing as can be observed from fl oods, famine and intensity and number of hurricanes in the U.S., increased famine in Africa. This is not only causing loss of property, but is also increasing diseases (in the affected areas) and adding to the economic burden.

Global warming has accelerated in the recent years; while the past 100 years saw an increase of about 0.75°C, the rate of increase of temperature in the past 25 years has been over 0.18°C per decade. The warming has been observed more over land than oceans. This rise in temperature is leading to sea-levels rise, glaciers melt and changes in precipitation patterns (for example from 1900 to 2005, precipitation has increased in eastern parts of North America, northern Europe, northern and central Asia and southern Europe while it has declined in southern Africa, parts of southern Asia, the Sahel, and the Mediterranean). In general, extreme weather events are increasing in terms of their frequency and intensity.

Impact of climate change is on both freshwater resources and also on oceans in terms of acidifi cation, coral reef bleaching. A change in ocean acidity is likely to reduce the ocean's capacity to absorb CO_2 from the atmosphere, thus compounding the effects of climate change, and will affect the entire marine food chain. Also, large-scale, irreversible system disruption and the destabilization of the Antarctic ice sheets are serious risks: changes to polar ice, glaciers and rainfall regimes have already occurred.

Melting ice and thermal expansion of oceans are causing sea level rise. In addition to exposing coastlines, where the majority of the human population live, to greater erosion and fl ooding pressures, rising sea levels might also lead to salt water contamination of groundwater supplies, threatening the quality and quantity of climate change and water resources freshwater access to large percentages of the population. According to World Resources Institute (2000, [11] a 1 metre rise in sea level will displace 80 percent of the population of Guyana.

Freshwater is important because challenges related to freshwater: too much water, too little water or quality of water (pollution) are all exacerbated by climate change [12].

There are several human-environment interactions that affect water, weather, and climate. These include dams, diversions, irrigation, deforestation, wetlands drainage, and the production of impermeable surfaces such as pavement. Though humans have been "pushing water around" since early civilization, the 20th century has seen a rapid acceleration in the scope, scale, and intensity of these interventions [13]. Over 45,000 dams were built in the 20th century and globally there are now over 800,000 dams, including over 45,000 "large" dams with

embankments of over 15m or reservoirs of over 3 million cubic meters ([13]; [14]). In total, these dams have impounded 500,000 km2 (an area roughly the size of France) and displaced between 40 and 80 million people [13].

Impact of Climate Change

Since climate change is severely affecting the availability of water and its quality, it also poses a direct challenge to health: water-borne, water wash and vector related diseases are spreading to wider geographical areas posing challenges to both the existing health system and safe water supply. Southern countries and vulnerable people, but also poor people in industrialized countries have been the main victims and suffering the most from both climate-induced physical impacts (temperature and sea-level rise, precipitation change, increase in the number and intensity of natural hazards such as drought, heat waves, storms and fl oods and societal effects (famine, food protests, diseases, migration) [15]. It can be seen in Figure 2 that as the temperature rises, the impact gets more severe. For example, in case of food: a slight or one degree rise might raise yield in some places at higher altitudes, while any further rise will actually lead to failed crops in many areas, but will have a more drastic affect in developing countries.

Usually, predictions of temperature rise are a global average; essentially temperature will increase in some parts more than the others. Even one degree temperature rise will have an impact on water systems, small glaciers, ecosystems and crops (affecting food security).

Regional impacts of climate change at places will be more than global average3. For example, models of climate change predict that in the U.S. annual-mean temperatures might rise by 2°C to 3°C over the next 100 years, however northern regions will experience a greater increase of up to 5°C and some places such as northern

Alaska might also see an increase of up to 10°C. Related to this increase in temperature other changes are also expected, such as in the U.S. precipitation, is predicted to continue to increase overall. Some GCMs predict a 20 percent increase for northern North America, a 15 percent increase in winter precipitation for northwestern regions, and a general increase in winter precipitation for central and eastern regions. Models predict a 20 percent decrease in summer precipitation, especially for southwestern regions, and a general decrease in summer precipitation is projected for southern areas.

