THE WATERS OF THE THIRD POLE:

SOURCES OF THREAT, SOURCES OF SURVIVAL:



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Contents

Summary **2**

Introduction: planning from the future **5**

1 The importance of the Hindu-Kush Himalaya (HKH) region as a water source **7**
Geology, water and land use 7
Climate influences and impacts 10
Glaciers and meltwater 10
Ecosystem degradation 11
The effects of climate change 12

2 The people of the HKH region **14**
Growing urban populations 14
Environmental migration and displacement 15
Agricultural productivity and water use 17
Water shortages and food security 18
Extraction and loss of groundwater 18
Water wastage 19
Water quality and pollution 20
Hydropower and dam-building 20
Transboundary water management 23

3 Emerging vulnerabilities and crisis drivers of the future **24**
Overview 24
Environmental hazards and their impacts 24
Floods and lake outbursts 24
Earthquakes 25
Mass land movements 25
Hazards in deltas and coastal zones 26
Arsenic contamination 26
Fires and atmospheric brown clouds 26
From crisis drivers to crises 27
Food insecurity 27
Mass displacement 27
Habitat and infrastructure collapse 28
Demise of livelihoods 28
Changing disease patterns 28
Rising conflict 29
A matrix of interactions 30

4 Humanitarian perspectives **31**
An uncertain future 31
Preparing for humanitarian futures: dimensions and dynamics of future humanitarian crises 31
The present state of play 33
Humanitarian consequences 35

Conclusions and recommendations **36**
Conclusions 36
Recommendations 38

References **40**

Endnotes **42**

Appendix 1: Future stories **45**

Summary

[1] The purpose of this report is to open up a dialogue on an issue that could put the lives and livelihoods of millions of people at risk in the foreseeable future. This issue is water – water as a vital resource and as a potential crisis driver in the Hindu-Kush Himalaya (HKH) region. In seeking to foster that dialogue, the report has three specific objectives: [i] to survey various types of potential water-related hazards and crisis drivers that could affect the region; [ii] to foster new types of alliances – including greater attention to what will be called humanitarian policy-maker/ science dialogues – for addressing the threats that the region may face; and [iii] to propose first steps that must be taken now to lead to prevention and preparedness measures commensurate with the nature and scale of threats facing the region.

The importance of the HKH region as a water source

[2] The HKH region, referred to by some as the Third Pole because it contains the largest area of frozen water outside the polar regions, is the source of ten major river systems that together provide irrigation, power and drinking water for 1.3 billion people – over 20% of the world's population. As **Section 1** notes, this regional water system is already under considerable stress and could be involved in future crises encompassing disputes over dams and river diversions, floods, water shortages and contamination.

[3] From Afghanistan in the west, through Pakistan, India, Nepal, Bangladesh and Bhutan to Myanmar and China in the east, the HKH region extends 3,500km over eight countries and is the source of ten major Asian river systems, including the Ganges, the Brahmaputra and the Yangtze, Mekong and Yellow rivers. However, the region is susceptible to high levels of climate warming, earthquake activity, extreme weather events, glacial melting and relative sea-level rise. The region's glaciers, rivers, wetlands, grasslands and coasts are all therefore affected.

[4] Despite the uncertainty surrounding projected changes, it seems highly likely that many of the changes already observed will continue in future decades. Warming in many parts of the region is likely to continue and it is probable many glaciers will continue receding. Rainfall and extreme events such as storms and floods are likely to increase throughout much of the HKH region. The apparent increasing variability in the summer monsoon rains, coupled with the unsustainable use of water resources, may increase the probability of more severe drought during dry seasons.

Human activity in the HKH region

[5] Large, fast-growing and rapidly urbanising populations, described in **Section 2**, are placing heavy demands on water and related environmental resources. Governments in the region are working to increase agricultural productivity and electricity generation, but with likely devastating effects on the environment. Longstanding antagonisms between countries and sub-regions are being exacerbated by disputes over increasing demand for diminishing or increasingly variable water resources. There are growing numbers of environmental migrants. These include both those people moving away from drying or degraded farmland or fisheries, and the millions displaced by ever-larger dams and river-diversion projects.

Vulnerabilities and crisis drivers

[6] The main natural hazards in the HKH region are earthquakes, mass movements, extreme weather, windstorms, droughts, floods and wildfires. Groundwater contamination is also a major concern. As outlined in **Section 3**, the impacts of all of these may be magnified by environmental and climatic changes, population growth, globalisation and increasing demands on resources; and all in various ways dramatically affect water availability and are affected by water as a crisis driver. Consequently, such hazards, particularly those relating to water quantity and quality, are likely to continue to hamper socio-economic development and poverty reduction in the region, and could contribute to a range of humanitarian crises, from conflict and mass migration to famines and cataclysmic floods.

Humanitarian perspectives

[7] There is much that remains uncertain and unknown about potential humanitarian threats across the HKH region. Yet, at the same time, as reflected in **Section 3**, there is ample expert opinion to suggest that the region offers a plethora of humanitarian threats that could severely affect the lives and livelihoods of millions of people. While this report is not intended to comment on the science that underpins those expert views, **Section 4** of this report does suggest that in light of new and traditional types of crisis drivers affecting and affected by water, those with humanitarian roles and responsibilities need to develop new approaches to crisis prevention and preparedness.

[8] To date, there is a general belief that too little attention is being paid to the region as an inter-related system, that short term-ism dominates the thinking of too many governments in the region and that too many gaps in knowledge and information-sharing are constraining the planning and action essential to meet the types of crises that the region may well have to face in the future.

Conclusions

This report attempts to point out risks that need to be considered when dealing with what has been defined as the region affected by the waters of the HKH region. While recognising the abundance of initiatives that have already been undertaken in the region by governments, research organisations and community-based organisations to deal with many aspects of potential future threats, this report nevertheless concludes that there are issues which must be recognised and addressed as soon as possible:

- **The HKH region is already in a state of crisis, affecting many vulnerable people**. While there are indicators throughout the region that humanitarian crises are already taking place, their impacts on and implications for the region are all too often ignored, handled in geographic or sectoral isolation or not adequately understood

- **Threats in the future.** A growing number of experts in and outside the region are concerned about the region's prospects over the next two decades. They see the dimensions and dynamics of water-related crises increasing significantly

- **Intensification of insecurity**. In a region already sadly familiar with conflict, further conflict could result from the natural and human-made pressures facing the HKH region over the next twenty years. Water in this instance will be a significant factor

- **Development catastrophes**. This report emphasises the nexus between natural hazards and human intervention. It has been suggested that the development initiatives being undertaken throughout much of the region could lead to crises that will readily deserve the epithet 'catastrophes'

- **Lack of effective water management**. There is inadequate long-term water management at almost every level in the HKH region. At national and international levels, water management is marked by short term-ism and solutions that lack sectorally integrated approaches

- **Lack of systems perspectives**. One factor which continues to inhibit a proper understanding of the region is the failure to adopt a *systems perspective* of regional issues. Only in this way will the scale necessary to deal with the longer-term threats and means to offset them be identified

- **Knowledge gaps and lack of understanding.** There is no adequate shared understanding about the region as a whole, no 'map' of potential risks and opportunities that would serve as a useful planning instrument. It is evident that there are considerable uncertainties in the HKH region.

- **Lack of coordinated, comprehensive research.** While there are considerable pools of research on various aspects of the HKH region, data gathering and interpretation have been carried out without cohesion or continuity. There remains a great deal of academic and policy research that is uncoordinated and carried out by organisations without the institutional capacity to support effective information exchange

Recommendations

The recommendations that follow are intended to suggest ways to strengthen humanitarian crisis prevention and preparedness activities in a region that may become increasingly vulnerable to large-scale water-related disasters and emergencies:

- **HKH region to move up the planning agenda.** In a world in which the types, dimensions and dynamics of humanitarian threats will increase exponentially, the attention given to the potential vulnerabilities of a region which is home to 20% of the world's population has to increase

- **Need for a new planning construct.** The complexities which will underpin so many of the crisis drivers that may affect the region require a new planning construct, or, framework. The proposed construct will have to have four core components: [i] *vulnerability* needs to be the main focus; [ii] a regional approach to vulnerability mapping; [iii] greater integrated modelling of the interactive nature of future threats; [iv] preparedness planning based upon *futures* scenarios

- **Need for non-intrusive means for international support.** Given the highly complex and politically sensitive nature of potential future crisis drivers in the region, humanitarian intervention from traditional humanitarian organisations will have to be less intrusive, and more able to support local and regional prevention, preparedness and response capacities. This would include [i] creation of humanitarian professionalisation programmes for sharing best practices and standards; [ii] means for regular sharing of data on regional dimensions of vulnerability; [iii] regionally-developed scenario exercises to assess and test appropriate approaches for international support for regional crises; [iv] pre-response arrangements between relevant regional bodies and international counterparts

