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Climate Change and Water: Impacts to Human Health and Consumption

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Climate change and water: Impacts to human health and consumption

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Abstract

Climate change can exacerbate existing vulnerabilities in terms of water resources and the ability of infrastructure to cope with shocks (caused by increased variability of weather events). However, how such shocks translate into impacts on health and well-being is rather complex.

One of the aims of this paper is to examine the current evidence on impact of climate change on water and how this might further translate into impact on access to water and sanitation and how this might affect health outcomes. Our analysis here suggests that institutional and policy failures rather than climate change may have much greater impact on health outcomes due to lack of access to water and sanitation.

The second aim of this paper is to examine and develop the concept of water insecurity. The main contribution of this paper is to demonstrate that water insecurity is multi-dimensional and that there are different elements of water insecurity manifesting different aspects of inequalities in a given society. This is done principally using data available from the Joint Monitoring Programme (JMP) of WHO and UNICEF in innovative ways to provide a more detailed picture of water insecurity in different countries disaggregated further in terms of the urban and rural population. As far as we know, no one has previously used the JMP data in this way to develop the idea of water insecurity. In addition to cross-country analysis, case studies of countries such as Bhutan, Maldives, Papua New Guinea and Timor Leste highlight the complexity behind the figures of access to water and sanitation. The analysis in this paper emphasises the need for focusing on inequality and reducing water insecurity as a crucial step to promoting human development and reducing vulnerabilities to climate change in Asia and the Pacific.

Key words: Climate change, water, health, consumption

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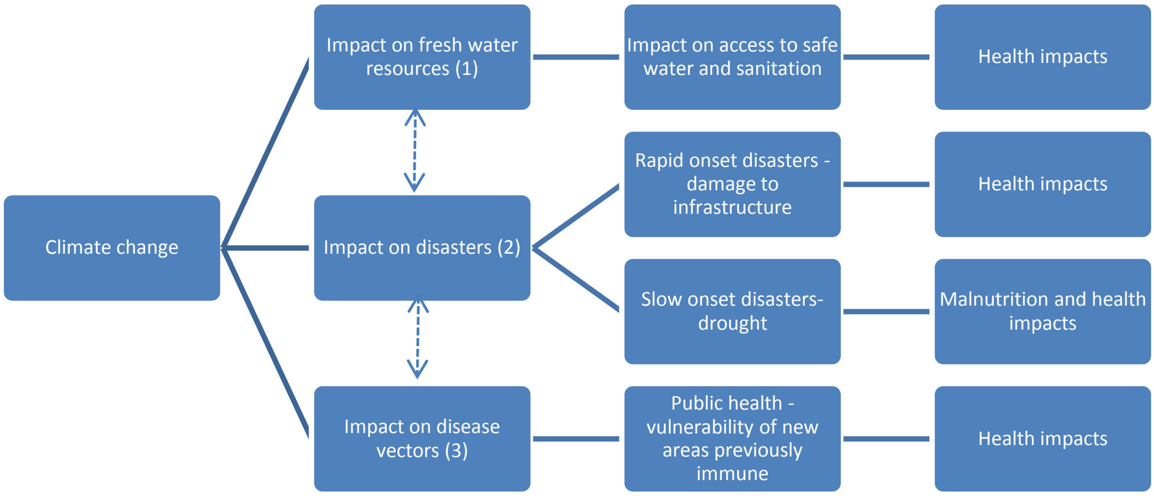
1. Introduction

Anyone concerned with human development and freedoms would find it unsettling that some 3.5 million lives including those of some 3 million children are lost annually worldwide due to water, sanitation and hygiene related risk factors (WHO, 2008). The reason for finding this not merely unpalatable but deeply unsettling is that while the existing situation is already a manifestation of injustice, climate change can exacerbate some of these risk factors including diarrhoeal disease, malnutrition and its consequences, and malaria. The aim of this background paper is to highlight the potential impact of climate change on water and health.

Climate change can have significant impacts on both water and health. Climate change projections suggest that in many regions in Asia and the Pacific, precipitation patterns will change significantly affecting the distribution of freshwater resources. This can exacerbate water insecurity and wipe out decades of progress that has been made in improving access to safe water and sanitation. The potential for increased frequency of climate change induced disasters also puts at risk health of population in post-disaster contexts to water-borne diseases. Climate change may indirectly contribute to flooding and increased vulnerability of population living in coastal regions especially of the Bay of Bengal. Climate change induced droughts and food insecurity can exacerbate malnutrition. Warming is also likely to contribute to the geographic spread of certain disease vectors and thus significantly increase potentially vulnerable population. Conceptually, these various routes of connecting climate change-water-health are shown in figure 1 below. Though conceptually it is easy to think of three routes, they are hardly independent or isolated.

Figure 1: Alternative routes to link climate change, water and health



The Inter-Governmental Panel on Climate Change (IPCC) was set up jointly by UNEP and the World Meteorological Organisation in 1988 with a resolution of the General Assembly to provide scientific advice on climate change. IPCC summarises scientific evidence on climate change, impacts, adaptation, and mitigation issues in assessment reports issued periodically. So far four such reports have been published with the fourth assessment report or AR4 in 2007. The fifth report is due to be published in 2013. AR4 is organised in terms of reports of three working groups- WG1 focusing on physical science basis of climate change, WG2 on impacts and adaptation and WG3 on mitigation measures. WG2 report's chapter 3 included a significant discussion on the impact of climate change on fresh water resources (route 1 in figure 1). The main conclusions of that chapter include the following:

- "semi-arid and arid areas are particularly exposed to the impacts of climate change on freshwater (high confidence)";
- "higher water temperatures, increased precipitation intensity, and longer periods of flow exacerbate many forms of water pollution, with impacts on ecosystems, human health, water system reliability and operating costs (high confidence)";
- "climate change affects the function and operation of existing water infrastructure as well as water management practices (very high confidence)" (IPCC,2007a).

Though the WG2 report did not include a separate chapter on disasters (route 2 in figure 1), these have been discussed within various sections in the report. Within chapter 3, section 3.4.3 focused on floods. Though the report noted that there is no evidence for climate-related trend with regard to floods, it also noted that "…a warmer climate with its increased climate variability will increase the risk of both floods and droughts" (IPCC, 2007a).

Chapter 8 of WG2 (IPCC, 2007a) report focused on health and covered all three routes suggested in figure 1. With regard to storms and floods, that chapter (in section 8.2.2) noted that "…populations with poor sanitation infrastructure and high burdens of infectious disease often experience increased rates of diarrhoeal diseases after flood events"; and also that "…flooding may lead to contamination of waters with dangerous chemicals, heavy metals or other hazardous substances". With regard to drought, it was noted that while establishing causal link between climate variability and human nutrition may be complex, "…both acute and chronic nutritional problems are associated with climate variability and change" (in section 8.2.3). Other sections discussed water and disease and vector-borne diseases (such as due to rodents and ticks). Conclusions in this chapter suggest that projected health impacts of climate change will be predominantly negative with most severe impact in low income countries.

An important evidence for route 3 in figure 1 above comes from studies by Colwell and colleagues on cholera (Colwell,1996; Pascual et al 2000; Belkin and Colwell,2005; Jutla et al, 2011; Reyburn et al, 2011; Vezzulli et al 2012). These studies suggest that the periodicity in the outbreaks of the epidemic is related to sea surface temperature (SST) and the boom in phytoplankton which then leads to an increase in zooplankton which acts as a host to *vibrio cholerae.* By examining evidence including by satellite imageries, these researchers were able to make a clear connection between warming (and rising SST) and disease outbreak.

Though all 3 routes are important, the main focus of this paper is on route 1. The other two routes are analysed briefly.

2. Aims

Against this background, this paper has the following aims:

a. To provide a brief overview of conceptual issues in applying a human development approach to water and climate change interactions;
b. To examine current evidence on health impacts of water and assess alternative scenarios of how climate change impacts on water in the region might translate into various forms of health impacts and disease burdens;
c. To use the concept of water security to examine the potential for climate change induced water insecurity at alternative frames of analysis, namely, water security at the level nations, of water sharing or water transfers between intra-national units, at the level of decentred communities and at the level of individual households;
d. To examine the main institutional barriers to improving water and sanitation services within the diversity of institutional settings that exists in the Asia-Pacific Region and identify good practices and lessons learned;
e. To identify key policy recommendations.

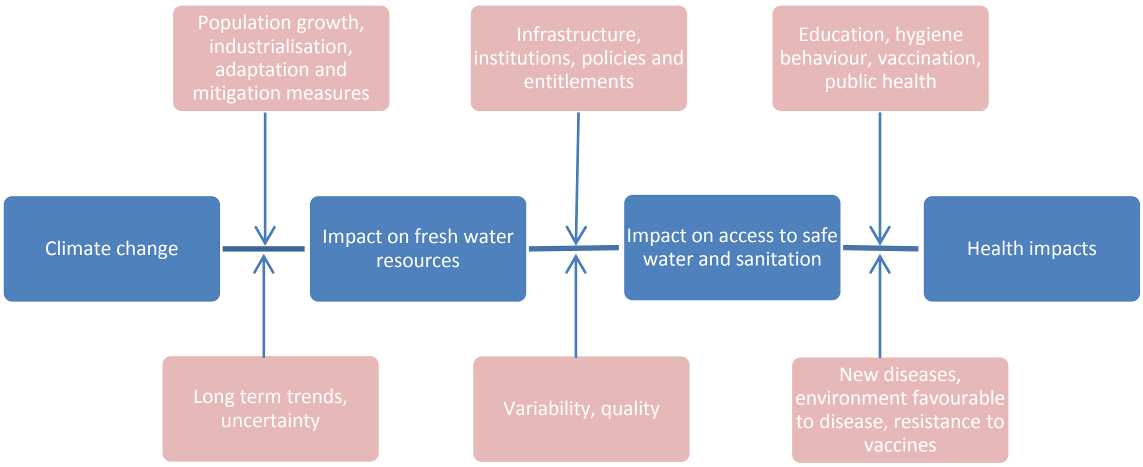
The outline of rest of this paper is as follows. Section 3 provides a brief summary of human development approach to climate change, water and health. Section 4 provides a brief review of the link between climate change and health. In section 5, a brief overview of climate change and water resources in Asia and the Pacific is provided. Section 6 summarises the health impact of water and sanitation in terms of deaths and disease burden. Sections 7 and 8 contain analysis of cross-section data. Section 7 focuses on water resources and access to improved sources of water and the role of economic and institutional factors. Section 8 develops a new indicator of water security from the WHO-UNICEF data and various conjectures are examined here. This section also includes brief discussions on various case studies of different types of vulnerable communities. Section 9 provides a brief discussion on disasters and health impacts; section 10 briefly considers the impact of climate change on vector borne diseases. Section 11 presents conclusions.

3. A human development perspective on climate change, water and health

With regard to climate change and human development, the Global Human Development Report 2007 noted: "…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" (UNDP, 2007: 10). Reducing dangerous climate change will enhance the freedoms (and capabilities) of those in present as well as future generations. However, the main challenge concerns distribution of the burden or costs of mitigation and adaptation. While Stern (2006) review presents an economic argument for acting now, HDR 2007 aims to present an argument on equity. This is further developed in UNDP (2011).

With regard to climate change-water-health as discussed in figure 1 earlier, each of the causal links between climate change and human health are subject to external and internal drivers. For example, external drivers such as population growth, economic growth and industrialisation and adaptation and mitigation measures may determine how climate change impacts on availability of freshwater resources. How fresh water availability impacts on access to safe water and sanitation depends on external factors such as availability and extent of infrastructure, the quality and nature of institutions governing water resources, effectiveness of policies and the entitlements they provide. Notwithstanding that people have access to safe water and sanitation, ultimate health impacts depend on external drivers including level of education and awareness, hygiene behaviour, cultural factors and the quality of health and public health institutions.

Figure 2: Climate change-water-health (route 1 of figure 1 elaborated)



Human development is "…the expansion of people's freedoms and capabilities to lead lives that they value and have reason to value" (UNDP, 2011:1). A human development approach in the design of adaptation and mitigation strategies means focusing on sustainable human development i.e., enhancing the capabilities of present generation without compromising the capabilities of future generations (Anand and Sen,2000). A human development approach means understanding how to put people at the centre of development and how the enhancing of substantive freedoms affects the external factors that impinge on each of these links in the route. A human development approach also requires us to take both inter-generational and intra-generational equity seriously and understand how the external drivers affect or do not affect those households or individuals who are most vulnerable.

An approach based on deliberative public scrutiny can help in empowering individual households to make reasoned decisions regarding their reproductive rights such that population growth is sustainable. At the next level, in translating existing fresh water resources into safe access to water and sanitation, a human development approach helps in shifting attention from treating water as a commodity to focusing on functionings - the beings and doings that people can achieve with water.

Entitlements determine access to resources. Even if entitlements are uniformly (equally) distributed, the outcomes (having water to drink or cook food, having a bath or washing clothes) achieved may vary depending on individual circumstances (conversion factors). The outcomes may not automatically translate into substantive freedoms. Examples of freedoms related to access to water include: freedom to live a long and healthy life with dignity, freedom to be well-nourished, freedom to have access to resources to realise a decent standard of living, freedom to live in healthy and hygienic surroundings, freedom to learn (or acquire knowledge), and freedom to pursue cultural traditions (without impinging on freedom and dignity of others). Lack of access to improved water sources contributes to disease burden and erodes the freedom to live a long and healthy life. Diarrhoeal disease among children impacts on their ability to attend school and thus erodes freedom to learn. Chronic episodes of water borne diseases impinge on freedom to be well-nourished.

Clarifying and protecting the entitlements of individual citizens is an important step (Anand,2007a). A human right to water can be a useful component of a broader set of entitlements which may be required to enable an individual citizen to achieve substantive freedoms though a human right proclamation alone is seldom effective (UNDP,2006; Anand,2007b). The human development approach is also helpful in approaching health impacts changing focus from negative freedoms such as avoidance of disease to positive freedoms such as long and healthy life.