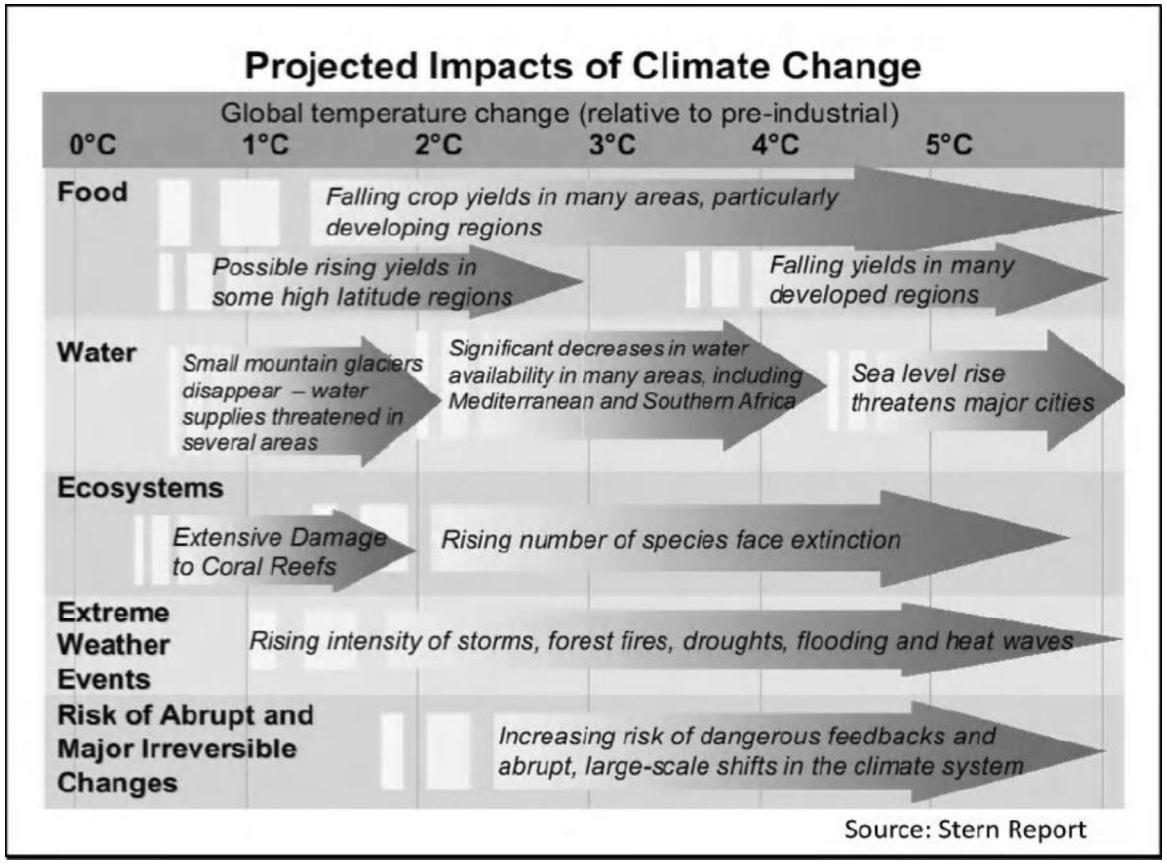

Figure 2. Projected impacts of climate change. Source: Stern Report [16].

Although, there are predictions that precipitation will increase in most regions, yet there will be net decreases in water availability in those areas due to offsetting increases in evaporation [17; 18].

Besides impact on climate and health, climate change will also impact movement of people, agriculture (food security), energy and industries (because of variation in availability of water). The direct supplyside effects of climate change outlined previously, including increased water scarcity, fl ooding, accelerated glacial melting and rising sea levels, have the potential to accelerate human migration. Studies have shown that climate change refugees will range between 250 million to about a billion between now and 2050. Just to give a perspective to it—in New Orleans the population diminished by 29 percent after Katrina.