- **Foster cross-regional humanitarian policy-maker/science dialogue**. Measures are needed to promote essential policy-maker/scientist dialogue, including: [i] greater sharing of scientific information amongst countries in the region; [ii] accessible forum – including online capacities- for policy-makers to interact with natural and social scientists; [iii] proposed forum's focus to give attention to interactive nature of possible regional threats; [iv] practical results of dialogue to be made accessible to threatened communities; [v] strengthened scientific and humanitarian research capacities in the region

- **Promote innovation consortia.** Linked to the previous recommendation, a forum to help identify, prioritise and implement scientific and technological innovations to offset potential humanitarian threats. Of particular importance in this context is to work with local communities to identify innovative solutions that directly relate to local needs

- **Address knowledge gaps and coordination for comprehensive research.** The numerous knowledge gaps touched upon in this and related studies need to be closed, and so it would be timely to bring together leading sectoral and regional experts to establish a prioritised programme of essential futures-oriented analyses to narrow knowledge gaps where possible. This initiative has to focus not only upon knowledge gaps within the region, but also upon those gaps in understanding about the ways that global issues, e.g. subsidised agriculture, that could impact upon the region's vulnerability

- **Vulnerability mapping exercise**. A platform for developing a regional mapping exercise and system is required to identify and monitor those factors that could create humanitarian crises at local and regional levels. With an established platform, the mapping exercise in the first instance will need to focus on how such factors interact, their dynamics and probable dimensions of impact.

Introduction: planning from the future

The objective

More than one in five people, including the populations of Bangladesh, China, India and Pakistan, depend to some degree on water from rivers originating in the Hindu-Kush Himalaya (HKH) region. This region is sometimes referred to as the Third Pole because it hosts the largest expanse of frozen water outside the polar regions. Its drainage basins are one of the world's most dynamic, complex and intensive *risk hotspots*. Further, this highly active geologic and climatic zone is subject to the growing socio-economic demands of some 1.3 billion people, and is a region of considerable human conflict. The supply and quality of water in this region is under extreme threat, both from the effects of human activity, and from natural processes and variation. Many parts of the region are already experiencing the first signs of serious water stresses.

If the predictions for population growth, climatic variation and the demands of agricultural and energy in the region are correct, the present stresses may well seem relatively minor in years to come. Concerns about future water stress in this region are by not new. There is a burgeoning literature from a growing number of research institutes and fora that testify to the array of existing and emerging natural and human-driven hazards in the region. And yet, despite the attention that scientists, humanitarian and development policy-makers have given to such threats from their own institutional perspectives, there has been little attempt to look holistically at the inter-relationships and dynamics of such hazards as major crisis drivers.

This report suggests that more consistent and coherent efforts are needed to focus upon the dimensions and dynamics of potential threats in the region, including the ways in which hazards will inter-relate and interact. Without this research focus and planning perspective, the ability to mitigate future humanitarian crises that may directly and indirectly affect the lives and livelihoods of hundreds of millions, will be severely impaired.

Sources of survival – sources of threat offers a particular perspective on crises in a regional context. The analysis focuses on the theme of water and looks at the interplay between natural and human phenomena that could threaten the lives and livelihoods of substantial numbers of people in this major region of the world. This report, however, is not intended to predict or forecast *what will be*, nor is it designed to contribute to the complex scientific debate that surrounds issues of climate change, meltwater, recharge rates and precipitation. Rather based upon literature reviews and interviews with scientific and disaster management experts in and outside the region, it suggests possible scenarios that should alert organisations with humanitarian roles and responsibilities to future planning challenges and opportunities. Its contribution should be seen in terms of exhorting humanitarian organizations to undertake more futures-oriented planning, to think more speculatively about *what might be*.

In this context, the report has three specific objectives.

- It intends to survey potential water-related hazards and crisis drivers that could well affect the region in the foreseeable and longer-term future. The combination of "the knowns" with informed speculation is intended to help policy-makers, planners and practitioners think creatively and practically about *what might be*. It is in this sense about *planning from the future.*[1]

- The report seeks to promote new types of alliances for addressing the threats that the region may face. Such alliances include a greater focus on *humanitarian policy-maker/science dialogues*.

- More broadly, the report highlights a concern that the level of attention given to the region's vulnerability is not proportionate to the scale of the threat. There are therefore essential first steps that must be taken now to close the gap between prevention and preparedness measures and the nature and scale of the types of threats facing the HKH region.

The context

The main natural hazards in the HKH region, identified in **Section 1**, are earthquakes, extreme weather, windstorms, droughts, floods, mass movements, wildfires and natural contamination. The impacts of all of these may be magnified by environmental and climatic

A common ecosystem

'…large water management projects have created social, ecological, and economic problems, the repercussions of which cannot be immediately gauged. For instance, China has initiated massive infrastructural projects in Tibet, where many major Asian rivers originate. Industrialisation upstream in China has led to soil erosion, deforestation, and landslides, whose impacts are felt in the lower riparian states of Bangladesh and India. That these countries are part of a common ecosystem was made tragically clear by the flash floods that ravaged northeast India in 2000 caused by a landslide in Tibet.' [2]

changes, population growth, globalisation and increasing demands on resources. Consequently, natural hazards, particularly those relating to water quantity and quality, will continue to hamper socio-economic development and poverty reduction efforts in the region, and could contribute to conflict. The distribution and volume of water and its sediment load may change dramatically in the future if predictions of climate change and population growth and development are correct.

The rivers that flow from the Himalaya provide water to at least 20 per cent of the world's population.. These rivers flow through some of the poorest, most densely populated and intensely irrigated areas in the world. Hundreds of millions of people depend to some degree on this natural water supply for drinking water, power generation and agriculture. If this water supply is significantly altered through, for example, climate change, this could threaten the lives as well as the livelihoods of the region's inhabitants. ***Section 1:The importance of the HKH region as a water source*** outlines key influences affecting water in the region.

A fully integrated systems approach is essential to the understanding and appropriate management of water in the vast HKH region. This requires definition and quantification of the components of the system and the linkages and feedbacks between them. Without this holistic perspective, the gross mismanagement of the system that is already in evidence will continue and worsen. To avoid this countries in the region will need to put aside their differences and communicate to share knowledge and data. This will require a new era of collaboration and trust, which could also contribute to the diffusion of regional political tensions.

When seeking to understand the full consequences of HKH region phenomena, planners and policy-makers too often become fixated on borders, defining issues within boundaries and ignoring the cross-border implications of natural and human events. In the context of the HKH region, this would be a deeply flawed perspective. In this report, ***Section 1, The importance of the HKH region as a water source***, identifies the main characteristics of the region as an integrated and inter-related system, albeit one spanning more than 3500 kilometres.

The HKH region also offers important insights into the sorts of crisis drivers that can result from the interaction of natural phenomena and human intervention. ***Section 2, The people of the HKH region*** discusses some of the human dimensions of the region, including demographic trends, food security, potable water, energy and industry. This prepares the way for ***Section 3, Emerging vulnerabilities and future crisis drivers***.

Prediction and forecasting is not the ultimate purpose of this exercise. Nevertheless, ***Section 4*** offers insights on possible dynamics and dimensions of future crises which though speculative seem at the same time plausible. This section argues that these sorts of perspectives need to be taken into account by those responsible for humanitarian prevention and preparedness as well as response.

This report also has another purpose. There is little doubt in the minds of a large number of experts who have reflected on the HKH region that the sorts of crisis scenarios emanating from the region and reflected in this report are possible though not inevitable. At the same time, there are serious unknowns about a region that has been described as a blank or 'white spot' for data on a 'Himalayan scale'. The need to focus on these unknowns, on the *what might be's*, from a humanitarian perspective is becoming increasingly urgent, and this is but one of the ideas presented in the final section, ***Conclusions and recommendations***.