4. Climate change and health

One of the earliest assessments of climate change impacts on human health was made by McMichael and colleagues (WHO,1996). Among other things, the report examined evidence on relationship between temperature and mortality with case studies including two from China and one from Egypt. Effect of climate change on biological disease vectors was also examined. For example, evidence seemed to suggest that impact in terms of new cases of malaria could be between 300 and 500 million and schistosomiasis could be over 200 million. Dengue fever cases could increase by over 50 million a year. The study also considered the health impacts of sea level rise and stratospheric ozone depletion. The report identified several recommendations for further research.

These issues were re-visited in a subsequent assessment (WHO, 2003). With regard to climate change models and impacts on disease vectors, this study examined in detail the potential link between El Nino Southern Oscillation (ENSO) and spread of diseases such as Malaria and cholera. The study also estimated the overall likely impact of climate change on disease burden for the year 2000 (p. 152). These suggested that worldwide, climate change contributed to 5.5 million DALYs being lost due to climate change in year 2000; approximately 2.8 million of these were lost due to malnutrition; another 1.5 million due to diarrhoea. Malaria contributed to another 1 million DALYs lost; floods contributed to about 200 thousand DALYs lost. Regional distribution suggested that nearly half of all DALYs worldwide were lost in East and South Asia region.

The 51st World Health Assembly in 1998 highlighted the links between climate change and health. A decade later, the 61st World Health Assembly issued resolution 61.19 on climate change and health and called upon all member states to "…develop health measures and integrate them into plans for adaptation to climate change as appropriate" (WHO,2008). Climate change and health was also the focus of 2008 World Health Day (WHO,2008).

WG2 of IPCC (2007a) noted (in chapter 8) that climate change affects the spatial and temporal distribution of diseases such as malaria, dengue, tick-borne diseases, cholera and other diarrhoeal diseases. The report noted that "…The projected health impacts of climate change are predominantly negative, with the most severe impacts being seen in low income countries…Projected increases in temperature and changes in rainfall patterns can increase malnutrition, disease and injury due to heatwaves, floods, storms, fires and droughts, diarrhoeal illness, and the frequency of cardio-respiratory diseases due to higher concentrations of ground-level ozone".

Climate change is "…the biggest global health threat of the 21st century" according to the UCL Lancet Commission on the health effects of climate change (Castello et al, 2009).The Commission noted that while direct effects such as the increased frequency of heat waves etc., may have an impact on mortality especially among the elderly, the indirect effects of climate change on water, food security and extreme climatic events "…are likely to have the biggest effect on global health". The report considered six areas that connect climate change to health outcomes:

- Changes in patterns of disease transmission and mortality
- Food
- Water and sanitation
- Housing and human settlements
- Extreme events
- Population and migration.

The report calls for a public health movement to frame climate change as a health issue.

Goklany (2009) challenges the conclusions reached by the UCL Lancet Commission and argued that the data on relative health risk does not suggest climate change to be the number one risk. Goklany used the data from year 2000 on disability adjusted life years (DALYs) for various health risks. In his analysis, in a list of 26 risks, climate change takes 22nd rank while 'underweight' (malnutrition) takes the 1st rank to be followed by unsafe sex as 2nd major risk. DALYs lost due to physical inactivity are twice the magnitude of DALYs lost due to climate change.

The authors of UCL Lancet Commission replied to Goklany pointing out that 2000 WHO data may be out of date because of the nature of the knowledge then and information about climate change. They claimed that in the nine years since WHO original data, further studies have attempted to examine the extent of warming and its potential impact. Further, one can argue that even the risk of malnutrition is likely to be exacerbated by climate change.

The Global Burden of Disease 2010 study was released in December 2012. These figures do not fundamentally alter the overall picture on burden of disease and the relative risk of climate change. . According to these estimates, worldwide, the number of deaths attributable to unimproved water and sanitation had fallen from over 715,000 in 1990 to 337,000 in 2010 (Lim et al, 2012). This fall is consistent with the progress that is being made with regard to MDGs though there is much progress to be made. This is highlighted from the fact that nearly two thirds of the deaths are attributable to lack of improved sanitation.

Direct and indirect impacts

Direct impact of climate change on health is likely to include: additional heat related mortality in northern latitudes; mortality directly attributable to precipitation variability, coastal and inland flooding; and the spread of vector-borne diseases especially malaria.

According to data from EM-DAT international disasters database, during 2000-2009, worldwide, extreme temperatures were responsible for some 91,061 deaths worldwide forming some 5.9 per cent of all disaster related deaths. Within the Asia-Pacific region, extreme temperatures resulted in 15,163 deaths during the same period.

A set of papers published in *Science* highlight the potential increase in the area that may be affected by malaria due to climate change. Rogers and Randalph (2000) used multi-variate models and came up with estimates of the spread of malaria which are more cautious than previous estimates by others mainly based mainly on biological models.

Harvell et al (2002) noted in their study of impact of climate change on disease risks:

> “...The most detectable effects of directional **climate** warming on disease relate to geographic range expansion of pathogens such as Rift Valley fever, dengue, and Eastern oyster disease. Factors other than **climate change**—such as changes in land use, vegetation, pollution, or increase in drug-resistant strains—may underlie these range expansions. Nonetheless, the numerous mechanisms linking **climate** warming and disease spread support the hypothesis that **climate** warming is contributing to ongoing range expansions. We found no unequivocal examples of natural changes in severity or prevalence resulting from directional **climate** warming per se. However, current data on temperature-dependent pathogen development and replication rates, and on associations between disease occurrence and **climate** variation, suggest several ways in which **climate** warming has altered and will alter disease severity or prevalence.”

Studies on the outbreak of cholera also allude to climate change impact. Sharp (2002) points to Rodo et al (2002) study that suggested that up to 70 per cent of variation in cholera outbreaks during 1980-2001 can be accounted for the El Nino Southern Oscillation (ENSO). A subsequent note published by the authors in *Nature* (Koelle et al, 2005) concludes:

> “We have shown the existence of refractory periods during which climate-driven increases in transmission do not result in large outbreaks. Once the interplay of climate forcing and disease dynamics is taken into account, clear evidence emerges for a role of climate variability in the transmission of cholera.”

The UCL-Lancet Global Health Commission (Costello et al 2009) noted that incidence of dengue fever is likely to be affected by climate change. By 2080 about 6 billion people will be at risk from contracting dengue fever compared with some 3.5 billion people if there were to be no change in the climate.

While the direct impacts are significant, the indirect effects are likely to be several orders of magnitude larger. One of the indirect impacts is through increased variation in climate and the vulnerability of population to natural disasters.

5. Climate change and water resources in Asia and the Pacific

Almost all of the significant impacts of climate change in the Asia and the Pacific impact on water resources. The key points to note from the report of the WG1 of IPCC (2007b) AR4 are the following:

- "All of Asia is very likely to warm…;
- It is very likely that summer heat waves/hot spells in East Asia will be of longer duration, more intense, and more frequent…
- Summer precipitation is likely to increase in northern Asia, East and South Asia and most of Southeast Asia, but it is likely to decrease in central Asia.
- An increase in the frequency of intense precipitation events in parts of South Asia, and in East Asia is very likely.
- Extreme rainfall and winds associated with tropical cyclones are likely to increase in East, Southeast and South Asia" (section 11.4).

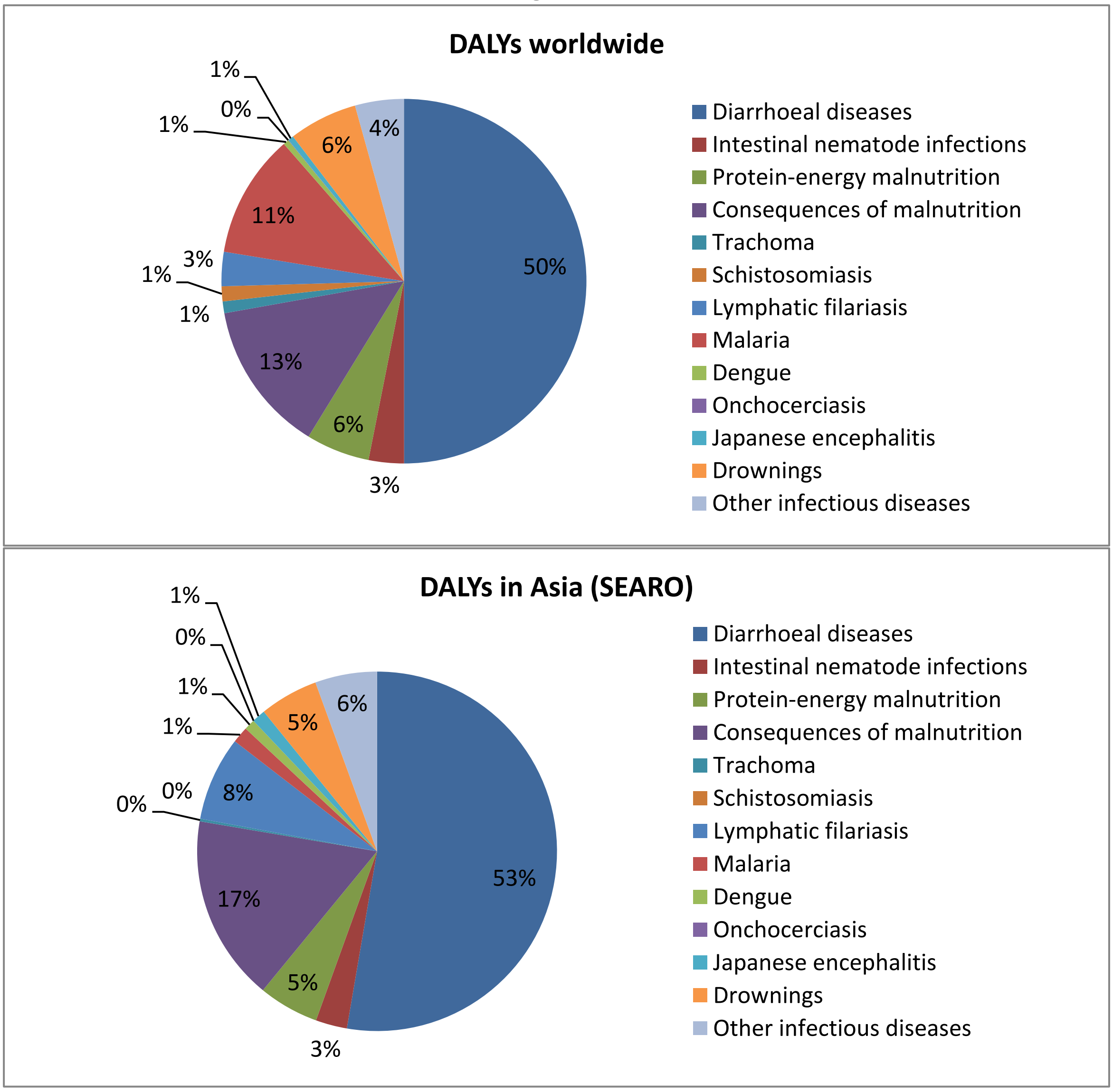
Further to the discussion on water and climate change in the AR4, a technical report was issued by the IPCC on this subject (Bates et al, 2008). This report noted that while some regions may benefit from increased annual runoff, globally the negative effects of increased variability in rainfall and surface flows will outweigh the expected benefits. The report also noted that: changes in water availability and quality due to climate change will affect food availability; the changes affect functioning and operation of existing water infrastructure; that the current management practices may not be robust enough to withstand the impacts of climate change; that adaptation options designed to guarantee water supply during normal as well as drought conditions should include both demand side as well as supply side strategies. The report also noted that many gaps exist in current knowledge with regard to observations and research needs related to climate change and water.

Data from the WHO-UNICEF Joint Monitoring Programme indicates that out of 884 million people worldwide without access to improved sources of water, 484 million people live in the Asia-Pacific region. Similarly, 1,903 million people in the Asia-Pacific live without access to improved sanitation is 1,903 million as compared with 2.6 billion people without such access worldwide. The variation in distribution of water resources throughout the region and in the social and ecological pressures in managing the resources suggests that climate change induced variability can have significant impact on water security. This variability can also impact on making entire communities highly vulnerable.

6. Water supply, sanitation and health

The link between access to water and sanitation and health conditions is well–known. A study of WHO (2008) focused on estimating the burden of disease and mortality directly related to water, sanitation and hygiene. This report notes that water, sanitation and hygiene related factors contribute to 3.4 million deaths (or 5.4 per cent) out of some 59 million deaths from all causes and to a burden of disease of 128 million DALYs (8.4 per cent) out of 1.5 billion DALYs of globally from all causes. Worldwide, the principal contributors to the burden of disease due to water, sanitation and hygiene included: diarrhoeal disease (50 per cent of DALYs), malnutrition (6 per cent), consequences of malnutrition (13 per cent), malaria (11 per cent) and drowning (6 per cent). (See the bottom panel in figure 3.) In Asia region, three main contributors to burden of disease were: diarrhoeal disease (53 per cent), consequences of malnutrition (17 per cent) and lymphatic filariasis (8 per cent).

Figure 3: Burden of disease attributed to water, sanitation and hygiene related factors (SEARO denotes South and East Asia region of WHO)



Source: Based on WHO,2008 and data update from WHO.

Another WHO (2009a) study of environmental burden of disease also noted that (unsafe) water supply and sanitation are amongst the ten global health risks. Based on that report's findings, the summary of DALYs and mortality for all the risk categories for Asia-Pacific and the world based on data for 2004 are presented in Appendix 1. Worldwide, unsafe water and lack of sanitation contributed to 64 million DALYs being lost and in that regard takes the fourth rank after childhood malnutrition, unsafe sex, and alcohol abuse. Within developing countries, unsafe water and lack of sanitation in fact takes the second rank after childhood malnutrition.