Agriculture is by far the largest consumer of freshwater. Globally, about 70 percent of freshwater is used in irrigated farming, and far greater volumes of water are used in rainfed agriculture. Although average temperatures are predicted to increase more dramatically in the northern hemisphere, the changes in temperature- dependent agriculture will be felt more signifi cantly in developing regions because of their heavy reliance on small-scale farming, dependence on rainfed agriculture, a fragile infrastructure and limited capacity to respond to emergencies. Many African communities will be at risk, particularly subsistence farmers with low incomes in sub-saharan Africa. This will essentially impact income of these small farmers, as increased droughts may exacerbate poverty levels and increase vulnerability of these people.

Current climate variabilities already present serious challenges for food security in many developing countries. Rural based populations in countries that rely on rainfed-agriculture and primarily depend on subsistence farming

systems are especially vulnerable. In general, water scarcity can limit food production and supply, putting pressure on food prices and increasing countries' dependence on food imports.

Climate change and health

The greatest health impact of climate change will be borne by the poor (mainly in developing countries, but also in developed countries) who are already facing a host of health- related problems due to socio-economic conditions.

As shown in the Figure 3, climate change will impact us in different ways: by changing regional weathers and extreme weather conditions i.e. too much or too little rainfall, higher temperatures leading to heat waves causing illnesses and death, especially of vulnerable people, worsening air quality due to smog, increasing water and food-borne diseases etc.