1 The importance of the HKH region as a water source

The Hindu-Kush Himalaya (HKH) region extends some 3500km from Afghanistan in the west to Myanmar and China in the east, and runs through Pakistan, Nepal, India, Bangladesh and Bhutan. It includes the Tibetan Plateau and is the source of ten huge Asian river systems: the Tarim (Dayan), Amu Darya, Indus (including Sutlej), Ganges, Brahmaputra (Yarlung Tsangpo–Brahmaputra), Irrawaddy, Salween (Nu), Mekong (Lancang), Yangtze (Jinsha), and the Yellow (Huang He) (see Figure 1). The drainage basins of these rivers cover an area of 8.6 million square kilometres, which is equivalent to the size of Brazil, and provide water for an estimated 1.3 billion people, or around 20% of the world's population (see Table 1). In total, around 3 billion people directly and indirectly benefit from the water, food and energy provided by the river basins that originate in the HKH region. For ease of reference, the HKH region will be defined in this report as the HKH region mountain ranges (marked green in Figure 1) and the river systems of which they are the source (marked blue in Figure 1).

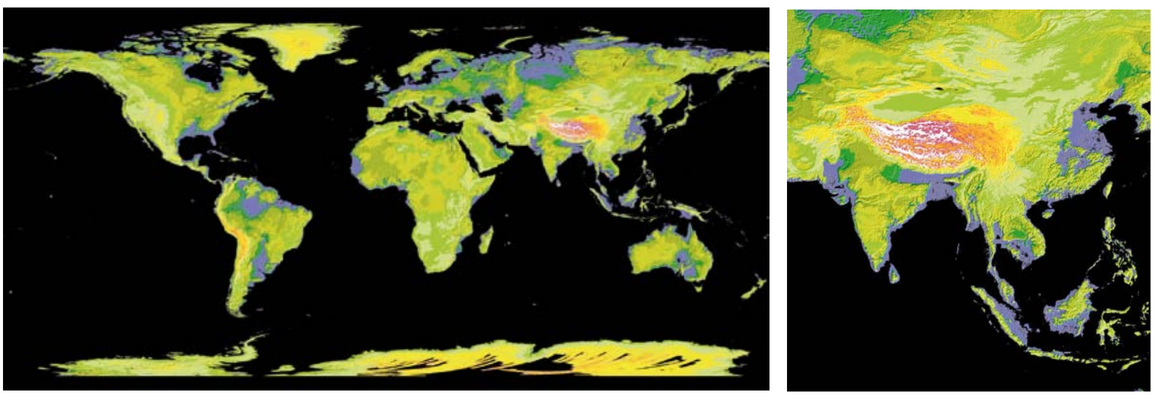
Figure 1: The ten major river basins of the HKH region

Note: The HKH region as defined by ICIMOD (www.icimod.org/?page=43). The region extends from 58–122°E and 9–43°N. Downloaded 7 August 2009.

Geology, water and land use

The HKH region is one of the most geologically active zones on Earth. Through the process of plate tectonics, the Himalaya have been forming over the past 55–65 million years through the collision of the Eurasian and Indian plates. Most of the mountain elevation has occurred during the past 2 million years and the world's largest mountains (see Figure 2) are still growing and remain a highly active geological zone today. This zone has the highest relief and rate of uplift anywhere, and an extremely high incidence of earthquakes (see Figure 3). Around 15% of the great earthquakes (magnitude 8 and above) in the twentieth century were located in this region.[3] The upper reaches of the Indus and Yarlung Tsangpo-Brahmaputra rivers run along the Indus-Yarlung suture zone, which marks the interface of the Indian and Eurasian plates.

Figure 2: Topographic images of the world and of southern Asia



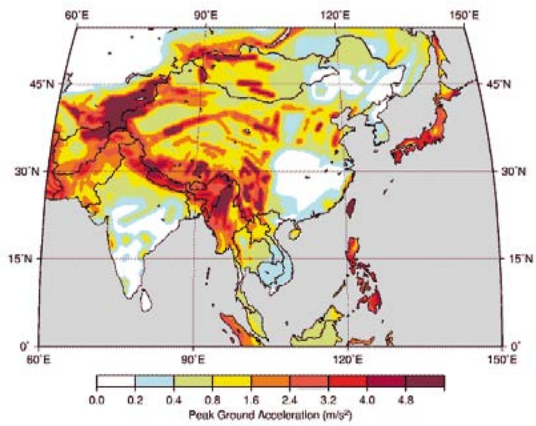
Note: The lowest elevations are purple, medium elevations are greens and yellows, and highest elevations are orange, red and white. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) image released 29 June 2009 by the National Aeronautics and Space Administration (NASA) and Japan's Ministry of Economy, Trade and industry (METI), and downloaded courtesy of NASA and METI.

Table 1: Characteristics of the ten major river basins originating in the HKH region

	Amu Darya	Brahmaputra	Ganges	Indus	Irrawaddy	Mekong	Salween	Tarim	Yangtze	Yellow	TOTAL
River basin area (km^2)	534,739	651,335	1,016,124	1,081,718	413,710	805,604	271,914	1,152,448	1,722,193	944,970	8,594,755
Countries in river basin	Afghanistan, Tajikistan, Turkmenistan, Uzbekistan	China, India, Bhutan, Bangladesh	India, Nepal, China, Bangladesh	China, India, Pakistan	Myanmar	China, Myanmar, Laos, Thailand, Cambodia, Vietnam	China, Myanmar, Thailand	Kyrgyzstan, China	China	China	
Mean discharge (m^3/sec)	No data	19,824	18,691	5,533	13,565	11,048	1,494	146	34,000	1,365	105,666
Glacial melt in river flow (%)	No data	12.3	9.1	44.8	Small	6.6	8.8	40.2	18.5	1.3	
Forest cover (%)	0.1	18.5	4.2	0.4	56.2	41.5	43.4	0.0	6.3	1.5	
Grassland, savanna and shrubland (%)	57.3	44.7	13.4	46.4	9.7	17.2	48.3	35.3	28.2	60.0	
Wetlands (%)	0.0	20.7	17.7	4.2	6.3	8.7	9.5	16.3	3.0	1.1	
Cropland (%)	22.4	29.4	72.4	30.0	30.5	37.8	5.5	2.3	47.6	29.5	
Irrigated cropland (%)	7.5	3.7	22.7	24.1	3.4	2.9	0.4	0.6	7.1	7.2	
Dryland area (%)	77.8	0.0	58.0	63.1	4.4	0.8	0.1	38.6	2.0	79.4	
Urban and industrial area (%)	3.7	2.4	6.3	4.6	1.9	2.1	0.5	0.3	3.0	5.9	
Loss of original forest cover (%)	98.6	73.3	84.5	90.1	60.9	69.2	72.3	69.3	84.9	78.0	
Population (thousands of people)	20,855	118,543	407,466	178,483	32,683	57,198	5,982	8,067	368,549	147,415	1,345,241
Population density (people per km^2)	39	182	401	165	79	71	22	7	214	156	
Large cities (>100,000 people)	9	6	11	11	6	9	1	1	9	9	72
Water supply per person in 1995 (m^3 per year)	3,211	1,700–4,000	1,700–4,000	830	18,614	8,934	23,796	754	2,265	361	
Degree of river fragmentation	High	Not reported	Not reported	Not reported	Not reported	Medium	Not reported	High	Medium	High	
Number of dams in basin: >15m and >150m high (and those >60m under construction)	6, –, (2)	–, –, (3)	–, –, (5)	–, –, (0)	–, –, (0)	4, 0, (3)	4, 0, (1)	0, 0, (0)	63, 4, (38)	40, 3, (7)	

Source: Compiled from the data of Jianchu et al. *(2007), and references therein, and Revenga* et al. *(2003), plus ICIMOD (2007).*

Figure 3: Earthquake risk in Asia



Note: The map shows seismic hazards estimated terms of peak ground accelerations with a 10% chance of exceedance in 50 years (Zhang et al., 1999). The site classification is rock. Downloaded from www.seismo.ethz.ch on 4 August 2008.

Such is the size, elevation and climate of the HKH region that it hosts the largest areas of glaciers, snow and permafrost outside high latitudes, which is why it has become known by some as the Third Pole. These huge reservoirs of frozen fresh water represent the sources of a number of the world's greatest rivers, and so the Third Pole region is often described as the 'water tower of Asia'.

The fertility and productivity of the region's river valleys and deltas, and of the world's oceans, are influenced by the geology and climate of the HKH region. The mountains are so high that they strongly influence regional climate and weather patterns, and the action of ice, water and wind sculpts the mountains and valleys into their spectacular forms. The rivers have steep, cold and dry upper catchments, and flatter, hot and mostly humid lower catchments. The rate of weathering and erosion of the growing mountains is one of the highest in the world, and this is why huge volumes of sediment and dissolved minerals are produced and transported downstream to the great river plains, deltas, and adjoining oceans (see Figure 4).