Re-produced below are figures pertaining only to the environmental risks identified in the report. Worldwide, unsafe water, sanitation and hygiene account for 64 million DALYs or approximately 4.22 per cent of all DALYs lost due to various risks. Within the Asia-Pacific region, unsafe water, sanitation and hygiene account for nearly 25 million DALYs or 3.5 per cent of all DALYs.

Table 1: WHO study on risks: DALYs lost due to environmental risks

Total DALYs (000s)	**World**	**South East Asia**	**Western Pacific**	**Asia-Pacific**
Unsafe water, sanitation, hygiene	64240	20176	4599	24775
Urban outdoor pollution	8747	1911	2644	4555
Smoke from solid fuels	41009	12492	5001	17493
Lead exposure	8977	4044	1531	5575
Global climate change	5404	2320	192	2512
Environmental risks	128377	40943	13967	54910
Total DALYs (all causes)	1523259	442979	264772	707751

As % of Total DALYs	**World**	**South East Asia**	**Western Pacific**	**Asia-Pacific**
Unsafe water, sanitation, hygiene	4.22%	4.55%	1.74%	3.50%
Urban outdoor pollution	0.57%	0.43%	1.00%	0.64%
Smoke from solid fuels	2.69%	2.82%	1.89%	2.47%
Lead exposure	0.59%	0.91%	0.58%	0.79%
Global climate change	0.35%	0.52%	0.07%	0.35%
Environmental risks	8.43%	9.24%	5.28%	7.76%
Total DALYs (all causes)	100.00%	100.00%	100.00%	100.00%

Source: WHO (2009a)

From table 2, we can see that globally, environmental risks account for 5.3 million deaths (out of some 58.8 million attributable to all risks) or approximately 9 per cent of all deaths. Worldwide, unsafe water, sanitation and hygiene accounted for 1.9 million deaths. Within Asia-Pacific, deaths from environmental risks accounted for 2.7 million or approximately 9.8 per cent of all deaths. Deaths due to unsafe water, sanitation and hygiene were 694,000.

Table 2: WHO study on risks: mortality from environmental risks

	World	South East Asia	Western Pacific	Asia-Pacific
Unsafe water, sanitation, hygiene	1908	599	95	694
Urban outdoor pollution	1152	207	421	628
Smoke from solid fuels	1965	630	591	1221
Lead exposure	143	70	23	93
Global climate change	141	58	4	62
Environmental risks	5309	1564	1134	2698
Total Mortality (all causes)	58772	15279	12191	27470

	World	South East Asia	Western Pacific	Asia-Pacific
Unsafe water, sanitation, hygiene	3.25%	3.92%	0.78%	2.53%
Urban outdoor pollution	1.96%	1.35%	3.45%	2.29%
Smoke from solid fuels	3.34%	4.12%	4.85%	4.44%
Lead exposure	0.24%	0.46%	0.19%	0.34%
Global climate change	0.24%	0.38%	0.03%	0.23%
Environmental risks	9.03%	10.24%	9.30%	9.82%
Total mortality (all causes)	100.00%	100.00%	100.00%	100.00%

Source: WHO (2009a).

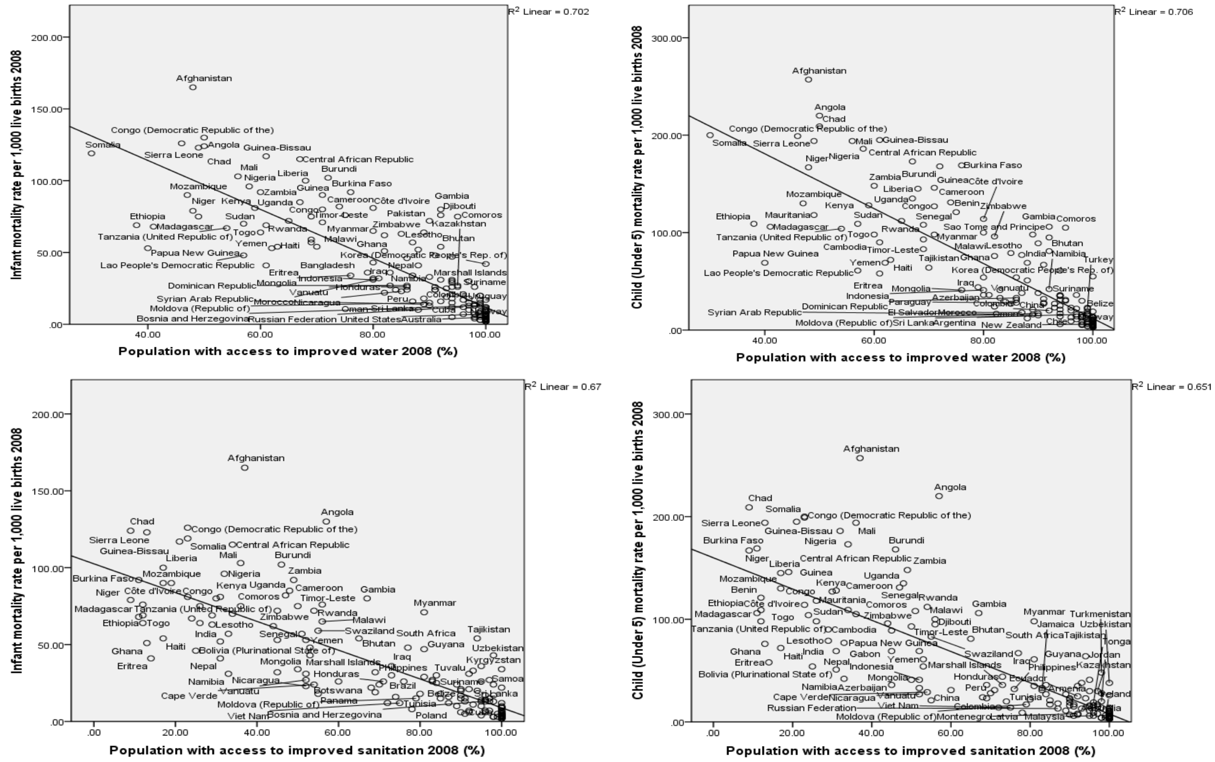
The WHO environmental burden of disease study (Pruss-Ustun and Korvalan, 2009) points out that 24 per cent of burden of disease worldwide and some 23 per cent of deaths can be attributed to environmental factors. Developing countries bear much of the environmental burden of diseases disproportionately. The report noted:

> "…The largest overall difference between WHO regions was in infectious diseases. The total number of healthy life years lost per capita as a result of environmental burden per capita was 15-times higher in developing countries than in developed countries. The environmental burden per capita of diarrhoeal diseases and lower respiratory infections was 120- to 150-times greater in certain WHO developing country subregions as compared to developed country sub-regions. These differences arise from variations in exposure to environmental risks and in access to health care." (p. 11).

The report noted that diarrhoea accounts of about 4 per cent of global burden of disease but nearly 94 per cent of diarrhoeal disease is attributed to environmental factors, in particular water and sanitation.

The results in figure 4 below clearly highlight the association between lack of access to water and sanitation and infant and under-5 year child mortality.

Figure 4: Top-left: access to water and infant mortality; top-right: access to water and under-5 child mortality; bottom-left: access to improved sanitation and infant mortality; bottom-right: access to improved sanitation and under-5 child mortality



Source: Author's calculation based on data from UNDP (2010)

Summary: The analysis presented in this section clearly highlights the links between unsafe water, sanitation and hygiene and health impacts in terms of DALYs lost and mortality.

7. Climate change and access to water and sanitation: Economic and institutional factors

An important argument linking climate change and health is in terms of potential impact on water resources distribution and how this may impact on access to water and sanitation (route 1 in figure 1). In this section an attempt will be made to examine the extent to which access to water and sanitation is determined by physical factors (freshwater resources) and institutional factors.

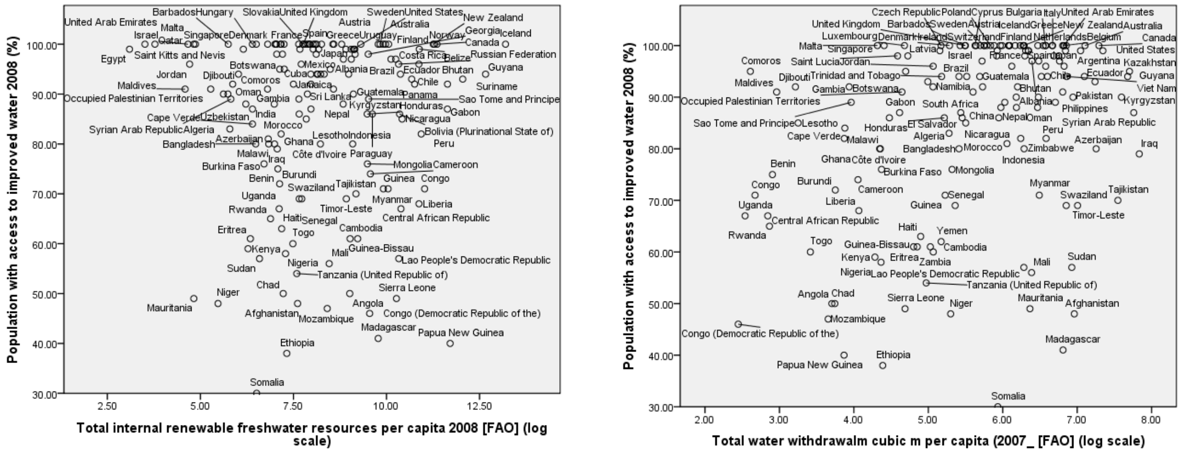
Since nation states are important actors concerning climate change negotiations, it will be useful for policy to examine the links and relationships using national level aggregate data. Some data is available from UNDP Human Development Report and from Food and Agriculture Organisation's *Aquastat* database.

The starting point is to consider natural resource constraint or carrying capacity argument. Thus access to water is determined by availability of fresh water resources.

Access to water = f (Water resources)	(1)

In this view, access to water is predominantly determined by natural factors such as precipitation or annual renewable freshwater resources. The same extent of precipitation results in different levels of the amount of annual renewable freshwater resources available in a country. Even when the same extent of freshwater is available, countries differ by how much of that water is used.

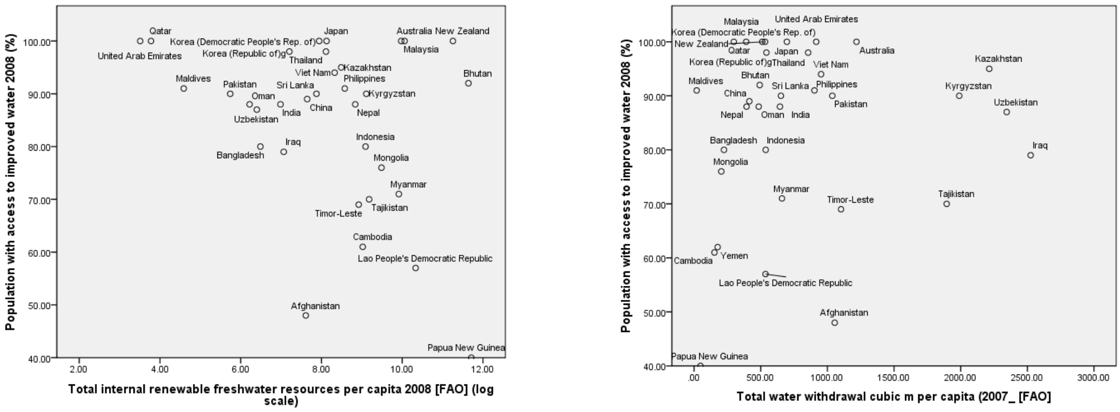
Figure 5: Lack of relationship between water resources and access to water.



Source: Author's calculations based on data from FAO Aquastat database and UNDP,2010.

From the evidence presented in figure 5 above, it appears that access to water (% of population having access to safe water) is unrelated to the extent of (internal renewable) freshwater resources available or the extent of such resources actually withdrawn.

Figure 6: Lack of relationship between water resources and access to water: Asia-Pacific region



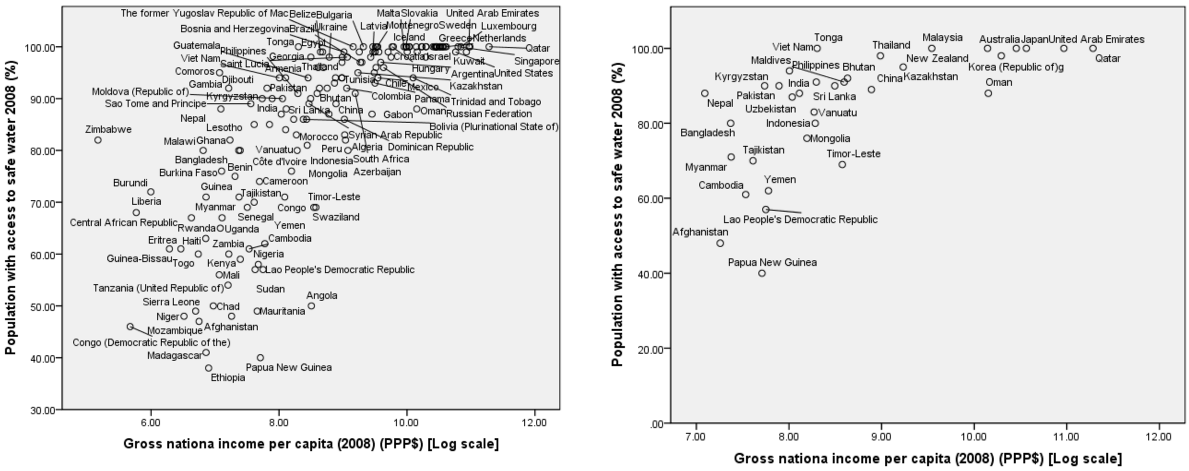
Source: Author's calculations based on data from FAO (2011) and UNDP,2010.