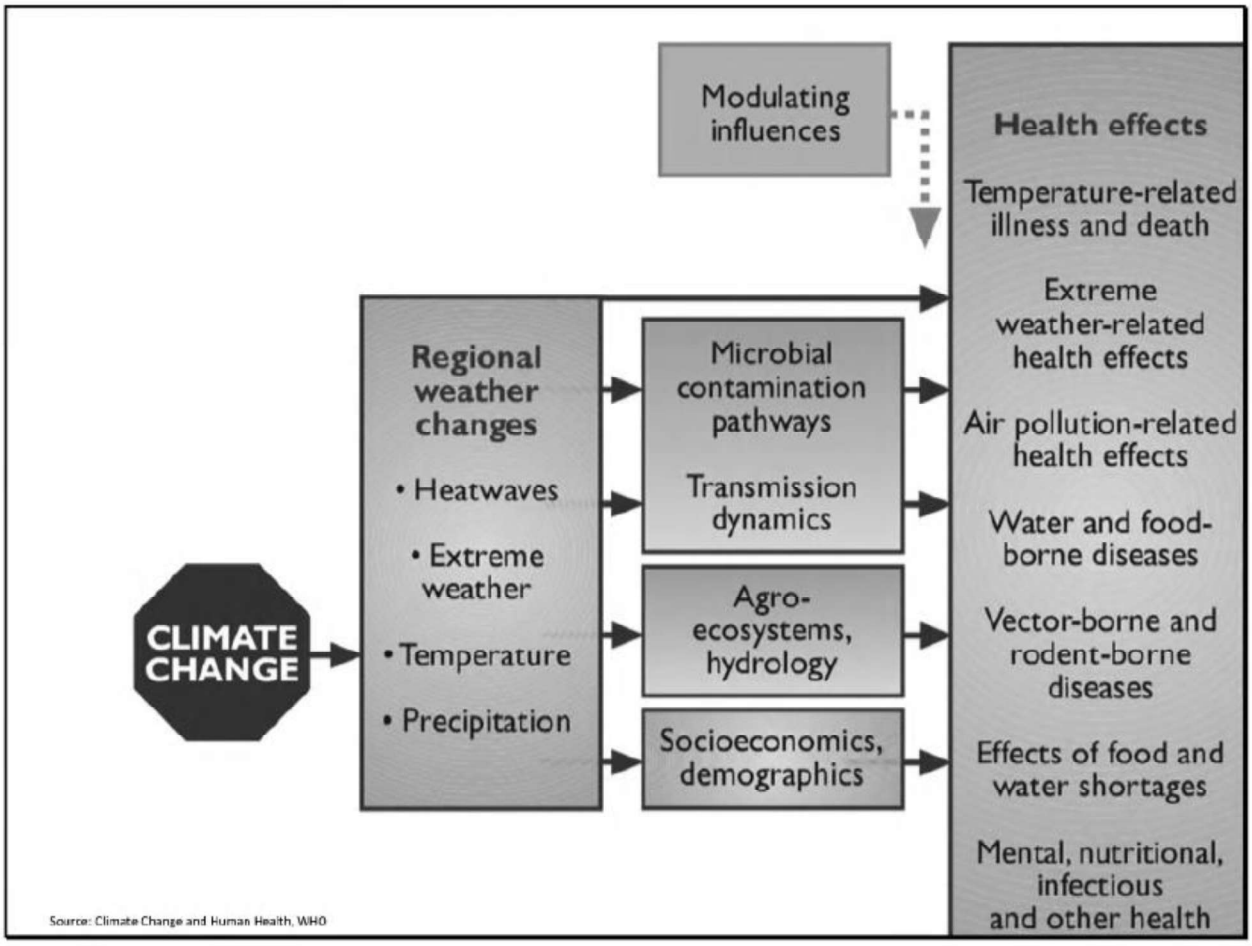

Figure 3 Impacts on climate change on health. Source [19].

The IPCC report [20] shows that the impact of climate change on health issues will be mainly negative (Figure 4). For example, in case of malaria, it will spread to more regions including higher altitudes because of favourable conditions due to change in climate (also shown in Figure 5).

With the change in temperature and precipitation pattern spread of malaria will vary (since the spread of disease is directly related to the amount of precipitation and temperature for mosquitoes to thrive): in some areas the geographical range of the disease will contract while in the other areas it will expand and even the season when it is transmitted might change. There is a direct co-relation between higher minimum temperatures and incidences of malaria outbreaks, which has been shown in case of Ethiopia. Countries such as Senegal, for example, has seen a 60 percent drop in malaria cases in the past 30 yr because of reduced precipitation. However, in areas where temperatures are rising in the traditionally cool climates and higher latitudes, these areas will become more suitable reproductive habitats for the mosquitoes spreading malaria. In other places already warm zones may also see an increase in mosquito populations. Although, countries such as Senegal have seen a decrease

in malaria incidences, it has returned to some places such as central and northern South America, most of Asia, some Mediterranean countries and much of the former USSR. Study estimates show that by 2080, approximately 260–320 million more people are likely to be affected by malaria [22].