The rivers are vital to the sediment and nutrient balance of the lower catchments and of the world's oceans. Large volumes of sediment are deposited in the broad and flat lower stretches of the river basins by downstream transport and flooding. These alluvial deposits are both porous and permeable and act as huge underground reservoirs of fresh water. They are recharged annually, mostly by meltwater from glaciers and precipitation associated with the Asian summer monsoon. Similarly, the processes of sediment transport and deposition occur throughout the year, but are most pronounced during periods of extensive rainfall and flooding associated with the monsoon.

Figure 4: False-colour Landsat image of the Ganges river delta, showing sediment flow

Note: The green colour represents the swamp forest of the Sunderbans, and the purple reflects the vast amount of sediment being transported out into the Bay of Bengal. Image taken on 28 February 2000, courtesy of NASA.

The distribution of land type and land use varies significantly between river basins, but cropland is important in most of them (see Table 1). The large rural populations are mostly located in the vast flat and fertile river valleys and deltas. In Bangladesh, for example, population density exceeds 500 people per square kilometre along the Ganges and Brahmaputra rivers, particularly in the mega-delta created by the coalescence of these two great rivers.

All the main rivers originating in the HKH region are fed to some degree by glacial meltwater, which accounts for a maximum of 40–45% of the river flow in the Indus and the Tarim, for example. The proportion of glacial melt in river flows is predicted to increase, as glaciers in the HKH region, except those in the Karakoram area, recede.[4] Increased melting may initially increase the volume of water in rivers, which might lead to more widespread flooding, but as glaciers recede and disappear the amount of meltwater entering rivers could decrease significantly. Such a situation may result in a substantial decline in the rates of groundwater recharge in some areas. This, in combination with variations in summer monsoon precipitation and surface water flows, may lead to highly significant water stress in many parts of the HKH region and associated river basins. For example, the gross per capita water availability in India is predicted to decline from the 2001 volume of around 1820 cubic metres per year to about 1,140 cubic metres per year in 2050.[5] To place these numbers in context, the UN defines "water scarcity" as a per capita availability of less than 1,000 cubic metres per year and "water stress" as less than 1,700 cubic metres per capita.[6]

Climate influences and impacts

During the latest phase of mountain building, about 40,000 years ago, the Himalaya experienced an ice age when the glaciers grew and sculpted the mountains into their present dramatic forms.[7] Subsequently, as the climate has warmed and the glaciers have shrunk, glacial lakes have formed and grown. Under the arid desert conditions to the north of the mountains the glacial lakes have evaporated to leave huge salt deposits, which the Tibetans mine for export to India. Groundwater in many of these arid northern regions is saline. Elsewhere the climate is much more humid, especially in the southeast.

Broadly, the major controls on climate in the HKH region are latitude, altitude and position relative to the Asian monsoon airflow.[8] The area shown in Figure 1 extends from 9°N to 43°N and has the most extreme altitudinal change of anywhere in the world (sea level to 8,848 metres at Mount Everest). Consequently, this huge area experiences every climate from tropical to extreme alpine. Such is the topography of the Himalaya that the tropical climate zone penetrates farther north in South Asia than anywhere else in the world. This phenomenon is most pronounced in the eastern Himalaya, where the valley of the Yarlung Tsangpo Brahmaputra channels warm air from the Bay of Bengal into the mountains and northward into Tibet.

Of all the factors affecting regional climate in the HKH region, the Asian monsoon is certainly one of the most important.[9] The monsoon is a wind that transports vast amounts of moisture and energy from the Indian Ocean in the summer months, and arises from the considerable differences in air pressure between southern and central Asia, which in turn is a consequence of temperature variations between the inner parts of the continent and the surrounding oceans. The summer monsoon arises when high pressure develops over the Indian Ocean, warm water evaporates and the resulting humid air flows northwards. Upon reaching the Himalaya, the air rises and cools, the moisture condenses and heavy precipitation ensues. The summer monsoon begins in the southeast of the Himalaya at around the end of May and slowly migrates westward to reach Kashmir by early July, but it also penetrates into southeast Tibet by moving northwards along the Yarlung Tsangpo–Brahmaputra valley.

The monsoon becomes drier as it moves westward, and winds reaching the Tibetan plateau are dry, which is why this region lies in a rain shadow and is very arid. Thus, during the winter monsoon, with high pressure over central Asia, it is dry air that flows southwards. However, the western Himalaya and adjoining Karakoram range do receive significant precipitation from storms tracking west during the winter. The resultant snow accumulation, coupled with the decline in summer temperature and runoff in this region since 1961, explains why glaciers in the Karakoram are thickening and expanding.[10] The Indian monsoon exhibits decadal variation, but on average it accounts for about 70% of the annual rainfall for the region, which falls between June and September.

Glaciers and meltwater

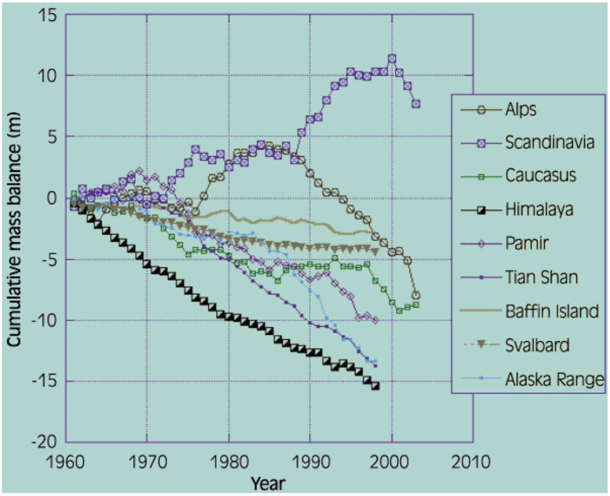
The Himalayan region alone has the largest concentration of glaciers outside the polar ice caps. The Himalayan glaciers act as the source of many of Asia's great rivers which supply water to about one third of the world's population, according to some estimates.[11] While this represents the number of people living in river basins with tributaries coming from glacierised mountains, this is a misleading generalisation.[12] The greatest vulnerability of large numbers of people to glacier state and dynamics occurs along the Indus and Tarim, where melt waters from glaciers comprise around 40% of average river flow. However, in most cases glacier melt represents a fairly small component of the total river flow (see Table 1).

The effects of global warming are already evident in the Himalayas where some two-thirds of glaciers are retreating fast (Figure 5).[13] Overall, the Himalayan glaciers are retreating faster than many others around the world (see Figure 6); they are thinning by up to one metre per year and retreating at rates ranging from 10 to 60 metres per year, and many small glaciers (less than 0.2 square kilometres) have already disappeared.[14] It is apparent that the rate of glacier retreat has accelerated in recent times in comparison to the 1970s.[15] During the last 30 years there has been a shrinkage of 5.5% in the volume of glaciers in China, and similar rates are found in Nepal, India and Bhutan.[16] During a glacier retreat,

Figure 5: The Gangotri glacier in the Indian Himalaya, showing ice retreat, 1780–2001

Note: Image courtesy of NASA Earth Observatory.

Figure 6: Changes in masses of Himalaya and other glaciers



Source: Dyurgerov and Meier (2005), cited in ICIMOD (2007), page 5.

the formation of new lakes is likely, as is merging and expansion of existing lakes, at the toe of a valley glacier. This may increase the risks of flooding (as discussed in Section 3 below) and changes in stream flow may have significant effects on ecosystems and water users.

It is increasingly recognised that glacial conditions in the region are very diverse, and so are their responses to climate change. If the main trend in most of High Asia does seem to be glacier retreat, various lines of evidence show that it is occurring at very different rates in different mountains, even within the same mountain range.[17] A 2006 survey of 5,020 glaciers in the mountains of western China and the Tibetan Plateau found widely differing rates of reduction. It also found that 894 glaciers, about 18%, have advanced in recent decades.[18] Variables, such as elevation, snowfall and the nourishment of these glaciers, alter glacier mass and behaviour. Given the inadequacies of available information and monitoring and the total absence of glacier monitoring, at elevations where the most critical ice and climate changes occur, predictions of glacier melt must be approached with caution. Recent evidence of glacier advances in the Karakoram Himalaya, illustrate many of these complexities.[19]

Ecosystem degradation

In the HKH region, most of the land area consists of wetlands or rangelands (see Table 1), vital in the region's water cycle. Acting as a buffer for glacial meltwater and runoff from precipitation, these ecosystems help to ensure that year-round stream flow remains relatively stable, as well as acting as valuable resources for local people. Although systematic data are still lacking, current observations indicate a general trend of degradation in Himalayan ecosystems, caused by human and climatic forces reducing their capacity to store and release water. If current trends continue, there may be an overall increase in seasonal stream-flow variations, combined with more major droughts and floods.[20] In addition to seriously affecting local livelihoods, degradation of high-altitude ecosystems is likely to have serious implications for the safety, food security and water security of downstream populations, many of whom are ill-equipped to mitigate or adapt to the shocks that such changes will bring.