The Environmental Kuznets Curve (EKC) view-point such as the results presented in Shafik and Bandyopadhyay (1992), Shafik (1994) and Grossman and Krueger (1994) suggested that access to safe water is determined by income (GDP per capita)[1]. This can be summarised thus:

$$\text{Access to water} = f\,(\text{Income}) \qquad (2)$$

However, countries at the same level of income differ in the proportion of population having access to safe water.

Figure 7: Same income- differences in population with access to safe water.



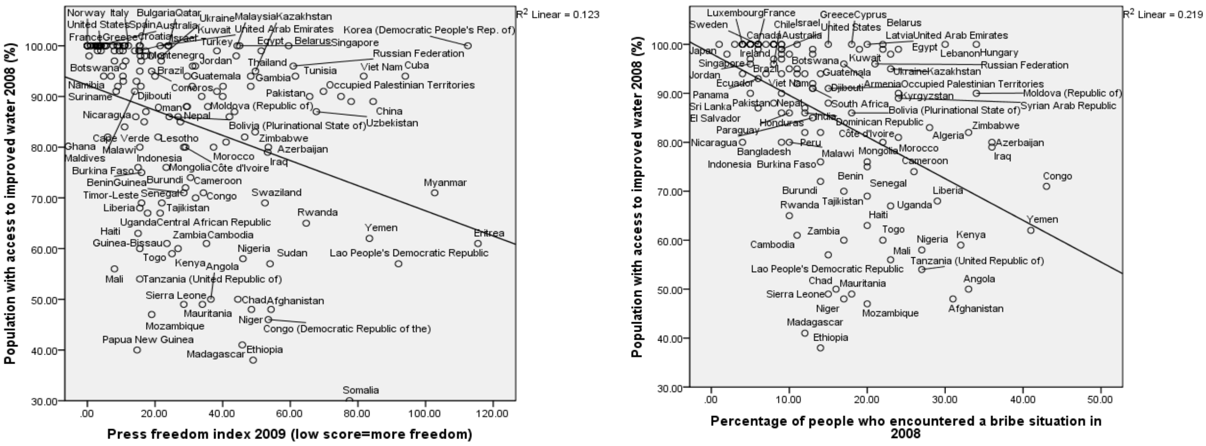
Data for 160 countries worldwide Data for 35 countries in Asia-Pacific

Source: Author's calculations based on data from UNDP,2010.

Following the work of various researchers such as Wade (1987), Ostrom (1990 and 2005), Bardhan (1989, 1993, and 2000), Uphoff et al (1998), Chopra and Duraiappah (2002), the role of institutions –formal as well as informal and collective- in determining access to water (though many of them in relation to irrigation) has been recognised. Institutions are humanly devised constraints that shape economic interactions (North,2003). While there is no single measure of institutions that can capture the rich tapestry of diversity of institutions that exists in any society, some indicators of agency and governance quality can be used as proxies or indirect indicators of dysfunctional institutions.

[1] Various critics of EKC view (such as Arrow et al,1995; Dasgupta and Maler,1997; Panayotou,1997; Bhattarai and Hammig, 2001,Dasgupta et al,2002; Stern, 2004) question the assumption of lack of feedback effect and the importance of institutional evolution.

Figure 8: Fewer people have access to water in poorly governed societies



Source: Author's calculations based on data from UNDP (2010)

Simple, imperfect and limited as they are, the two relationships depicted in figure 8 above indicate that access to improved sources of water is associated with less corruption and more freedom of press (i.e., more accountability and voice).

Therefore, access to water seems to be determined by income as well as institutional quality:

$$\text{Access to water} = f\,(\text{Freshwater Resources, Income, Institutions}) \qquad (3)$$

This is tested with data for some 111 countries. Gross national income per capita and corruption are the only significant variables. The extent of renewable freshwater resources per capita or the extent of water withdrawal per capita (in another regression not reported here) were not significant.

However, in the case of access to improved sanitation, apart from gross national income per capita, the extent of freshwater withdrawal per capita was also significant.

Table 3: Descriptive Statistics of variables included in regression analysis

	N	Minimum	Maximum	Mean	Std. Deviation
GNI per capita (2008 PPP$)	183	176.00	81011.0	13463.0874	15300.58429
Satisfaction with freedom of choice (% of population) 2009	147	24.00	96.0	65.5986	16.59743
Press freedom index 2009 (low score=more freedom)	169	.00	115.5	29.9036	25.89544
Percentage of people who encountered a bribe situation in 2008	128	1.00	43.0	14.8750	9.39593
Population with access to improved water 2008 (%)	168	30.00	100.0	85.9167	17.03305
Population with access to improved sanitation 2008 (%)	168	9.00	100.0	71.0357	30.18028
Income Gini coefficient 2000-2008 [UNDP,2010]	145	16.80	74.30	40.7855	9.46036
Total internal renewable freshwater resources per capita 2008 [FAO]	169	5.16	539683.0	18118.1987	52935.28378
Population affected by natural disasters average per annum for 2000-2009 (per million people)	179	.00	156115.0	16817.5363	27420.86106

Table 4: Regression estimates –access to water

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	15.017	15.759		.953	.343		
Gross national income per capita ($PPP)2008 [Log scale] ***	10.403	1.102	.807	9.443	.000	.470	2.127
Satisfaction with freedom of choice (% of population) 2009	-.086	.071	-.084	-1.207	.230	.706	1.416
Press freedom index 2009 (low score=more freedom)	-.051	.061	-.061	-.821	.413	.632	1.582
Percentage of people who encountered a bribe situation in 2008*	-.261	.144	-.133	-1.817	.072	.643	1.556
Income Gini coefficient 2000-2008 [UNDP,2010]**	.267	.130	.148	2.050	.043	.658	1.520
Nation with a coast	-2.690	2.580	-.070	-1.043	.300	.764	1.309
Population (in thousands) 2008 [FAO] (log scale)	-.913	.809	-.074	-1.129	.262	.805	1.242
Total internal renewable freshwater resources per capita 2008 [FAO] (log scale) *	-1.282	.675	-.129	-1.900	.060	.747	1.339
Asia-Pacific dummy variable	8.219	3.238	.195	2.538	.013	.580	1.726
Population affected by natural disasters average per annum for 2000-2009 (per million people)	-4.609E-5	.000	-.069	-.978	.331	.686	1.458

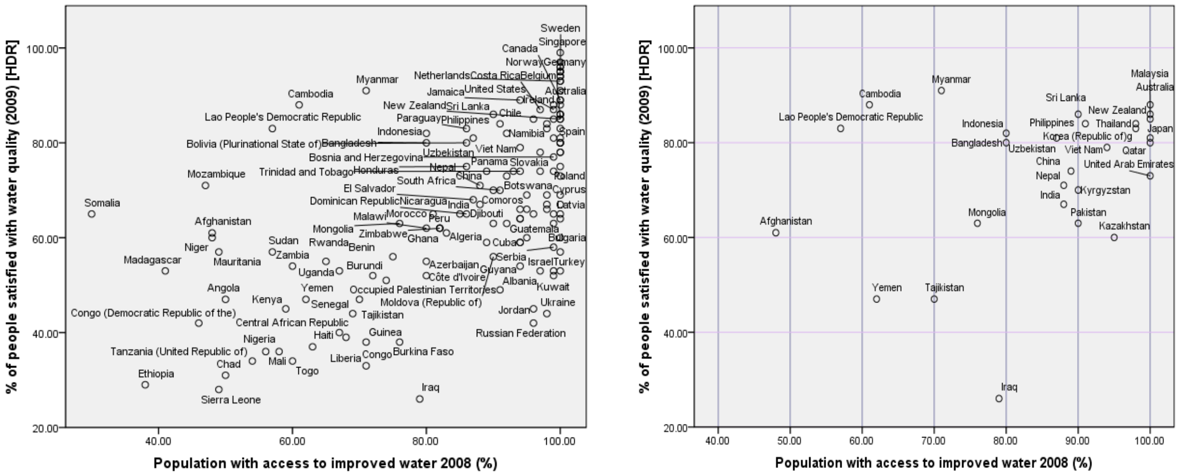
a. Dependent Variable: Population with access to improved water 2008 (%)
*b. *** significant at <1%; ** significant at <5%; * significant at < 10%.*
c. Adjusted R square 0.639.
d. To check for assumption of homoscedasticity, residuals were saved and a regression equation was estimated using the dependent variable and residuals (White test).

Impact of climate change on access to water would in turn depend on the impact of climate change on freshwater resources and on economic activity (and hence the national income). Climate change may not have a direct impact on institutions but institutions can have a mediating role on how well a society manages to maintain water security for all households. The concept of resilient institutions can be considered here.

While we do not have any variables in this analysis to capture climate change, we can draw some conjectures. The direct effect of climate change is likely to be on freshwater resources (total internal renewable water cubic metres per capita). However, the lack of significance of this variable raises doubts about the potential direct impact of climate change on water availability. The indirect impact of climate change is likely to be far greater in both intensity and magnitude. Several indirect impacts can be foreseen.

For example, impact of climate change on water resources can affect not merely the quantity but quality of water. Data from Gallup World polls suggests that even at present, in many countries where a large proportion of people do have access to water, many people are not satisfied with water quality (figure 9). With climate change, this proportion is likely to increase.

Figure 9: Access to water and satisfaction with water quality



Source: Author's calculations based on UNDP (2010)

For example, in the case of China, nearly 90 per cent of population has access to improved sources of water but only 74 per cent of the population expressed satisfaction with water quality. The corresponding numbers for India were: 88 per cent having access to water and 67 per cent expressing satisfaction with water quality. Zhang et al (2010) noted that a large number of lakes and rivers in China are classified as being polluted. Their comment below made in relation to China is equally relevant in many contexts within the Asia-Pacific:

> "…Water shortages compel populations to use contaminated sources, which might explain associations between water scarcity and health effects, such as oesophageal cancer. As industrial, agricultural, and municipal uses of water compete for an increasingly restricted supply, pollution of these resources will exacerbate shortages." (p. 1114).

Summary: The analysis presented in this section clearly highlights that how climate change translates into impact on access to water is not simple and straight forward. Whilst it is easier to predict how climate change impacts on physical quantities of water resources, what seems to matter more concerns economic conditions (namely, income per capita and income inequality) and quality of institutions (for example, proportion of people experiencing a bribe situation).

While this analysis so far has highlighted some structural relationships, from the aggregate or cross-country analysis, it is difficult to capture within country variations. Thus, the total amount of freshwater resources available per capita in a country may appear sufficient even while within country distribution of such resources could be very skewed such that much water may be available in one region and little elsewhere.

Box 1: Rural urban disparity in access to water in Papua New Guinea

Papua New Guinea consists of the eastern half of New Guinea island and several islands including New Britain, New Ireland, North Solomons and Manus islands. Of PNG's 6.6 million population, nearly 87 per cent is rural. The climate of Papua New Guinea is described as humid with average precipitation of 3,142 mm per year. The overall internal renewable freshwater potential is estimated to be 801 cubic km per year. This makes PNG water-rich with fresh water availability of more than 121,000 cubic metres per capita. However, actual amount of water withdrawn is smaller at about 13 cubic metres per capita.

Only 40 per cent of population has access to improved sources of water and 45 per cent has access to improved sanitation. However, the overall average figure does not fully reflect the rural urban disparity in access to water and sanitation. 87 per cent of urban population has access to water as compared with only 33 per cent of rural population. Likewise, 71 per cent of urban population and 41 per cent of rural population are served with improved sanitation facilities. In the capital city Port Moresby and a few other towns, sewerage systems are operational though population in slums do not have access.

In a country where a significant majority of the population lives in the rural areas, increasing access to improved water supply is possible but requires concerted efforts (see Bhutan case study). Though PNG is very well-endowed with water, localised access to drinking water and pollution of water resources especially due to natural resource (mineral) activities are becoming matters of concern.

Climate change is likely to exacerbate these stresses and exacerbate the vulnerability of rural population especially children. Already, water-borne diseases, especially typhoid and other diarrhoeal diseases account for about a third of all deaths among children (Kingston, 2004). Reducing rural-urban disparity and reducing vulnerability to health impacts appear to be policy priorities.

Source: FAO 2010a.

Box 2: Variation in water resources and access to water in Timor Leste

Of some 1.1 million inhabitants of Timor Leste, overall some 69 per cent of population was estimated to have access to improved water supply in 2008. Among urban residents, nearly 86 per cent have access; among rural residents this proportion is 63 per cent. Though overall precipitation is around 1,500 mm per annum, there is considerable variation from 565 mm along the north coast to over 2,800 mm in the central and western mountainous areas (FAO,2010). Though agriculture contributes to only a quarter of the GDP, nearly 80 per cent of economically active population depend on agriculture sector. Water supply and sanitation infrastructure also suffered damage during the violence after referendum for independence in 1999.

According to the WHO (2009c), environmental burden of disease results in some 1,800 deaths per annum and loss of 64 DALYs per 1,000 inhabitants. Malaria and diarrhoea together account for 27 DALYs per 1,000 inhabitants.

The main determinants of climate change vulnerability of Timor Leste are the geographic variation in rainfall and dependence on agriculture. An ADB (2004) review suggested that for urban areas the main constraints were inadequate water resources and lack of operation and maintenance expenditures while in rural areas the main constraint was the lack of appropriate institutional capacity.