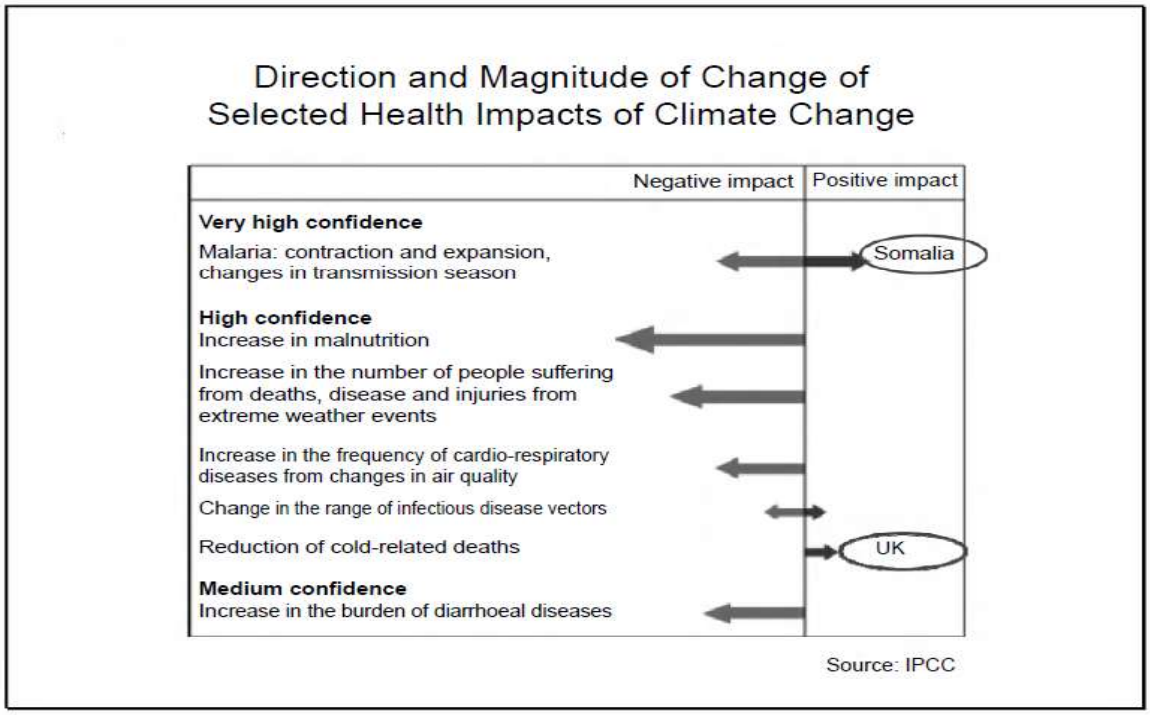

Figure 4. Direction and Magnitude of Change of Selected Health Impacts of Climate Change. Source [20].