High-altitude rangeland covers approximately 2.1 million square kilometres, or 60% of total land area in the HKH region. Around half of this land type is currently suffering from varying degrees of degradation. In addition to supporting biodiversity and livelihoods, rangeland plays an important role in regional hydrology.[21] Current patterns of soil erosion and loss of foliage cover are likely to lead to lower levels of water retention coupled with increased runoff. Higher rates of water loss through evaporation from bare, sandy soil may also decrease the overall transfer of water from wetlands to downstream areas.[22] The factors involved in the degradation process are complex but it is increasingly accepted that warmer and drier climatic trends in the region are likely to be behind much of the current damage to grassland vegetation.[23] Rising temperatures are also causing the shrinking of rangeland permafrost layers in higher areas, with observed consequences of increased soil instability and erosion.[24]

Wetlands, as defined by the Ramsar convention, include all areas of marsh, fen and peatland, together with associated lakes.[25] Currently, they cover around 17% of the land in the HKH region. Wetlands at the headwaters of the region's rivers act like a sponge, absorbing fluctuating amounts of incoming water from glaciers and precipitation before releasing it downstream. This is particularly important in winter, when the release of water accumulated earlier in the year offsets reductions in meltwater flow.[26]

Although wetlands in the HKH region are relatively under-researched, there are indications of a general trend of retreat. A recent satellite survey of the Qinghai-Tibetan plateau has shown a 10% reduction in wetland areas since the late 1970s.[27] More locally focused studies have also reported substantial losses, with one protected area in Kashmir shrinking by as much as 28%.[28] Increased air and surface temperatures and drops in precipitation brought on by current climate trends have all been highlighted as having negative effects on wetland areas.[29] Although increases in meltwater flows as a result of glacial retreat may actually increase wetland coverage in the short term, this trend is likely to reverse once volumes peak. This is likely to be more acute in rain-shadow areas, where wetlands are fed almost exclusively by glacial streams. In addition, wetlands are particularly vulnerable to the scouring effect of glacial-lake outburst

Table 2: Key observed trends in temperature and rainfall in the HKH region

Country/region	Change in temperature, heatwaves	Change in precipitation, intense rains and floods
Tibetan Plateau	0.16°C per decade increase in annual temperatures; 0.32°C per decade increase in annual winter temperatures	Precipitation generally increasing in northeast region
China	Warming during the last 50 years, which is more pronounced in winter than in summer, and the rate of increase is more pronounced in minimum than in maximum temperatures. Increase in frequency of short duration heatwaves in recent decade; increasing warmer days and nights in recent decades	Annual rainfall has declined in past decade in north and northeast China, but has increased in western China, the Yangtze River and along the southeast coast. Increasing frequency of extreme rains in western and southern parts, including Yangtze River, and decrease in northern regions; more frequent floods along the Yangtze River (in past decade) and in northeast China (since 1990); more intense summer rains in east China; seven-fold increase in flood frequency since the 1950s
India	0.68°C increase per century; increasing trends in annual mean temperature; warming more pronounced during post-monsoon and winter. Frequency of hot days and multiple-day heatwaves has increased in past century	Increase in extreme rains in northwest during summer monsoon in recent decades; lower number of rainy days along east coast. Serious and recurrent floods in Bangladesh, Nepal and northeast India during 2002, 2003 and 2004; record 944mm in Mumbai in July 2005; floods in Surat, Barmer and Srinagar during 2006 summer monsoon
Nepal	0.09°C per year change in Himalayas and 0.04°C in Terai region, more in winter	No distinct long-term trends in precipitation records for 1948–1994. Serious and recurrent floods in Bangladesh, Nepal and northeast India during 2002, 2003 and 2004
Pakistan	0.6–1.0°C rise in mean temperature in coastal areas since early 1900s	10–15% decrease in coastal belt and hyper-arid plains; increase in summer and winter precipitation over the last 40 years in northern Pakistan
Bangladesh	An increasing trend of about 1°C in May and 0.5°C in November during the period 1985–1998	Decadal rain anomalies above long-term averages since 1960s. Serious and recurrent floods in Bangladesh, Nepal and northeast India during 2002, 2003 and 2004

Source: Information taken from Cruz et al. *(2007).*

floods (GLOFs), as discussed further in Section 3 below.[30]

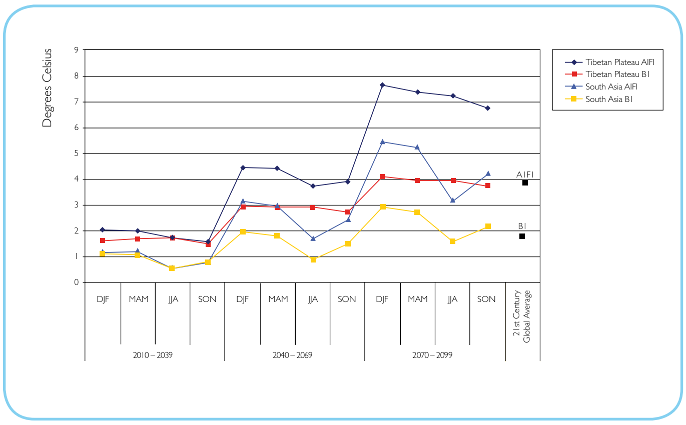
Rapid silting will also affect the water-storage capacity of wetlands. Soil eroded from deforested areas has already had a serious impact on Kashmiri wetlands,[31] with similar effects likely in cases of degraded rangeland on the Tibetan plateau. Pollution, agricultural reclamation, overgrazing, and submersion by reservoir lakes are all leading to an overall reduction in the extent and quality of wetland areas.[32]

The effects of climate change

Because of the great range of climate variability in the HKH region, it is possible here to make only very general comments about past, present and future climate trends and variability. Some key facts are presented in Table 2. The region overall has shown consistent trends in warming during the past 100 years with some areas exhibiting greater warming than the global average of 0.74°C over this period.[33] The degree of warming appears to increase with elevation, as observed in Tibet and Nepal, and warming is more pronounced in winter than in summer.[34] In fact, in some mountains, such as the Karakoram and Hindu Kush and the Hengduan in southwest China, summer temperatures exhibit consistent decline.[35]

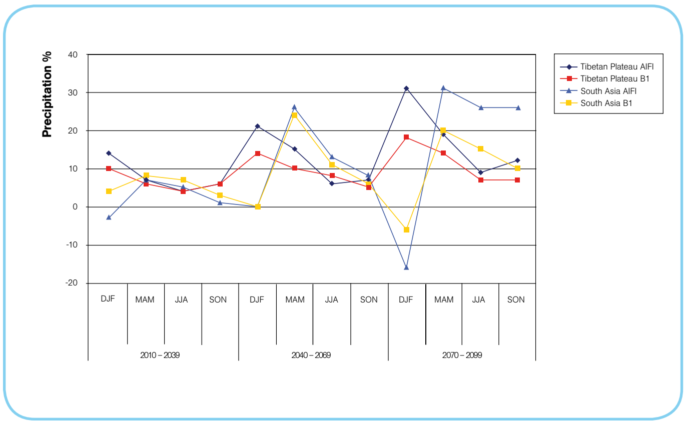
Climate change has a direct effect on the hydrological cycle. Perhaps nowhere else on Earth will this be more significant than in the HKH region, with huge volumes of water moving from mountains to sea. Changes in precipitation have been observed throughout the region, but these are highly variable (see Table 2). Decreasing trends in annual mean rainfall have been observed in the arid plains of Pakistan and northeast India and the total number of rainy days and annual amount of precipitation has decreased.[36] However, the frequency of occurrence of intense rainfall events has increased in many parts of Asia, in particular during summer monsoons, with the possibility of these causing more mass movements and more severe flooding.[37]

Figure 7: Projected changes in surface air temperature for the Tibetan Plateau and South Asia, 2010–2099



Note: The changes are relative to the baseline period, 1961–1990 for the Tibetan Plateau (75–100°E, 30–50°N) and South Asia (65–100°E, 5–30°N). Data from Cruz et al. (2007), Table 10.5. Data for SRES scenario A1 (highest future emission scenario) and B1 (lowest future emission scenario), with the global averages marked by black boxes for comparison. DJF – December, January, February; MAM – March, April, May; JJA – June, July, August; SON – September, October, November.