8. Water security

Water security can be applied at national, sub-national as well as personal levels. At national level, water insecurity means the aggregate quantity of water withdrawn is approaching or exceeding the limits imposed by historical, locational and technological factors. Countries in the Asia-Pacific vary in terms of the extent of internal renewable freshwater available from 5 m^3 per capita in Bahrain to 121,000 m^3 per capita in Papua New Guinea. In general, countries that have limited water resources tend to use a greater share of water that is available. If we look at the distribution of countries in relation to what proportion or internal renewable freshwater is actually withdrawn, we have a vast range whereby 4 countries in the Asia-Pacific and 26 countries in the world use less than 1 per cent of all freshwater available and 1 country in the Asia-Pacific and 18 worldwide using more water than is internally available. We can call this as ‘absolute’ approach to water insecurity. Thus, in countries which are presently using less than 10 per cent of all freshwater, ‘theoretically’ it should be possible to increase the amount of water withdrawn though there may be spatial or locational constraints. In the next category are countries where the amount of water withdrawn is between 10 and 20 per cent – where additional water withdrawal may be possible but is likely to be subject to location and technology. In the next set or category are countries whereby somewhere between 20 and 50 per cent of all internal renewable freshwater is already withdrawn. We can consider this as a situation ‘approaching water insecurity’. In the next category are countries using more than 50 per cent and in some cases more than 100 per cent of all internally available renewable freshwater resources. We can consider this as a situation of ‘water insecurity’.

Table 5: Conceptualising water security based on the share of available fresh water that is actually withdrawn

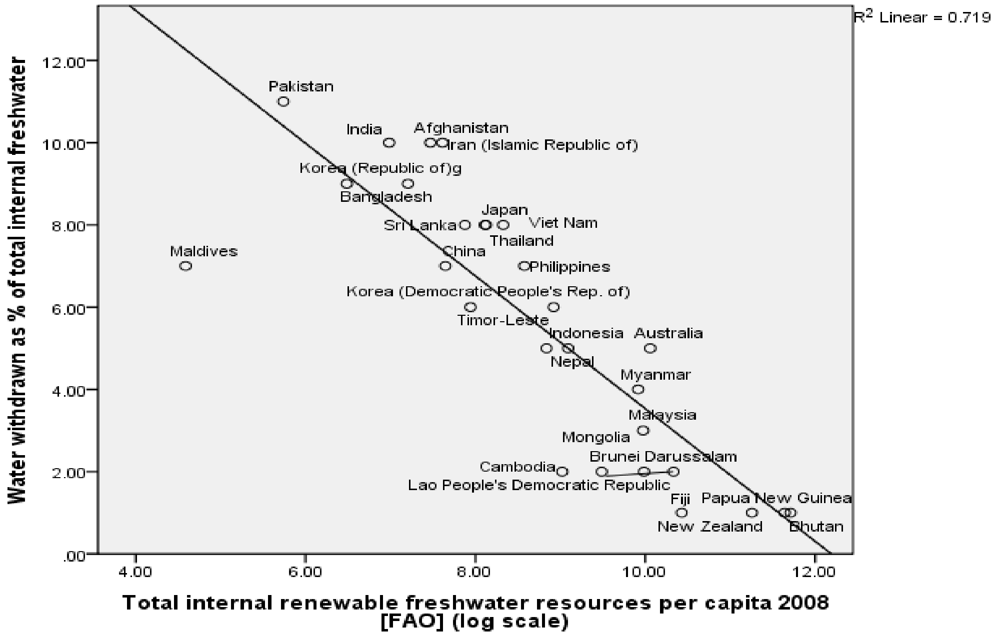
Water security category	Amount of water withdrawn as % of total internal renewable freshwater resources	Countries	Number of Countries in Asia-Pacific	All Countries
'Abundance' in theory	Less than 1%	New Zealand, Fiji, Papua New Guinea, Bhutan	4	26
	1% to 2%	Brunei Darussalam, Mongolia, Lao People's Democratic Republic, Cambodia	4	20
Relative abundance – spatial constraints	2% to 3%	Malaysia	1	9
	3% to 5%	Myanmar	1	5
	5% to 10%	Australia, Nepal, Indonesia	3	21
Spatial and technological constraints	10% to 15%	DPR Korea, Timor-Leste	2	12
	15% to 20%	Philippines, Maldives, China	3	12
Approaching water insecurity	20% to 30%	Japan, Viet Nam, Sri Lanka, Thailand	4	13
	30% to 50%	Bangladesh. Korea Republic	2	11
Water insecurity, scarcity, dependence on external sources	50% to 100%	Afghanistan, India, Iran	3	15
	Above 100%	Pakistan	1	18
Total			28	162

Source: Author's estimation based on FAO Aquastat data 2010.

This approach has two shortcomings (i) that the lines or boundaries between categories are arbitrary and choice of technology of withdrawing water is considered to be a purely economic decision and (ii) that the focus here is on water availability rather than water access.

An alternative approach is to define water insecurity in relation to the context of a given country. To do this, we can construct a statistical relationship between total internal renewable freshwater and amount of water withdrawn. Then for each country we can compare its existing position with the predicted position. It appears from figure 10 that there is a strong (negative) association between amount of internal renewable freshwater resources available and the proportion actually withdrawn. Given that the regression estimate is very high (R square 0.719), we can propose an alternative way to define water insecurity in relation to deviation above the line.

Figure 10: Water withdrawn depends on how much internal renewable freshwater is there.



Source: Author's calculation based on Aquastat 2011 data from FAO.

Thus, for example, Cambodia, Timor-Leste and Indonesia have approximately 8,000 to 9,000 cubic metres of internal renewable freshwater per capita. However, Cambodia and Indonesia use less than 10 per cent of available freshwater (and remain below the line).

Water insecurity may also depend on economic conditions. It is clear from table 6 below that the share of water withdrawn decreases with freshwater available and increases with income per capita.

Table 6: Regression Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	6.260	.749		8.359	.000		
	Total internal renewable freshwater resources per capita 2008 [FAO] (log scale)	-.969	.046	-.826	-20.912	.000	.997	1.003
	Gross national income per capita ($PPP)2008 [Log scale]	.424	.071	.237	5.995	.000	.997	1.003

Dependent Variable: Water withdrawn as % of total internal renewable water (log scale)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.872	0.760	0.757	1.14694

Predictors: (Constant), Gross national income per capita ($PPP)2008 [Log scale], Total internal renewable freshwater resources per capita 2008 [FAO] (log scale)

This analysis suggests that even small changes in the amount of water available due to climate change induced variability can tip countries from one sub-category into another and more insecure water category. There is also a positive message. This analysis also suggests that for many countries climate change adaptation strategies to overcome fluctuations in water availability are indeed possible.

We do not have data to analyse water insecurity at the sub-national level. However, the kind of analysis discussed above can be replicated at sub-national level to identify relative water insecurity within a country or a sub-region.

A new approach to water insecurity using WHO-UNICEF JMP data

Some indication of water insecurity at the level of individual can be examined from the proportion of people who have access to water. We can define various dimensions of insecurity:

Dimension 1: Those who have access v those who do not have access: Thus:

WS1 = f (proportion of population without improved water)

In table 7 below, this information is presented in the form of some categories. As we move from the left to the right in the table, a larger proportion of population does not have access to water (and thus, there is greater degree of water insecurity).

Table 7: Water insecurity (WS1) – (data pertains to year 2008)

Very low insecurity	Low insecurity	Medium insecurity	High insecurity
5% to 10% of population without access to improved sources	10 to 20% of population	20% to 30% of population	More than 30% of population
Viet Nam Bhutan Maldives Philippines	Sri Lanka Pakistan China India Nepal Vanuatu	Bangladesh Indonesia Mongolia Myanmar	Timor-Leste Cambodia Lao People's Democratic Republic Afghanistan Papua New Guinea

Source: Author's calculation based on JMP (WHO-UNICEF) 2011.

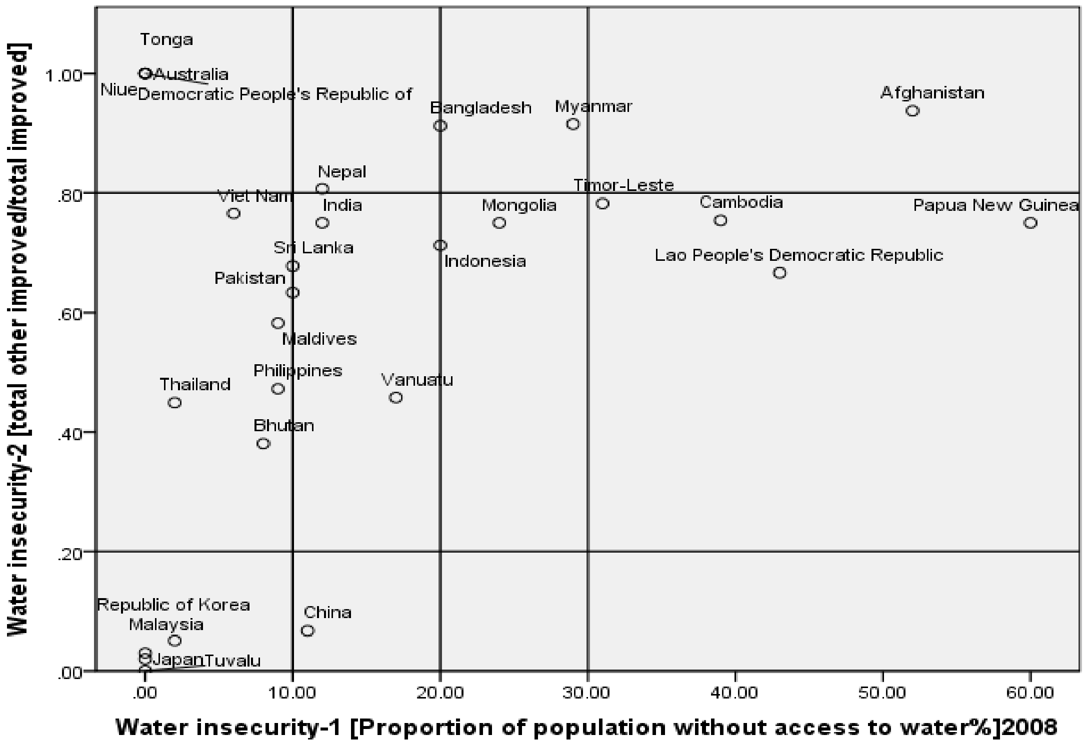
WS1 is directly relevant to target 10 of Millennium Development Goal 7. However, grouping countries into categories allows analysts to distinguish between different sets of policy priorities. Policy emphasis in high insecurity countries would be to increase access to water speedily and for those in low insecurity countries would be to maintain progress and improve on quality. Dimension 1 alone is adequate for emphasising the urgency for action in the case of 'high insecurity' countries. However, for all other countries (especially those in medium and low risk categories in the table above), this approach alone is not adequate in diagnosing policy challenges. The following discussion focuses on developing clarity on further dimensions of inequality which can be combined with WS1 indicator above to shine further light on specific aspects of insecurity.

Dimension 2: *Entitlement insecurity* caused by some people having piped water and not others. This can be captured by:

WS2 = f (Proportion with 'other improved' water/total population with improved water)

This ratio is useful when read along with WS1 indicator. When this ratio is closer to zero, a majority of those having access to improved sources will have access to a tap. As this ratio gets closer to 1, almost everyone in the population is having access to 'other improved' sources. In the middle there is a range whereby a proportion of all those who have access to improved sources but not access to tap. In that sense, the ratio can be an indicator of systemic inequality and the lack of entitlements (if a significant proportion of people need to depend on 'other improved sources' while some people have access to a tap). Any lines or boundaries are arbitrary but we can illustrate a few examples (see figure 11).

Figure 11: Entitlement insecurity caused by lack of entitlements



Source: Author's calculation based on JMP (WHO-UNICEF) 2011.

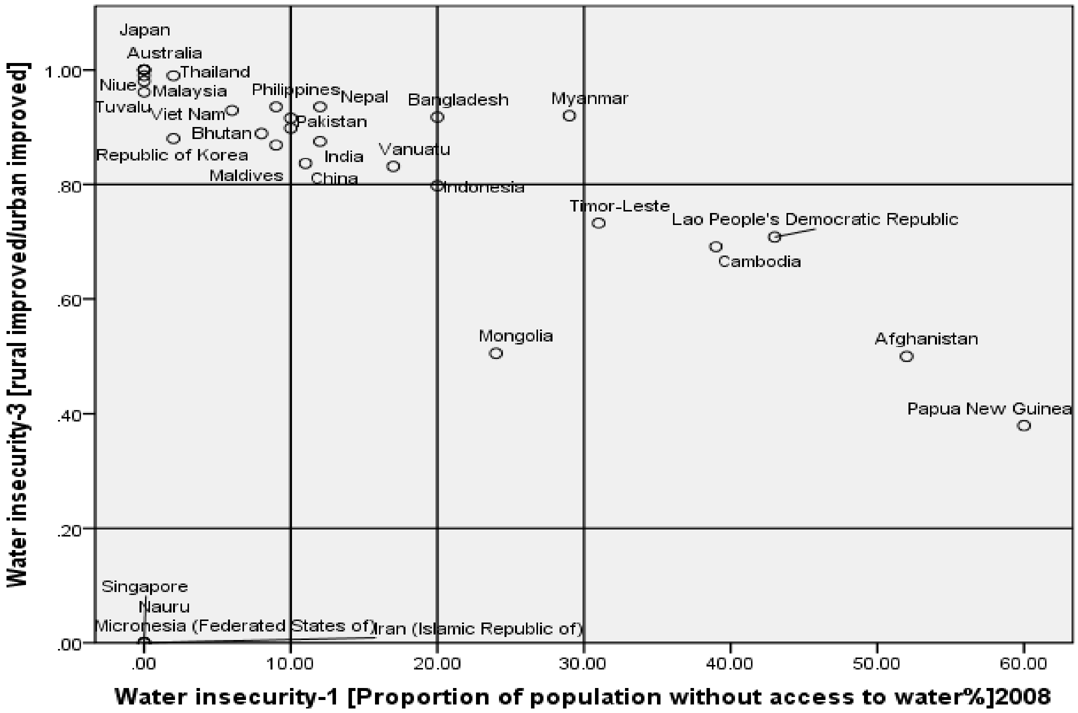
In China and India, less than 15 per cent of population does not have access to water. However, of those who do have access to water, almost all households in China have access to tap whereas in India, nearly 75 per cent of them have access to 'other improved sources'. In the event that climate change triggers changes in water availability, then this divergence is likely to create a 'water divide' in India between those who have secure access in the form of a yard tap and those with insecure access in terms of 'other improved sources'. In Bangladesh and Nepal, more than 80 per cent of people have access to water (or 20 of households do not have access) but of those having access, most of them have 'other improved sources'(hence WS2 indicator above 0.8).