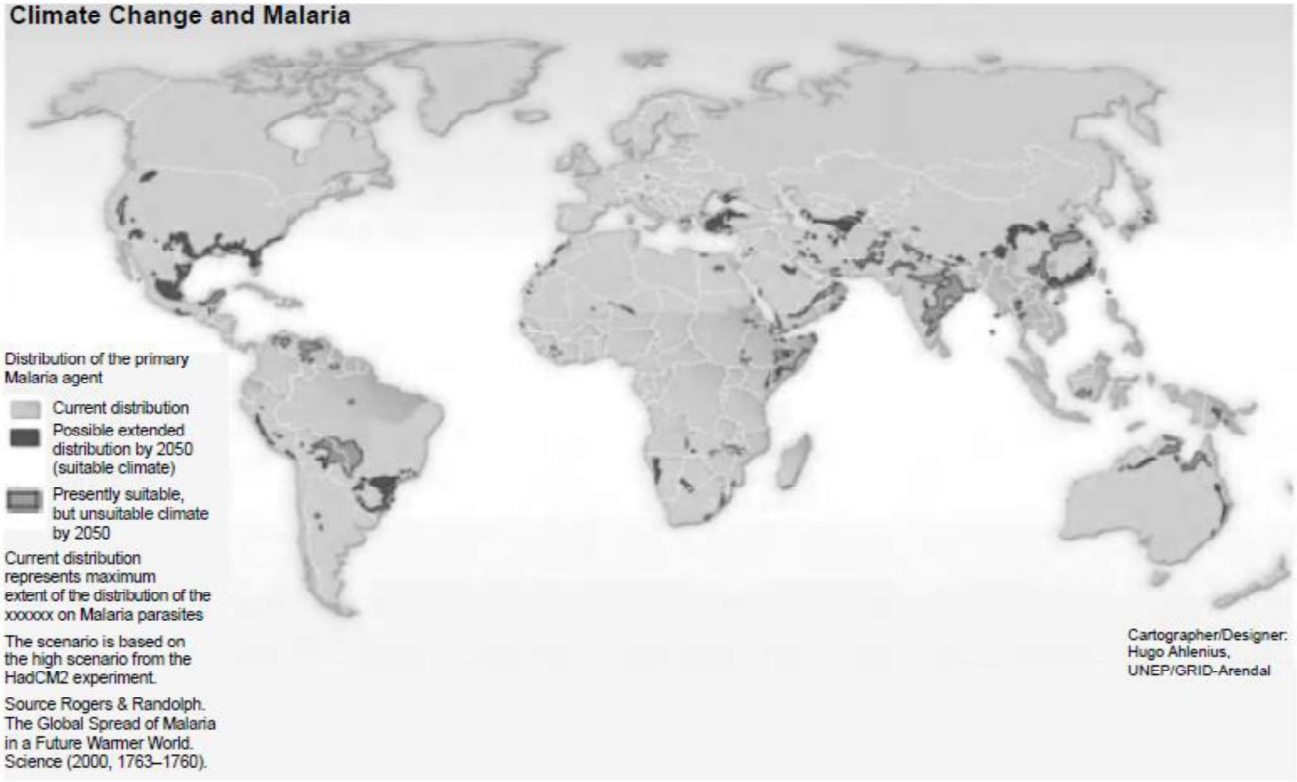

Figure 5. Climate Change and Malaria. Source [22].

The IPCC report [20] also predicts that malnutrition will be negatively impacted by the change in climate (Figure 4), which is expected if agriculture will be impacted by change in precipitation threatening food security. Even

today malnutrition is one of the most serious global health problems (FAO and WHO), about 178 million children globally are stunted and 1.5 million die annually from wasting, both important indicators of malnutrition. According to the IPCC report [20] there is an 80 percent cent chance that climate change will increase malnutrition and consequent disorders [22] .

Climate change will also have an impact on air quality, especially in cities, which will exacerbate the urban heat-island effect and increase the number of smog days and issues related to smog. Poor air quality is also known to cause respiratory health problems. The IPCC report [20] and other studies have shown that there will be an increase in cardio-respiratory morbidity and mortality associated with ground-level ozone [22].

The IPCC reports [20] predict that there will be an 80 percent chance of increase in mortality and morbidity due to climate change related Extreme Weather Events (EWEs). In 2007, 95 percent of the 16,000 global fatalities from EWEs could be directly attributed to climate change. Because of the change in temperature and precipitation patterns, EWEs have changed in frequency and intensity.

In August 2003, a heatwave in France caused more than 14,800 deaths while other European countries such as Belgium, the Czech Republic, Germany, Italy, Portugal, Spain, Switzerland, the Netherlands and the UK all reported total deaths in the range of 35,000. In France, around 60 percent of the heatwave deaths reported were those of seniors aged 75 and above [20]. Around the same time other impacts were also caused or exacerbated by the extreme weather conditions, such as outdoor air pollutants (tropospheric ozone and particulate matter) [20], and air pollution because of forest fires.

Extreme weather conditions not only increase air pollution and deaths related to extreme temperatures they also exacerbate water- borne and vector- borne diseases and increase their transmission. For example, when there is fl ooding in South Asia due to poor drainage and storm water management system rate of infectious disease transmission increases.

Also, in Brazil leptospirosis epidemic was linked to extreme fl ooding; cholera outbreaks have been linked to droughts in Amazon (due to limited access to safe drinking water) and epidemic meningitis have been linked to droughts in West Africa [22].

As discussed in the IPCC report [20] overall impact of changing temperatures will be negative increasing heatwave related and air pollution related deaths, however in some places the average increase in temperature might bring some positive impact in temperate regions. For example, in UK warmer winters might reduce cold weather-related deaths [22].

As discussed in the IPCC report [20], impact of climate change on health will include spread of endemic and epidemic infectious diseases, water-borne diseases and vector-borne diseases. As temperatures change mosquitoes spreading diseases will move to higher latitudes where they did not exist before. For example, West Nile and dengue have crept up in North American provinces.