Figure 8: Projected changes in precipitation for the Tibetan Plateau and South Asia, 2010–2099



Note: The changes are relative to the baseline period, 1961–1990 for the Tibetan Plateau (75–100°E, 30–50°N) and South Asia (65–100°E, 5–30°N). Data from Cruz et al. (2007). Data for SRES scenario A1 (highest future emission scenario) and B1 (lowest future emission scenario). DJF – December, January, February; MAM – March, April, May; JJA – June, July, August; SON – September, October, November.

Figures 7 and 8 give an idea of the regional temperature and precipitation changes that may occur within the next century.

Warming is likely to be well above the global mean in central Asia, the Tibetan Plateau and northern Asia, and above the global mean in eastern and South Asia.

Winter precipitation is very likely to increase in northern Asia and the Tibetan Plateau, and likely to increase in eastern Asia and the southern parts of South-East Asia.

Precipitation in summer is likely to increase in Northern, East and South Asia and most of Southeast Asia, but is likely to decrease in Central Asia. There is very likely to be an increase in the frequency of intense precipitation events in parts of South Asia and in East Asia.

Extreme rainfall and winds associated with tropical cyclones are likely to increase in East, Southeast and South Asia.[38]

Despite the uncertainty surrounding the projected changes in climate and associated processes in and around the HKH region up to 2100, it is probably safe to say that many of the changes already observed, such as those in Table 2 for example, will continue. Thus, regional warming is likely to continue and many, but not all, glaciers are likely to continue receding, especially at lower elevations. Precipitation, including extreme rainfall events, is likely to increase throughout much of the area, which will probably lead to more frequent and/or more intense flooding during the summer monsoon. The apparent increasing variability in the summer monsoon rains, coupled with the unsustainable use of water resources, will increase the probability of more severe drought during dry seasons. An understanding of the hydrologic system in the HKH region and the river basins stemming from it is essential to underpin appropriate water management strategies from now on. This will require extensive transboundary cooperation, which in itself presents a huge challenge.

2 The people of the HKH region

Alongside natural causes, new and continuing human activities have become 'primary drivers' of pressures on water resources.[39] Often, water scarcity is a function of poor governance, rather than a lack of resources. Population growth, more water-intensive agriculture, economic development and the collective pursuit of higher living standards are disrupting the natural balance of water systems and putting water resources under increasing stress. The result is aggressive over-exploitation and massive environmental degradation.

Growing urban populations

Population growth is already putting massive pressure on regional water resources, affecting water in terms of demand, water-use patterns and management practices. Despite varying regional trends, the overall situation in the HKH region is one of rapid population growth, migration and urbanisation. These represent some of the greatest pressures on water through increased demand and pollution. Some 60% of the world's population lives in Asia and it is estimated that there will be another 1.5 billion people in Asia by 2050.[40]

Asia has been experiencing increasingly rapid urbanisation since the 1970s. Approximately one third of Asia's inhabitants now live in urban areas, compared with one in ten in the previous generation (see Table 3). It is estimated that one out of every two Asians will live in cities before 2025.[41] Increased urbanisation boosts water demand through higher incomes, which in turn precipitates shifts in diets, such as increased consumption of more water-intensive foods such as meat, fruit and dairy products. In China, meat consumption has doubled over the past 20 years and is expected to double again by 2030.

While the rapid growth of cities has brought enormous economic benefits to most Asian cities, raising living standards and reducing poverty, these have come at considerable social and environmental costs. Many people who leave rural areas move into one of the Asian mega-cities (metropolitan areas with at least 10 million inhabitants), such as Shanghai, Dhaka and Mumbai, many of which are coastal. However, urban infrastructures are ill prepared to cope with this increased mass movement of people. No city highlights these vulnerabilities better than Dhaka in Bangladesh, which is projected to expand from 13 million to 22 million people by 2025 (see Table 4). The city has the highest population density in the world, but this is 200 times greater in its slums – astounding considering this area is covered by single-storey houses. Some 60% of households have no sewerage, and 90% of inhabitants

Table 3: Urban population in selected Asian countries, 1950, 2000 and 2030

	1950			2000			2030	
Country	Urban population (million)	Urban population (percentage of total)	Percentage growth (1950-2000)	Urban population (million)	Urban population (percentage of total)	Percentage growth (2000-2030)	Urban population (million)	Urban population (percentage of total)
China	69.53	12.5	556	456.34	35.8	94	883.42	59.5
India	61.70	17.3	352	279.05	27.7	107	575.68	40.9
Pakistan	6.95	17.5	573	46.76	33.1	185	133.23	48.9
Bangladesh	1.78	4.2	1837	34.354	25	187	98.55	44.3
Vietnam	3.19	11.6	472	18.19	24.1	150	45.49	41.3
Nepal	1.94	2.3	41	2.73	11.8	299	10.90	26.1
Bhutan	0.02	2.1	650	0.15	7.1	507	0.76	17.9

Source: United Nations (2002).

Table 4: Projected growth of the Asian mega-city to 2025

City	Population 2007 (million)	World size ranking	Population 2025 (million)	World size ranking
Mumbai	18.98	5	26.39	2
Delhi	15.92	6	22.50	3
Shanghai	14.99	7	19.41	9
Dhaka	13.49	10	22.02	4
Karachi	12.13	12	19.10	10
Beijing	11.11	16	14.55	15

Source: UN-HABITAT, 2008.

share a room with more than three people. In many regions, the rate of slum formation is nearly the same as overall urban growth.[42] Continued urbanisation will further strain the sustainability of cities unless there are major improvements in governance and management and massive investment in infrastructure.[43] The growth of these cities is very likely to result in more people inhabiting low-lying coastal areas vulnerable to predicted rises in sea level.

While inhabitants of the mega-cities are expected to represent 7.5% of the global population by 2015 (compared to 3.7% in 2010),[44] they nevertheless do and will continue to consume the lion's share of natural resources. However, although the mega-cities justly receive a great deal of attention, the majority of the urban population lives in smaller cities (under 500,000 people) or in semi-urban areas. The distinction between rural and urban areas is becoming highly blurred in many regions, as people in rural areas diversify into non-agricultural activities without substantial movements into urban areas, or people migrate to settle on the periphery of cities.[45] This phenomenon is widespread throughout South and East Asia and is putting even greater stresses on water and other natural resources, because such areas lack the formal management systems to allocate and use water resources safely and efficiently. As communities become more geographically spread out and less dependent on local resources, there is subsequently less incentive to contribute to the management of common resources such as water.[46] This massive, unprecedented population movement, especially to urban fringes, will present new types of water- and wastewater-related challenges for all HKH region countries.[47]

Environmental migration and displacement

People have always used migration as a livelihood adaptation strategy in the Himalayan region, moving in search of work, resources or better security. Migration presents challenges for rural communities, but also offers many potential benefits for strengthening livelihoods, poverty alleviation and natural resources management. The benefits generated by financial remittances are huge, representing a major source of income in most HKH region countries, including remittances from urban to rural areas, between countries within the region and from outside the region. In Nepal, almost half of households in mountainous regions received remittances totalling 35% of their income.[48] However, the numbers of people moving have risen rapidly during the last decades and, with its growing scale and complexity, migration is emerging as a major issue in the HKH region. Some 30 million (15%) of the world's total migrants now come from the Himalayan region, with flows doubling since 2002.[49] In the next decade, should river flows reduce significantly, migration out of irrigated areas could be massive.[50]

Studies by the European Commission have shown that 'environmental change affects human mobility most directly through livelihoods, which are dependent on ecosystem services such as agriculture, herding and fishing'.[51] The majority of people living in the Himalayan region rely directly on ecosystem services for their existence. Moreover, almost 70% of people in the mountain areas live in poverty, with limited resources and livelihood options. In the future, increasingly unreliable water supplies and environmental changes are likely to impact upon livelihoods, which in turn could force people to migrate.

In China 'environmental migration' is used to describe planned 're-location of people from ecologically fragile regions or those with an important ecological role to other areas, with the aim of achieving regulated economic and social development of population, resources and the environment'.[52] However, at regional level, only Chongqing municipality currently keeps records of its annual numbers of environmental migrants,[53] and there are few reliable estimates of the broader numbers of 'environmentally displaced' people. A tentative general estimate for the total number of people displaced to date in China as a whole has been

Case study 1: Seasonal migration for survival in the Ganges Delta

Temporary displacement and seasonal migration for survival have already become commonplace in Bangladesh. Densely populated Bangladesh is situated in a low-lying river delta, exposed to cyclones, storm surges and potential sea-level rise. Moreover, over half the population still relies on subsistence crop agriculture, and over 23% live on less than US$1/day. Consequently, it is believed that more environmental migrants will come from Bangladesh than from any other country. By 2100 more than 25% of the country may be inundated, permanently displacing 15 million people.