Dimension 3: Insecurity caused by urban bias: Those in the urban areas who have access v those in the rural areas who do not have access:

WS3 = f (Proportion of rural population with improved water/
Proportion of urban population with improved water)

In the absence of urban bias, this ratio will be close to 1. Where there is significant urban bias in the provision of water, this ratio will approach zero.

Figure 12: Insecurity caused by urban bias



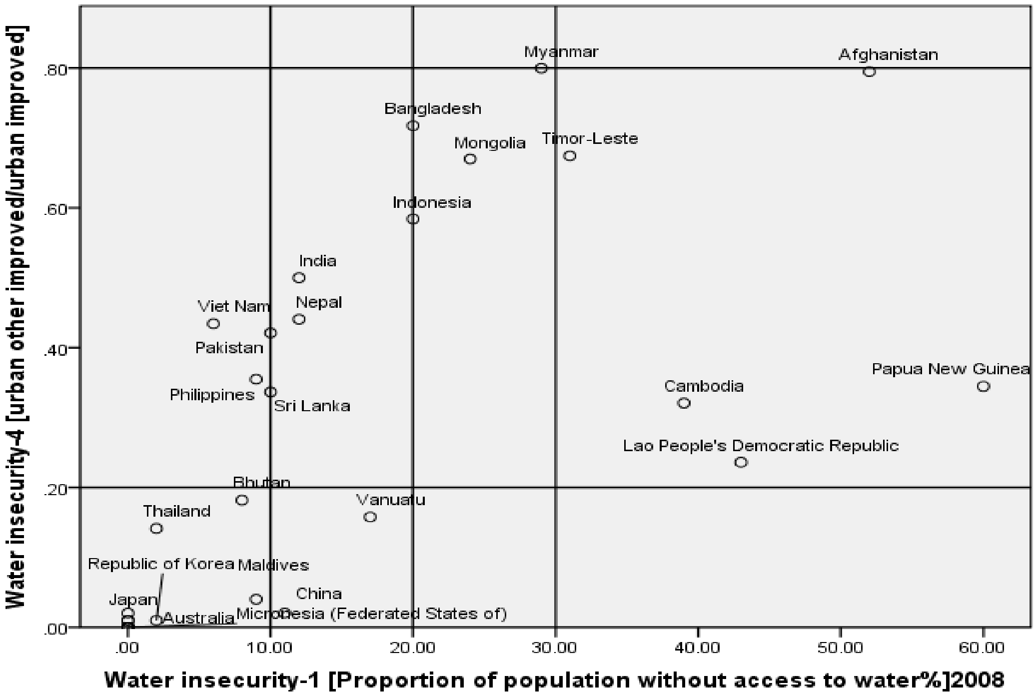
Source: Author's calculation based on JMP (WHO-UNICEF) 2011.

In figure 12, we can see that amongst countries which were earlier considered as 'low insecurity' countries based on WS1 alone (in table 7), in China and India, there is some evidence of urban bias. In medium and high water insecurity countries such as Mongolia, Afghanistan and Papua New Guinea, there is a clear evidence of urban bias. Thus there is likely to be some degree of water insecurity due to rural-urban difference in those who have access to improved sources of water.

Dimension 4: *Intra-urban inequality*: This is constructed as an indicator of those with piped water v those with improved but not piped water. This is captured by the ratio:

WS4=f (Proportion of urban with improved water/ urban population with improved water).

Figure 13: Lack of entitlements within urban population with access to water



Source: Author's calculation based on JMP (WHO-UNICEF) 2011.

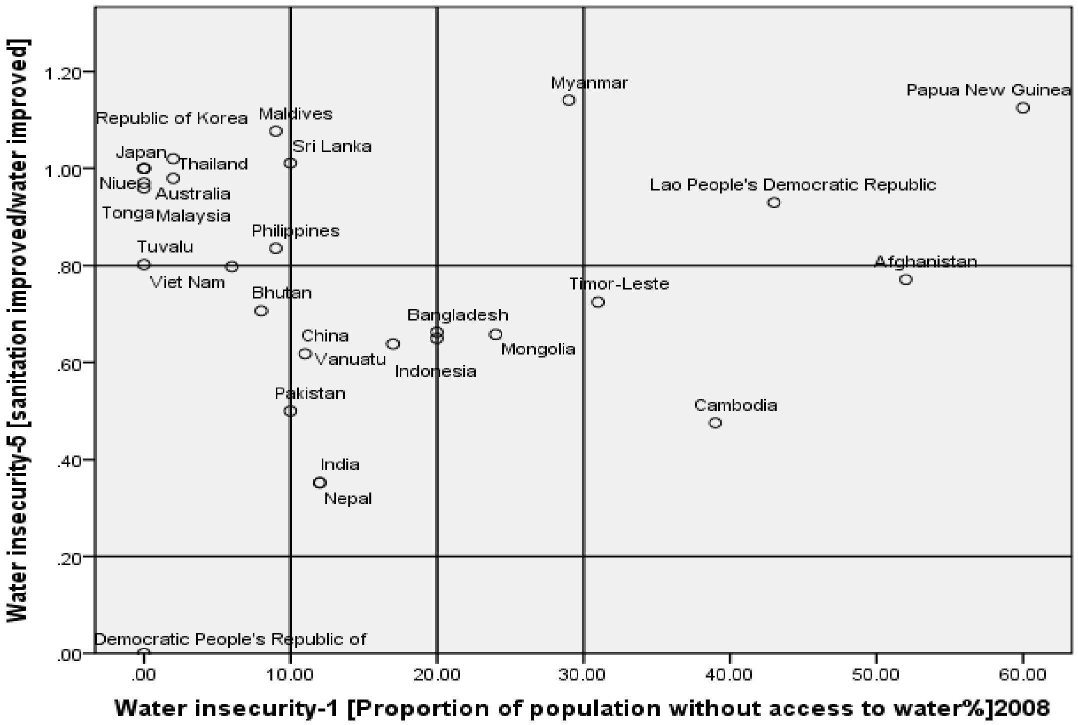
In appears from figure 13 that in Myanmar, Afghanistan, Bangladesh and Mongolia [group 1 countries], most of the urban households have access to 'other improved sources'. In Thailand, Bhutan, Vanautu, Maldives and China [i.e., group 2 countries], less than 20 per cent of urban households with access to water depend on 'other improved sources'. However, in India, Viet Nam, Pakistan, Nepal, Philippines, Cambodia and Papua New Guinea [or group 3 countries], between 30 and 55 per cent of all urban households depend on 'other improved sources'. In the event of climate induced water shortages, intra-urban conflicts are more likely in the third group of countries.

Dimension 5: *Health vulnerability*: Those with improved water but without improved sanitation.

WS5 = f (Proportion with improved sanitation /Proportion with improved water)

This insecurity is broadly an indicator of health risks. Where this indicator approaches 1, it is likely that water and sanitation investments are based on an understanding of health risks (especially diarrhoeal disease risk). Where (after controlling for access to water) this indicator approaches zero, that means even though access to water may have been improved, diarrhoeal disease risk would remain significantly high.

Figure 14: Health vulnerability related water insecurity



Source: Author's calculation based on JMP (WHO-UNICEF) 2011.

From figure 14, it can be seen that though earlier, based on WS-1 (i.e., proportion of population not having access to improved sources of water), China, Sri Lanka, India and Nepal were all placed in the same category as 'low insecurity' countries, here we can see that only Sri Lanka appears to have made progress in both water and sanitation access whereas in India and Nepal this ratio is 0.3 (i.e., for every 100 people having access to improved sources of water, only 30 people have access to improved sanitation).

Similarly, among the countries previously placed in the category of 'medium insecurity', in Bangladesh, Mongolia, and Indonesia, there is a need to improve both access to water and sanitation.

Water security of vulnerable populations

A further approach to examining water insecurity is to analyse the vulnerability of specific groups or populations. Some examples are discussed here.

a. *Megacities*: Out of 21 megacities (population in excess of 10 million), 10 are in Asia-Pacific region. A few other cities in the region already have populations very close to this threshold and will join this group in the next few years. A number of these are also 'coastal' cities and population in these cities is already vulnerable to flooding due to variability in precipitation. Future climate change is likely to increase the risks of coastal flooding. Such flooding puts at risk water and sanitation infrastructure. Population density of such cities makes them highly vulnerable to infectious disease outbreaks, especially, cholera, typhoid, and other diarrhoeal diseases.

b. *Slum population*: Another indicator of water insecurity is the extent of population living in slums in urban areas. From table 8 below, it is apparent that as of 2005 when data was available for a number of countries, some 430 million people were living in slums. The definition of a slum household is a household living in a shelter lacking in any one of the following: improved water, improved sanitation, durable shelter, sufficient living area, and security of tenure. Inevitably, a significant proportion of such population remain without improved access to water and sanitation. Though there have been concerted efforts to improve access, constraints that block progress include poor choice of technology by utility providers, gaps in meeting initial capital costs, lack of legal titles to land and institutional problems (i.e., while negotiating participation of all stakeholders requires appropriate political institutions, water infrastructure is often the responsibility of predominantly technocratic institutions).

   There is also a debate whether privatisation or private sector participation in urban water services results in disempowerment of slum population. In some Latin American countries, there is evidence to suggest that more people including poor households gained access to water from privatised utilities than from public utilities. However, evidence in Asia-Pacific has been mixed with some significant private sector involvement in East Asia (China, Malaysia, and to some extent Philippines) while in general there has been considerable reluctance to private sector involvement in water supply in South Asia.

Table 8: Urban population living in slums

Slum population in urban areas	1990	1995	2000	2005	2007
Afghanistan	2,458,024				
Bangladesh	18,987,750			25,183,914	
Bhutan	60,900				
Cambodia	869,697			2,309,403	
China	137,272,376	153,984,865	169,599,869	174,586,910	173,987,716
India	120,745,903	122,376,256	120,116,801	113,222,671	109,501,151
Indonesia	28,407,172	29,912,074	30,620,311	28,573,650	26,852,240
Iran (Islamic Republic of)	17,093,798			14,581,085	
Korea, Republic of	11,728,393				
Mongolia	866,000			869,137	
Myanmar				6,703,422	
Nepal	1,573,656			2,595,102	
Pakistan	17,620,080			26,189,233	27,508,317
Philippines	16,223,587			23,174,910	23,891,071

Sri Lanka	899,248				
Thailand	1,997,580			2,061,180	
Viet Nam	8,100,345			9,192,230	
Total	**384,904,509**	**306,273,195**	**320,336,981**	**429,242,847**	**361,740,495**

Source: UN Statistics (MDG indicators database)

A human right to water is considered to be relevant to all households but it can particularly work in empowering households living in slums to gain access to water.

c. Mountain societies

Though in principle many mountain regions have higher level of water resources per capita, such resources are not easy to access. As a result, population in mountainous areas often faces a 'double jeopardy' both from heavy rainfall and associated health burden during rainy season and lack of access to improved water within reasonable distance during the rest of the year. As seen from the case study of Papua New Guinea, a significant proportion of population in such societies face water insecurity throughout the year. Climate change is likely to increase such risks.

However, as the case study of Bhutan indicates, with concerted and long term action, it is possible to significantly increase access to safe water and sanitation.

Box 3: Bhutan's success in improving access to water and sanitation

The Kingdom of Bhutan is a land-locked nation in the Eastern Himalayas. It has a population of approximately 690,000 persons. It has very diverse climates with sub-tropical systems in the plains and lower foothills to cold-temperate climate in the mountain areas. Annual average precipitation is 2,200 mm but there is significant variation from around 500 mm is Gidakhom near Thimpu to around 21,000 mm in Samdrup Jhongkar district. At the First Asia Pacific Water Forum in Japan in 2007, the Prime Minister of Bhutan highlighted the retreat of glaciers and the threat of floods caused by glacial lake bursts. With climate change, such events are likely to become more frequent and devastating.

Since 1974, UNICEF has been involved in the development of rural water supply and sanitation (RWSS) programme by way of developing small scale and appropriate technological models. By 1982 it was estimated that 10 per cent of Bhutan's population benefited. Steadily, rural population's access to water and sanitation has been gradually increased. As the WHO assessment noted, by 1990, 30 per cent of rural population and 60 per cent of urban population had access to water.

According to the 2007 Bhutan Living Standards survey some 90.9 per cent of all households had access to improved sources of water. It is particularly noteworthy that over 88 per cent of rural households had access to improved sources of water. The 2008 MDG Report of Bhutan noted that with the exception of one district, namely, Gasa where 57 per cent of households had access to water, in all other districts, over 80 per cent of population had access to improved sources of water.

Continues…

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Progress in access to improved latrines was greater with 60 per cent of rural population and 80 per cent of urban population having access. In 1993, a Royal Decree withdrew subsidy for building latrines and the law required that every household is responsible to build a latrine at their own cost. While sanitation coverage in rural areas increased from 50 per cent in 1990 to 87 per cent in 2000, during the same period, the coverage in urban areas actually decreased from 80 per cent to some 77 per cent mainly due to rapid growth in urban population due to rural to urban migration. Overall, sanitation coverage increased from over 66 per cent in 1990 to nearly 88 per cent by 2000 and to nearly 96 per cent by BLS survey in 2007. This is significantly greater than the South Asian average of 34 per cent (in 2005). The 2008 MDG report noted that Bhutan's success in increasing access to both water and sanitation is largely due to the success of the 1974 RWSS programme. Source: Government of Bhutan and UNDP (2008).