Increasingly, the focus of climate change literature is leaning towards prediction, adaptation, and mitigation of possible climate events on the global, regional, and country levels, with emphasis on the role of carbon as a greenhouse gas (GHG). However, in recent years, a body of literature has emerged which examines the essential roles of water in global environmental change [13; 23; 24]. As the most abundant GHG, and greatest single contributor to the "greenhouse" effect, water vapour exerts a warming effect on global temperatures. However, water vapour condenses, forming clouds which in turn refl ect radiation, thus exerting a cooling effect as well. These dual properties make water vapour not only the most abundant, but also the most important GHG [23].

Climate change and water stress

"Of all basic needs, access to clean water is probably the most important" argue Potter and others [25]. Water is essential for all aspects of life, especially when people depend on it for sustaining their livelihood. Only 2.5 percent of all water is freshwater, and most of it is frozen in Antarctica and the Greenland icecaps. Only 1 percent of the world's total freshwater is available for human use [26]. Though water cannot be depleted, pollution and salt water intrusion threatens its human use. In combination with increasing demand and climate variability, water can become scarce, thereby affecting human security. Developing countries in particular are at greater risk to experience water stress due to their geographical location and dependency on climate-sensitive economies.

Even today, about 900 million people are without access to clean drinking water [27]. In sub-Saharan Africa, about 70 percent of the population work in subsistence agriculture, highlighting the importance of suffi cient and clean water supplies [28]. Water is a source of economic activity, crops cannot thrive without it, but it can also contain bacteria, protozoa, viruses and parasites causing water-borne diseases, such as cholera, bilharzia and typhoid fever.

The majority of water, and much of it is freshwater, is consumed for (irrigation) agriculture and industrial processes. Irrigation agriculture consumes large amounts of water to the extent that in dry seasons, water levels may become critically low. Over-extraction of water can threaten entire ecosystems, and jeopardize food production [29]. At the same time, the use of pesticides and fertilizers releases nutrients to the water cycle contributing to water pollution [30]. The pollution and overexploitation of freshwater reservoirs can lead to water stress.

When water is considered a free good, it can be challenging to control and restrict overuse of groundwater. A study in India shows that groundwater tables have fallen by more than one metre per year, as there are no limits to extraction. Especially rural areas close to cities are affected as they provide the needed water to the urban sprawl [31].

Other factors leading to water stress are increasing population, largely in urban areas, changing consumption patterns and growing economic activities that are putting more pressure on water resources (Scheffran 2010). Global population is estimated to reach 11 billion in 2050 [26]. Most of this growth will happen in urban centres. Yet, urban growth may not be per se negative. Urban areas are characterized by higher population densities, which could imply lower water supply costs. Yet, the rates of diseases and mortality in developing countries are still high [30]. In fact, piped water may reduce costs but the water maybe of low quality [30;31].

In many instances, economic considerations come fi rst. China is a good example, where the economy has grown and still is growing tremendously at the cost of the environment. As Gleick describes: "China's water resources are over allocated, ineffi ciently used, and grossly polluted by human and industrial wastes, to the point that vast stretches of rivers are dead and dying, lakes are cesspools of waste, groundwater aquifers are over-pumped and unsustainably consumed, uncounted species of aquatic life have been driven to extinction, and direct adverse impacts on both human and ecosystem health are widespread and growing" (Gleick 2010). For many developing countries, tourism is a vital source of income. It is, however, questionable that in times of water stress, tourists have free access to water whereas the local population is subject to water regulation (Benjaminsen and Svarstad 2006). To lower these pressures, recycled water could be used. In some countries, treated waste water is used for irrigation (Madeley 2002). Another benefi t of nutrient-rich sewage is that it acts as a fertilizer (Madeley 2002). However, this is not without risks, as wastewater can contaminate drinking water, making it unsafe to drink.