Flooding currently displaces about 500,000 people every year. In 1998 flooding submerged 68% of the country and temporarily displaced 30 million people. The massive flooding in 2007 affected 10 million people and reduced crop yields by 13%. This was followed by Cyclone Sidr only months later, which further devastated the country. Millions more people were exposed to food insecurity requiring evacuation, shelter and relief assistance.

The increased intensity of floods has exacerbated land erosion along riverbanks – the main direct cause of landlessness.[54] At the same time, returns from crop production are also declining. With widespread failure of rural livelihoods, struggling farmers have been migrating to urban areas. Although people are desperately trying to find alternative ways to adapt, mainly by leaving agriculture for other livelihoods such as shrimp farming, the worsening environmental situation could render migration the most realistic available option for many Bangladeshis. There is a noticeable lack of investment in finding viable alternative livelihoods for those vulnerable to climate change.[55]

Case study 2: Response to reduced water supply in Minqin County, China

In Minqin County, Gansu, problems of water supply have been increasing over the past two decades. The oasis there is fed by the Shiyang River, with headwaters located in the Qilian range. Snowfall on the mountains has been steadily decreasing, with snowlines retreating at an average rate of around 2 metres per year. The amount of water flowing annually into the oasis via the Shiyang has fallen from an average of 400–600 million cubic metres in the 1960s to just 85 million in 2002. If current trends continue, the river is expected to be virtually dry by the end of 2010. To date, the county's people have resorted to ever-increasing levels of groundwater extraction. A recent report estimates that non-sustainable groundwater extraction in Minqin County is currently 428 million cubic metres per year, causing groundwater levels to fall by an annual average of 0.4–1.0 metres.[56] Consequently, authorities have developed a strategy to reduce local population in line with falling water availability, thus attempting to use environmental migration to mitigate environmental problems, and attracting widespread criticism within China and abroad.

set at 30 million, although there is little firm empirical evidence to support such claims.[57]

Displacement caused by large infrastructure projects, especially dam construction, has become common in China – as in other countries within the region – in response to the escalating demand for electricity and water associated with rapid urbanisation. In the Three Gorges Dam Project, more than 1.4 million people were moved.[58] People displaced in these projects are normally poor and powerless and do not participate in any way in decision-making concerning the projects. Their resettlement conditions are very often unsatisfactory. In many cases there are likely to also be further, unintended environmental consequences of such projects forcing more environmental migration.[59]

Table 5: Withdrawal of fresh water by sector in selected countries, 2000

Country	Percentage of national water use		
	Agriculture	Domestic	Industrial
Afghanistan	98.19	1.81	0.00
Bangladesh	96.17	3.19	0.65
Bhutan	95.24	4.76	1.19
India	86.46	8.09	5.45
Nepal	96.46	2.95	0.59
Pakistan	96.03	1.93	2.05
China	67	6	25

Source: FAO, AQUASTAT database.

To date, the majority of China's 'environmental migration' projects have involved the relocation of nomadic communities away from fragile grassland areas. Resettlement programmes for Tibetan nomads were introduced in the 1960s, and have since expanded. Some 60,000 people were displaced from the Three Rivers Source area, Qinghai province, between 2003 and 2008,[60] and the current goal of the provincial government is to settle all nomadic herders by 2011.[61] Recent studies have shown that the resettlement scheme is creating new social problems and the environmental benefits are uncertain. It seems that this kind of project may be as much about the urbanisation of nomadic peoples (largely ethnic Tibetans and Mongolians) as it is concerned with protecting the environment.

Agricultural productivity and water use

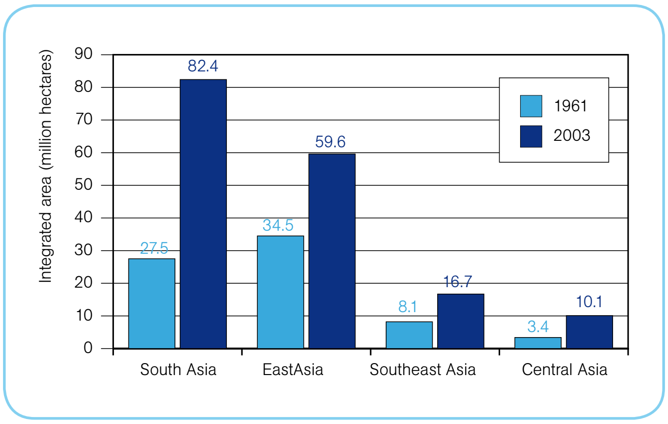
The agricultural productivity of many parts of the HKH region and the adjacent plains areas are heavily dependent on the availability of dry-season water from the Himalayan glaciers. The shrinking of the glaciers therefore could seriously threaten the long-term sustainability of food production in the region. Agriculture is by far the main consumer of water (see Table 5), accounting for 95% of total water use, against an average global agricultural use of 70%. In most countries in the region, agriculture continues to be the most important sector of the economy in terms of its contribution to GDP, food security[62] and employment. Projected water allocations suggest that by 2030, agriculture will continue to be the primary user of fresh water, even as domestic and industrial demands, including for energy production, increase sharply.

Economic development, especially in China and India, is increasing demand for more varied, water-intensive diets, including meat and dairy products. Wheat and feed grains have increasingly emerged as particularly important cereal crops in a region traditionally dominated by rice consumption. Between 1967 and 1997, meat consumption more than tripled, and demand for dairy products more than doubled. Consumption of high-value crops such as fruit, sugar and edible oils also increased substantially.[63] Overall, demand for food and animal feed is expected to double in the next 50 years.[64] At the same time agriculture is facing increased competition for water supplies from industrial and domestic usage.

Irrigation has been vital to food security and improving rural welfare in the HKH region, especially during the Green Revolution. From 1970 to 1995, the area under irrigation in Asia more than doubled (see Figure 9), making this the world's most intensively irrigated continent.[65] China and India are now the biggest grain producers in the world, together producing half the world's wheat and rice. However, irrigation, and accompanying technological innovations in fertiliser and insecticides have been both capital-and water-intensive. While this expanding water use was the key factor for tripling the world's grain harvest between 1950 and 2000, the consequence is that Asia has been accumulating a water deficit in some regions. Over time, the efficiency levels of state irrigation schemes have dropped, and individual farmers have turned increasingly to using diesel and electric pumps to obtain groundwater. Privately pumped groundwater now represents the bulk of irrigation water in some countries in the region. (This is discussed further below under 'Extraction and loss of groundwater'.)

Grain production has actually stagnated in the HKH region since the1990s due to high production costs and low returns because of the artificially low price of grains.[66] As a result, many farmers in the region have been substituting grain for other crops or even abandoned land. In Nepal, as much as 30% of cultivated land has been abandoned.[67] Between 1979 and 1995, China lost more than 14.5 million hectares of arable land due to increasing urbanisation, industrialisation and population growth. Farmers are substituting food

Figure 9: Irrigated areas of Asia, 1961 and 2003



Source: IWMI-FAO, 2009.

Table 6: Demand for food in South and East Asia, 2000 and 2050

	South Asia			East Asia		
Crop	2000	2050	Change (%)	2000	2050	Change (%)
Wheat	96	205	114	121	193	60
Maize	17	32	88	184	341	85
Rice	113	202	79	219	287	31
Total cereals*	249	471	89	529	935	77
Meat	8	32	300	75	190	153
Milk	114	382	235	19	60	216

* *Includes food and feed; production figures in millions of tonnes.*
Source: de Fraiture et al. *2007*

crops for other products and the resulting sharp increase in food-crop prices is further weakening overall food security in the Himalayan region.[68] Pakistan is losing cropland in other ways, notably as Middle Eastern investors are making large purchases of farmland. It is rumoured that these land deals are aimed at monopolising local water rights, and the *Economist* has reported a reference to them as 'the great water grab'.[69]

Water shortages and food security

There is increasing concern that water scarcity and pollution could create dangerous shortfalls in agricultural production in some areas of the HKH region, particularly in the Punjab region of India, which produces the country's largest agricultural surpluses, and in neighbouring Pakistan.[70] Existing signs of growing water scarcity include declining water tables in North India, Pakistan, and North China, and drier rivers, such as the Yellow River in China, no longer discharging to the sea for extended periods of time. Climatic change may aggravate water shortages in these areas. Although some estimates on China's agricultural production are cautiously optimistic, a recent report released by the International Water Management Institute (IWMI) and the UN Food and Agriculture Organisation (FAO) warns that water scarcity will cause widespread food shortages in Asia in the near future, unless water efficiency is improved.[71] Another UN report, "The Environmental Food Crisis", warned that the melting glaciers and snow could jeopardize world food security and drive prices to unprecedented levels.[72] While food demand is rising rapidly, the option of expanding irrigated land area in Asia to feed a growing population is becoming increasingly problematic due to both water and land constraints. In South Asia, for example, 94% of the land suitable for farming is already in production.[73]