This case study suggests that developing appropriate technological solutions, piloting new approaches, training local people, up-scaling and maintaining steady progress, using incentives where necessary, combining legislation and moral persuasion are all important in improving access to improved sources of water and sanitation in all countries, but more so in mountainous regions.

d. Small islands

Climate change is a threat to access to water in small island states such as Maldives, Kiribati, Nauru and Vanuatu. At the first meeting of the Asia-Pacific Water Forum at Beppu in Japan in December 2007, representatives of Asia-Pacific Small Island States highlighted the vulnerability of their freshwater resources to projected sea level rise due to climate change.

Box 4: Case study- Water supply and sanitation in Maldives

The Republic of Maldives has a population of nearly 300,000 persons. 60 per cent of population lives in rural areas (Governmet of Maldives,2009a). Though the country consists of some 1,192 islands, fewer than 200 are inhabited. A third of the nation's population lives in Male the capital. Annual rainfall is approximately 2,000 mm. Much of the rainwater is harvested or collected from roof tops and stored in tanks for use. Maldives does not have any permanent rivers or streams; only freshwater is found in groundwater 'lenses' or small pockets. These are highly susceptible to saline water intrusion. All the groundwater sources near the capital have become brackish or saline.

According to WHO-UNICEF Joint Monitoring Programme, nearly 86 per cent of urban population and 2 per cent of rural population has access to improved sources of water. However, 86 per cent of all households depend on desalinated water supplied by pipe. The Male Water and Sewerage Company Private Limited (MWSC) supplies water and sanitation services in the capital and four other atolls. In January 2010, Hitachi Plant Technologies Limited took a 20 per cent stake in the MWSC. Hitachi's Singapore based subsidiary Aquatech is a major producer of reverse-osmosis technology. On average, households spend about 6 to 9 per cent of household income on water. This is significantly higher than the 5 per cent figure which is normally considered as the basis for defining water-poverty.As per the Census of 2006, out of 46,000 households, only about 5 per cent did not have access to toilet. However, of those who did have access, nearly 23,250 households connected to septic tank while some 17,000 households had toilet connected to sea (Government of Maldives, 2009b)

Continues…

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In 2008, some 6,000 cases of diarrhoea were reported for children under the age of 5 years and another 12,000 cases were reported for those above 5 years of age (Government of Maldives, 2009c) . A majority of these cases were from atolls other than the capital city. There have also been some 1,800 cases of dengue fever and 175 cases of typhoid in 2008.

In 2008, some 6,000 cases of diarrhoea were reported for children under the age of 5 years and another 12,000 cases were reported for those above 5 years of age (Government of Maldives, 2009c) . A majority of these cases were from atolls other than the capital city. There have also been some 1,800 cases of dengue fever and 175 cases of typhoid in 2008.

Tourism is the mainstay of the economy; however, freshwater availability is crucial to tourism as well. Annually, some 500,000 tourists are estimated to visit Maldives. If we assume that average duration of stay is one week, this is equivalent to increasing the population of the islands by 10,000 persons.

This case suggests that for small islands, access to freshwater can be an important dimension of vulnerability to climate change in addition to sea level rise.

a. Disability and access to water

Though disability is not included discussion of vulnerable people in WG2 report of AR4 of the IPCC (2007a), there are two dimensions to consider disability with regard to access to water and one dimension with regard to climate change.

With regard to access to water, the first dimension concerns a disabled person's access to safe water and the issue of fairness. As discussed in section 3 above, Amartya Sen's capability approach clearly highlights how the same quantity of resources may not translate to same well-being freedoms due to individual circumstances. The so called 'conversion factor' i.e., the mechanism that allows an individual to convert resources into outcomes can vary significantly from person to person. The amount of water required per day varies due to cultural values, temperature and other factors. However, since the definition of improved access to water includes in it a subjective judgement about such water being available within a 'reasonable' distance, there is a danger that such judgements completely ignore the issue of access to water by disabled persons (whose definition of reasonable distance may well depend on mobility, availability of a carer and so on). This does not mean that disabled persons do not have access to water. Though we took the example of a physically disabled person here, it needs to be noted that the fundamental issue is about the freedoms of persons with any form of disability including mental or psychological disability. However, definitions addressed to an average citizen may not reflect the fact that most citizens do not fit the profile of average citizen. In almost all Asia-Pacific countries, existing social norms encourage compassion and require able-bodied persons to assist disabled persons. However, such social norms are not adequate to guarantee access to water as a matter of right.

The second dimension concerns causality in that lack of access to improved water and sanitation may have been a primary or secondary cause of disability. Thus, the question is not about access to water by a disabled person but whether lack of access was responsible for causing disability in the first place. For example, contaminated water may result in diarrhoea or intestinal nematode infections which in turn cause malnutrition which may have caused contributed to disability. For example, poliomyelitis is caused by a virus that is transmitted by faecal-oral contamination. In the Asia-Pacific, polio is endemic in Afghanistan, India and Pakistan and it appears to have been reimported in China and Nepal. Globally, 642 cases of wild poliovirus (WPV) cases were reported in 2011 – of these nearly 300 were in Asia and the Pacific. Other water borne infectious diseases that can result in disability include onchocerciasis or fialriasis (globally 66% attributed to water and sanitation – WHO,2008).

Data on disability is fairly limited. In high income countries such as Australia and New Zealand, close to 20 per cent of population is considered to have disabilities. However, in developing countries, there is considerable under-estimation and under-reporting of disability. Data from India and Indonesia for example put disabled persons to be about 1 to 3 per cent of population.

Notwithstanding these data limitations, it can be hypothesised that (a) disabled persons already face difficulties with regard to access to water and sanitation in many of the developing countries in Asia and the Pacific (b) such individuals are likely to be more vulnerable in the case of disasters; (c) with climate change as the likelihood of disasters increases, vulnerability of the disabled people will also increase; (d) as climate change accentuates spatial and temporal distribution patterns, it is likely to exacerbate competition to control water resources which may worsen the outcomes for all vulnerable people including the disabled persons.

Climate change and water insecurity

Climate change in Asia-Pacific will have two kinds of impacts on water resources – in some regions such as Central Asia, the summer precipitation is likely to decrease while in many other parts including in Northern Asia, East and South Asia and most parts of South East Asia, summer precipitation is likely to increase. As such, increased flow in rivers poses greater flood risk and associated hazards.

Though the foregoing analysis of water insecurity is a static analysis focusing on data from year 2008, it highlights vulnerabilities that already exist even in countries that have made significant progress in increasing the proportion of population with access to improved sources of water. Climate change is highly likely to accentuate and worsen some of these insecurities and diminish the impact of significant progress. The methodology suggested here needs to be replicated with details of sub-national level data to 'climate proof' water security.

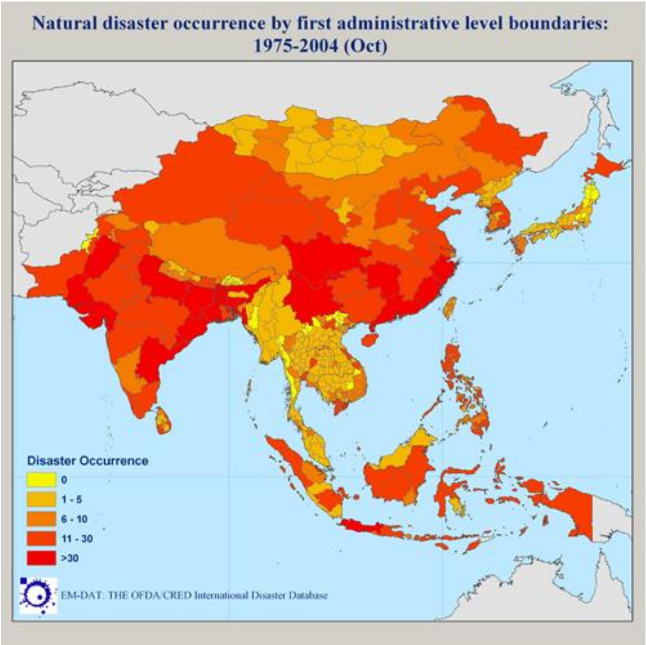
A human right to water as recommended at the UN General Assembly in July 2010 and supported by several nations including those in the Asia-Pacific can be useful in securing the rights of the vulnerable. It is particularly helpful in countries within the 'low insecurity' and 'medium insecurity' categories where even while one form of insecurity (namely, proportion of population without access to 'improved sources') has been decreased, there remain significant challenges for progress due to continued and institutionalised forms of inequality in access to water. However, in my earlier analysis (Anand,2007b) I have argued that formalising a human right to water through legislation is perhaps merely a first step. Unless the full extent of institutions are developed to clearly assign the roles and responsibilities of duty-bearers and how they will be held to account, it appears that a formal human right to water may remain ineffective and limited in scope.

9. Climate change-Disasters- Water and sanitation- Health

As already noted in section 4 above, the report of the WG1 of the AR4 suggested that the Asia-Pacific region is likely to experience greater frequency of climate extremes. This is likely to increase the frequency of events such as cyclones (especially in coastal regions in South East and South Asia), floods (in South Asia and parts of East Asia). The United Nations (2011) Global Assessment Report on Disaster Risk Reduction notes that between 1970 and 2010, the total number of tropical cyclones has remained more or less the same at around 86 cyclones per decade; the total number of countries hit by tropical cyclones has also more or less remained at around 145. However, the number of disasters reported (and thus included in EM DAT) has increased from 21 in 1970s to 63 in 2000s.

An evaluation of World Bank's portfolio of disaster projects by the Independent Evaluation Group (IEG,2006:3) noted that the reported number of disasters had increased from less than 100 in 1975 to over 400 in 2005. The report also noted that the economic cost of disasters also increased by over 15 times during the same period. The report noted that disasters appear to strike with regular periodicity and a small number of countries appear to be far more vulnerable- for example just 10 countries accounted for 208 of 528 disaster projects of World Bank between 1984 and 2005. Four of these top ten countries are in the Asia-Pacific region – China, India, Bangladesh and Vietnam. Climate and weather patterns are involved in both rapid onset disasters such as floods and hurricanes and also in slow onset disasters such as drought.

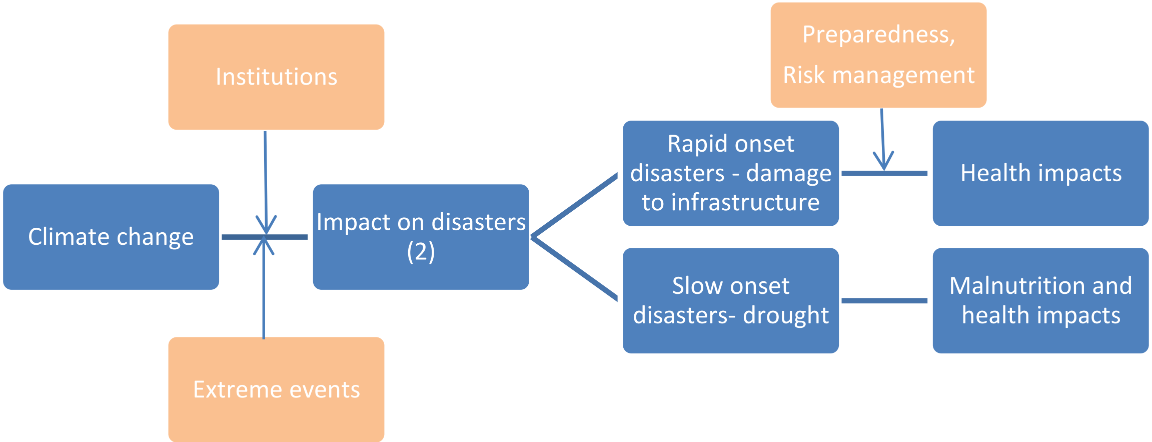
Figure 15: Disaster occurrence in Asia-Pacific



Source and copyright: EM-DAT (available from http://www.emdat.be/asia-geo-referrenced accessed on 29 April 2013).

In this section, we focus on route 2 of figure 1 presented in the introduction to this paper to which we can add institutional dimensions.

Figure 16: Climate change, disasters and health (route 2 of figure 1 elaborated)



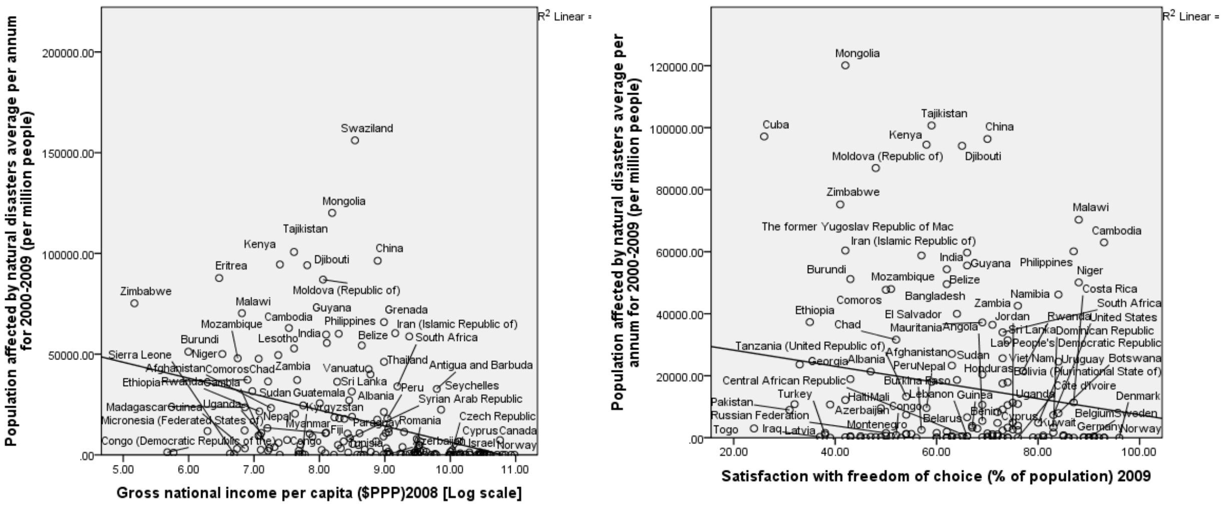
A natural hazard is a significant adverse event caused by natural factors such as volcanic activity, weather patterns, coastal or river based flooding, significant period of precipitation anomaly or aridness. Not all natural hazards turn into disasters. When a natural hazard affects social and economic well-being of a community significantly, a disaster occurs. The same magnitude extreme event may produce different magnitudes of impact. For example, even though the earthquakes in Haiti in January 2010 and Tohoku in Japan in March 2011 were both of similar magnitudes, casualties in Haiti were over 200,000 as compared with 28,000 lives lost in Japan. This highlights the importance of vulnerability and also the role of institutions. In Japan, advance warning systems, awareness of citizens as to what to do in the event of a disaster, internalising disaster risk awareness in the design and construction of buildings may have contributed to reducing mortality from disasters considerably. As Scott (2009) notes:

Disaster risk = Hazard X Exposure X Vulnerability

Toya and Skidmore (2007) and Padli et al (2010) also reach a similar conclusion with regard to association between economic conditions (per capita GDP) and disaster related fatality and economic impacts. Recently, Ambraseys and Bilham (2011) argued that mortality due to earthquakes appears to be correlated with level of corruption.