Climate change, or increasing temperatures, will most certainly impact on the hydrological cycle, and increase competition for water resources. It is less clear, as to what extent increased water stress affects (national and international) security. Some have argued that water is becoming the new oil, claiming that competition over scarce freshwater will spark armed confl icts (Clarke and King 2006). The literature is divided, and there is little evidence in the past that confl ict over shared rivers or freshwater lakes have led to armed confl ict. On the contrary, case-study research demonstrates that cooperation is more likely to emerge than confl ict (Scheffran 2010). As Scheffran(2010) argues: "historical international relations over shared freshwater resources were overwhelmingly cooperative; violent conflict was rare and far outweighed by the number of international water agreements." On the individual level, water stress can mean restrictions in water use and overall availability.

Most important and apart from external factors such as climatic disturbances, access to water, is context specific. Hierarchal divisions often regulate access to water and affect water distribution. Adams argues that "the distribution of water refl ects the distribution of power" [30]. A good example is the privatization of water. There is an ongoing debate whether privatization is addressing overuse. By serving profit maximizing motives, it may not prevent over-extraction in the long term, but most importantly, privatization can lead to unaffordable water for the poor. In this context, water stress may make the poor worse off, illustrating the link between poverty and water availability [30].

In the worst case, regulating water distribution through privatization can spark confl ict, as witnessed in Bolivia in 2000. In the city of Cochabamba, street fi ghts and demonstrations erupted when water utilities were privatized. This was at the disadvantage of the poor, who, after privatization, had to pay 20 to 30 percent of their income for water. Households earning as little as US$ 80–100 monthly income had to pay up to US$ 20 for water (Chávez 2006). Privatization often leads to asymmetric distribution of water as the poor pay proportionally more for the service than those who are well off. What is needed is a pricing structure that acknowledges the ability to pay as well as generating necessary investments to ensure access to safe water.

Adequate water management is needed to address water stress in the future. It is not the absolute availability or scarcity of water that creates water stress but the mismanagement of it. Man-made pollution is one of the main factors: "In developing countries 90% of waste water and 70% of industrial waste runs straight into the surface water without any form of treatment. As a result, more than 5 million people die every year of water-related diseases, 10 times more than the number of victims of armed confl icts" (GRID-Arendal 2010).

To tackle these challenges, a proactive rather than a reactive approach to water management becomes necessary. Proactive means to anticipate the water scarcity before it becomes an acute issue. This requires sustainable water management, and "water availability can be increased through artifi cial groundwater recharge, damming, rainwater harvesting and desalination" (Arthurton et al. 2007). Desalination has been successfully established in the Middle East, though it consumes great amounts of energy, making it a limited solution for ensuring global water supply, especially for the developing world. Clean water and health are vital for sustainable development. Climate change will most likely have impacts on the water cycle and human health but the change and relative infl uence of climatic factors remain uncertain. There is a little evidence that water stress or health risks will lead to armed confrontation or "water wars" but there is compelling evidence that water stress and health risks accelerated by climate change will affect human security. On the contrary, cooperation over shared water bodies is more common than confrontation. And, while observed global temperatures continue to rise, the number of armed confl icts has decreased worldwide

By focusing on human security, the threats of a warmer and more variable climate become more tangible. With growing populations, the challenge will be the provision of safe and clean drinking water while avoiding water pollution. Sustainable water management is a key here. A warmer climate is likely to reduce water availability while reducing agricultural productivity. Uncertainties remain about the relative importance of temperature and precipitation on agriculture, calling for future research. Societies that derive their income from subsistence agriculture will be directly affected by changes in the hydrological cycle. Rising temperatures and changing precipitation patterns are also connected to human health, impacting on the prevalence of malaria and tick-borne encephalitis. Though the research community is divided on the spread of infectious disease due to warming, malaria and tick-borne diseases are climate-sensitive, and globally one of the major health risks. Most important, strategies to mitigate climate change will have unintended consequences for human wellbeing, such as increasing food prices as a result of biofuel production or nuclear contamination and proliferation, with serious impacts on human wellbeing and international security. The challenges for policymakers are clear whereas possible solutions and their ripple effects remain uncertain. Bringing climate change research back to the individual level, acknowledges our vulnerability but also our potential to fi nd adequate solutions to climate change.

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