Disasters themselves need not result in health impacts and mortality. A WHO (2012) paper notes that out of 14 major floods that occurred between 1970 and 1994, only one led to a major diarrhoeal disease outbreak. The report notes that the major perceived risk of floods is contamination of water sources but notes that even when this happens as in the case of floods in Iowa in 1993 and Tajikistan in 1992, "…the risk of outbreaks can be minimised if the risk is well recognised and disaster-response addresses the provision of clean water as a priority". Our analysis of cross-country data (see figure 17) also suggests a weak association between population affected by natural disasters and both per capita income and freedom of choice (an indicator of freedoms and quality of institutions).

Figure 17: Vulnerability to natural disasters – do income and institutions have a role?



Source: Author's estimations based on data from UNDP (2010)

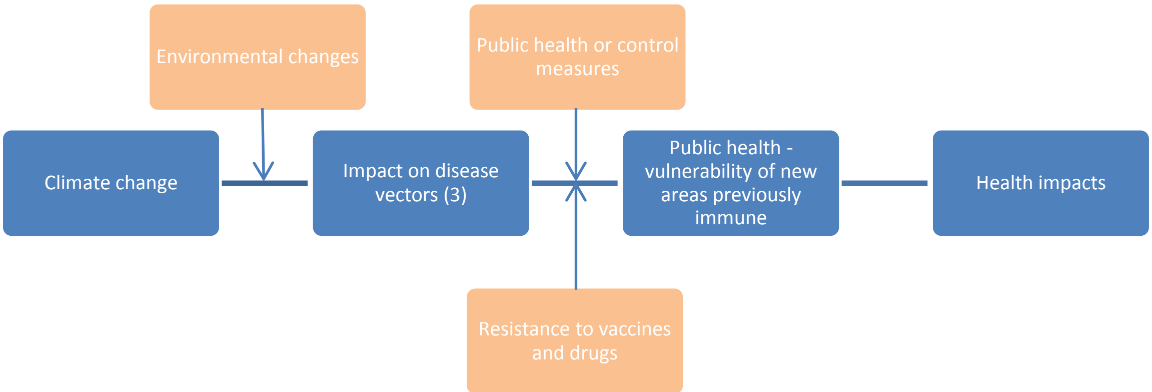
This highlights the importance of disaster preparedness, planning and risk management strategies. The IPCC (2011) report on the assessment of disaster risk is due to be released in February 2012. The summary released recently notes that: though the number of tropical cyclones may not increase, wind speeds associated with such cyclones are likely to increase; there is medium confidence that droughts will intensify in some areas. The report also notes:

> "…In many regions, the main drivers for future increases in economic losses due to some climate extremes will be socioeconomic in nature".

10. Climate change and vector borne diseases

A brief mention has already been made in the introduction of this paper about the evidence that has been presented by Colwell and various authors on the connection between sea surface temperatures and cholera outbreak in the coastal regions of Bay of Bengal.

Figure 18: Climate change-disease vectors and health (route 3 in figure 1 elaborated)



An earlier analysis of climate change and vector borne diseases suggested that malaria and dengue fever were likely to be the most important vector borne diseases in the topics and sub-tropics while encephalitis was emerging to be a public health concern (Githeko et al, 2000).

WG2 of AR4 of IPCC (2007a) stated that dengue is "…the world's most important vector-borne vial disease". The report noted that while several previous studies reported associations between spatial, temporal or spatio-temporal patterns of dengue outbreak and climate change, these results may not be entirely consistent. The report noted that "…approximately one-third of the world's population lives in regions where the climate is suitable for transmission". A more recent WHO (2009b) factsheet suggests that approximately two fifths of global population is at risk.

Worldwide some 1.3 billion people are at risk of lymphatic filariasis and over 120 million people infected of which 40 million people have been incapacitated (WHO,2011). Mosquitoes act as the vector transmitting the disease – anopheles mosquitoes in rural areas and culex in urban areas. Culex mosquitoes can breed in both freshwater and also in polluted waters in urban and semi-urban environments.

WG2 report of AR4 of IPCC (2007a) notes that the "…spatial distribution, intensity of transmission and seasonality of malaria is influenced by climate in sub-Saharan Africa". Malaria accounts for 14 million DALYs (approximately 11 per cent) of global burden of disease. Approximately, 0.5 million DALYs are lost in the Asia region due to Malaria (WHO,2008). Though overall malaria risk may be lower in the Asia-Pacific region, certain groups including children may be more vulnerable. A recent study raises a concern that most of the pregnant women worldwide at risk of malaria infection live in the Asia-Pacific region (McGready et al, 2012).The IPPC (2007a) report notes that "…Despite the known causal links between climate and malaria transmission dynamics, there is still much uncertainty about the potential impact of climate change on malaria at local and global scales". A cause for concern with regard to malaria is that the parasite is becoming drug resistant.

These brief discussions suggest that there is need for further examination of risk of spread of vector borne diseases due to climate change.

11. Conclusions

Asia and the Pacific is very diverse in terms of the extent of population with access to improved sources of water and improved sanitation. These variations are reflected in the variations in environmental burden of disease and in indicators such as infant and child mortality rates. Even in countries where a significant proportion of population is considered to have access to improved sources it is possible that a considerable section of population remain water insecure due to the definition and subjectivity of what constitutes improved access.

Water, sanitation and hygiene related factors contribute to 994 thousand deaths and a disease burden of 38 million DALYs in Asia region (WHO,2008). Main contributors to the disease burden include diarrhoeal disease (53 per cent of DALYs), consequences of malnutrition (17 per cent), lymphatic filariasis (8 per cent) and drownings (5 per cent). Both malaria and dengue contribute about 1 per cent each.

We have seen in this paper that countries differ in the proportion of internal freshwater that is withdrawn. Availability of water is only one aspect. It is not easy nor straight forward to anticipate the links between climate change, availability of renewable fresh water, technology of withdrawal and translating all this into 'access to improved water' for the population. Analysis based on data for 162 countries including 49 countries in the Asia-Pacific region indicated that income per capita remains a significant variable in explaining variation in proportion of households with access to improved sources of water. However, the hydrological factors as well as economic and institutional factors also appear to be important as well. While the possible links between climate change and hydrological resources are discussed previously (in Bates,2008), the models discussed in the present paper indicate the scope for further analysis of climate-economy interaction models and climate-institutions interactions.

The Bhutan case study indicated that through sustained programme of intervention and a combination of various policies and technologies, it is possible to make substantial increase the proportion of population with access to water and sanitation. Such institutions are also needed to increase the resilience of existing water institutions in the face of climate change and to increase the adaptation capacity of societies. While in Bhutan, UNICEF and the Government of Bhutan played a central role, the case study of Maldives suggests that there is some scope to involve private sector and promote partnerships. However, in the case of Male, it appears that residents pay a significant share of monthly income for water.

An attempt has been made here to develop a set of new indicators of water insecurity using country-level data on different aspects of access to improved sources of water and sanitation from WHO-UNICEF Joint Monitoring Programme (JMP). These indicators suggest that even in countries that have made significant progress in providing access to ‘improved sources of water’, there remain crucial aspects of insecurity due to the nature of entitlements to water given to some sections of the society and not others or not making adequate progress in one dimension of access to water and not others. This analysis also indicates that while national level aggregate indicator of access to water is useful, it may not reveal institutionalised insecurity due to urban bias. Though this was a static analysis, this approach to water insecurity clearly highlights the potential vulnerabilities that exist even in countries that have made significant progress. From this analysis, it is clear that we need to continue to make progress in access to improved sources of water and sanitation in countries such as Papua New Guinea, Afghanistan, Lao People’s Democratic Republic, and Cambodia. It is also clear that even in other ‘medium insecurity’ or ‘low insecurity’ countries, there remain important dimensions of insecurity. Climate change is likely to make it harder to make significant changes in the extent of water that can be withdrawn. We can anticipate that even as more people gain access to improved sources of water, the proportion who report satisfaction with water quality could gradually decline if climate change induced pressures result in further exacerbating the existing patterns of water insecurity.

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Appendix 1: DALYs and mortality by risk group

	Attributable DALYs (000s)			Attributable mortality (000s)		
	World	**South East Asia**	**Western Pacific**	**World**	**South East Asia**	**Western Pacific**
Population (000s)	6437	1672	1738			
Total DALYs (all causes)	1523259	442979	264772	58772	15279	12191
Childhood and maternal under-nutrition						
Underweight	90683	34342	3358	2225	829	59
Iron deficiency	19734	7946	3373	273	122	12
Vitamin A deficiency	22099	8548	653	651	252	20
Zinc deficiency	15580	3928	557	433	111	15
Suboptimal breastfeeding	43842	12809	3307	1247	366	92
Other nutrition related risk factors and physical activity						
High Blood pressure	57227	13447	11856	7512	1438	1764
High cholesterol	29723	9856	3930	2625	756	345
High blood glucose	41305	13326	7722	3387	1044	570
Overweight and obesity	35796	5133	5536	2825	343	414
Low fruit and vegetable intake	15974	4865	3841	1674	450	451
Physical inactivity	32099	9010	5575	3219	782	573
Addictive substances						
Tobacco use	56897	12764	12848	5110	1037	1405
Alcohol use	69424	12066	18393	2252	354	641
Illicit drug use	13223	2585	1886	245	73	41
Sexual and reproductive health						
Unsafe sex	70017	10559	1832	2355	332	65
Unmet contraceptive need	11501	4934	348	163	73	3
Environmenal risks						
Unsafe water, sanitation, hygiene	64240	20176	4599	1908	599	95
Urban outdoor pollution	8747	1911	2644	1152	207	421
Smoke from solid fuels	41009	12492	5001	1965	630	591
Lead exposure	8977	4044	1531	143	70	23
Global climate change	5404	2320	192	141	58	4
Occupational risks						
Risk factor for injuries	11612	4029	2918	352	121	95
Carcinogens	1897	391	747	177	32	72
Airborne particulates	6751	1820	2755	457	118	220
Ergonomic stressors	898	261	289	1	0	0
Noise	4509	1574	1356	0	0	0
Other selected risks						
Unsafe healthcare injections	6960	2308	2586	417	121	195
Child sexual abuse	9018	4048	2303	82	38	24

Source: WHO (2009)

Appendix 2: Access to water and sanitation (based on UNDP,2010)

HDI Rank		Region	HDI 2010	Population without access to water 2008 (%)	Population without access to sanitation 2008 (%)	Infant mortality ratio per 1,000 live births	Under -5 mortality ratio per 1,000 live births
11	Japan	AE	**0.884**	0	0	3	4
12	Korea (Republic of)	AE	**0.877**	2	0	5	5
27	Singapore	AE	**0.846**	0	0	2	3
37	Brunei Darussalam	AE	**0.805**	..	..	6	7
57	Malaysia	AE	**0.744**	0	4	6	6
89	China	AE	**0.663**	11	45	18	21
92	Thailand	AE	**0.654**	2	4	13	14
97	Philippines	AE	**0.638**	9	24	26	32
100	Mongolia	AE	**0.622**	24	50	34	41
108	Indonesia	AE	**0.600**	20	48	31	41
113	Viet Nam	AE	**0.572**	6	25	12	14
120	Timor-Leste	AE	**0.502**	31	50	75	93
122	Lao People's Democratic Republic	AE	**0.497**	43	47	48	61
124	Cambodia	AE	**0.494**	39	71	69	90
132	Myanmar	AE	**0.451**	29	19	71	98
	Korea (Democratic People's Rep. of)	AE	…	0	..	42	55
70	Iran (Islamic Republic of)	AS	**0.702**	..	..	27	32
91	Sri Lanka	AS	**0.658**	10	9	13	15
107	Maldives	AS	**0.602**	9	2	24	28
119	India	AS	**0.519**	12	69	52	69
125	Pakistan	AS	**0.490**	10	55	72	89
129	Bangladesh	AS	**0.469**	20	47	43	54
138	Nepal	AS	**0.428**	12	69	41	51
155	Afghanistan	AS	**0.349**	52	63	165	257
	Bhutan	AS	…	8	35	54	81
2	Australia	AP	**0.937**	0	0	5	6
3	New Zealand	AP	**0.907**	0	..	5	6
85	Tonga	AP	**0.677**	0	4	17	19
86	Fiji	AP	**0.669**	..	..	16	18
103	Micronesia (Federated States of)	AP	**0.614**	..	..	32	39
123	Solomon Islands	AP	**0.494**	..	..	30	36
137	Papua New Guinea	AP	**0.431**	60	55	53	69
	Kiribati	AP	…	..	..	38	48
	Nauru	AP	…	..	..	36	45
	Palau	AP	…	..	..	13	15
	Samoa	AP	…	..	0	22	26
	Tuvalu	AP	…	3	16	30	36
	Vanuatu	AP	…	17	48	27	33