To meet expected cereal demand by 2050 (see Table 6), IWMI's projections show that, with present trends of yield growth, irrigated farmland would have to increase by 30% in South Asia and by 47% in East Asia. Without water-productivity gains, South Asia would need 57% more water for irrigated agriculture and East Asia 70% more. Given the existing scarcity of land and water, such a scenario is highly untenable unless action is taken now. While some official data from both India and China present an optimistic picture of future food security, the international consensus predicts a major slow-down in agricultural growth.[74] The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) estimates that crop yields could decrease by up to 30% in Central and South Asia by the mid-21st century due to water stress. In its long-term scenario, the International Food Policy Research Institute (IFPRI) envisions that by 2020 cereal production in China and India will fall by 15%, resulting in a shift from near food sufficiency in cereals to huge imports. In Bangladesh wheat production is expected to fall by 32%, and rice production by 8%. In Pakistan, it is estimated that by 2025, there will be a shortfall of 28 million tonnes in the production of all major food grains and crops due to water shortages.[75]

Recent scenarios presented in the IWMI-FAO report[76] however do not incorporate climate change, which is likely to make rainfall more erratic and increase the strain on already overstretched irrigation systems. In 2009, the Indian monsoon was late and weak, following the lowest June rainfall in 80 years. Areas around the Yellow River in China suffered severe droughts in 2008, and lower precipitation is affected by El Niño. As a result, even the IWMI-FAO report s pessimistic assumptions may prove overly optimistic. However, as the report highlights, there are multiple opportunities available to improve the efficiency of irrigation and water-use which are urgently needed. More investment in innovative water-saving technologies and alternative options such as rain-fed farming could boost production to adequate levels.

Extraction and loss of groundwater

Countries have been pursuing unsustainable policies of aggressive groundwater use. In some of Asia's key agricultural areas, including the Punjab in India and the North China plain, pumping underground aquifers is causing water tables to fall by 2–3 metres per year.[77] The motivation to rely more upon groundwater has been fuelled by populist policies that provide heavy subsidies. Accordingly, farmers often pump more groundwater than is needed for optimising crop production, and there is no regulatory framework to control groundwater extraction. If the present rate of extraction is maintained, it is estimated that the aquifers below the north China plain will become completely dry in 30–40 years.[78]

In India, where nationally groundwater provides 45-50% of irrigation needs and 50-80% of domestic water usage,[79] groundwater depletion is a serious concern.

Case study 3: Groundwater levels in the GBM delta

Shallow groundwater levels in the Ganges–Brahmaputra–Meghna (GMB) delta vary with the wet and dry seasons in this region of West Bengal and Bangladesh. It has generally been assumed that shallow aquifers throughout Bangladesh are annually recharged every monsoon, but a recent study[80] has found that this may not be the case and that shallow groundwater storage is decreasing. Some of the decrease is associated with the city of Dhaka, but most of the decline is associated with groundwater abstraction for irrigation for rice production, which has more than doubled in recent decades. In the Dhaka district, groundwater abstraction is increasing rapidly, largely associated with industrial and domestic usage.

Recent data published from the NASA Gravity Recovery and Climate Experiment (GRACE) for northern and North-Western India, eastern Pakistan and parts of Bangladesh confirm that groundwater is being used at a highly unsustainable rate, particularly for crop irrigation. Between 2002 and 2008 rainfall was close to the long-term climatic mean and other terrestrial water-storage components (snow, glaciers, surface water, soil moisture and biomass) did not contribute significantly to the observed decline in total water levels. Therefore, the major contributor by far to groundwater depletion was human activity and not natural decline or variability in precipitation and other sources of water.[81]

Further, in estuarine and southern coastal regions in Bangladesh, groundwater levels have been rising over the past two decades, corresponding with rising sea level in this area.[82] The abstraction of groundwater and rise in sea level both cause the freshwater–seawater interface in shallow aquifers to rise and seawater to penetrate inland, perhaps as far as 100km in some parts of the GBM delta.[83] Salt-water intrusion in the coastal zone threatens the world's largest mangrove forest in the Sundarbans,[84] where fresh ground and surface waters are essential for maintaining a salinity level that allows mangroves to exist.

The message is clear: if population continues to grow and water-intensive crops, such as rice, remain the staple food, the GBM delta and many other parts of Asia is likely to face a major growing water crisis. Shortages of potable water and reductions in agricultural output may result, potentially leading to extensive social, political and economic stress. Maize or sorghum could be a replacement for rice, but government policies and market demand would have to change to promote these less water-intensive crops.

Suicides of farmers who cannot get enough water to continue planting have become common in recent years,[85] including instances of protest by mass suicide.[86]

Water wastage

Water resources are under stress not only because of over-extraction of groundwater, but also because of inefficiency. Of all sectors, agriculture has the lowest water efficiency and the lowest output per unit of water.[87] In China, according to one estimate, a cubic metre of water sent from the countryside to Tianjin yields 60 times as much income in the urban area as it does in the countryside.[88] Thus, in economic, though not necessarily in social terms, any significant reductions in water usage would probably have to come from rural areas. Artificially low water prices have resulted in endemic water wastage across the agricultural sector. More commercial pricing of water would provide incentives to increase efficiency, but any significant rise in water prices would drive millions of marginal farmers over the edge and accelerate the rapid rush to the cities. More expensive water would almost certainly mean decreased agricultural output and increased demand for imported food. Consequently water saving in agriculture, though vital, is likely to come slowly and painfully.[89]

Inappropriate water management has contributed to environmental and supply problems, including water-quality reduction, water-logging and salinisation. State policies continue to lead farmers in some water-scarce areas of Pakistan and India to opt for water-intensive crops such as rice and sugarcane. One recent example is the Water Transfer Project in China, designed to transfer massive volumes of water from the water-rich south to the water-poor north. However, some of this water is targeted for agricultural use to produce food for south China. In other words, this so-called solution has resulted in a 'virtual water flow' through food shipments from the north to the south, with increasingly apparent high economic and environmental costs.[90]

Water quality and pollution

Water pollution is a growing concern in most Asian countries.[91] Inadequate monitoring systems in many places result in a lack of information about pollution loads and water quality, and the often-serious impacts of polluting activities on human and ecosystem health remain unreported or under-reported. However, without substantial progress in regulation and enforcement, pollution is expected to increase as a result of economic development driven by urbanisation, industry and intensive agriculture.[92] Section 3 of this report contains more information on groundwater contamination from saltwater intrusion and natural arsenic contamination.

At the domestic level, nearly all household water is eventually discharged as wastewater. Even in urban centres where wastewater is collected through sewer systems, this is often discharged to fresh-water, land or oceans after little or no treatment. This means that the problem of increasing contamination by wastewater is not being solved but simply transferred from one location to another. While attention focuses on the multiple challenges of mega-cities, smaller urban areas, with few financial and technical resources due to their lesser political influence, are set to continue current trends of poor wastewater management. Thus, water quality as well as water quantity is gravely threatened.

Industrial wastewater discharges mostly receive inadequate treatment in nearly all Asian countries. Land disposal of wastewater is also contaminating groundwater, which is often an important source of drinking supplies. Increasing use of agricultural chemicals is a further complication in the HKH region.[93] In China, an estimated 70% of rivers are polluted, leaving 300 million people with limited access to clean water. In India the level of water pollution is unknown,[94] but some 38 million people in India are affected by waterborne diseases due to contaminated drinking water, and an estimated 1.5 million children die of diarrhoeal disease each year.[95] In southeast Asia in 2004,100 million people were estimated to be living without safe water and 185 million were without adequate sanitation.[96]

In a recent report the Asian Development Bank considers the scale of tackling pollution in Asia: 'Considering the cost of construction and efficient operation of wastewater management systems, and the number of trained and experienced personnel needed to manage them – ranging from managers to plant operators and technicians, who are mostly not available at present – resolution of this problem in the foreseeable future will be a Herculean task'.[97] The task is even greater given that we are dealing with transboundary water supplies, where water allocation needs to be negotiated with multiple countries, and that any waste-management systems need to be built to withstand floods, earthquakes and other disasters, such as the Indian Ocean tsunami of 2004.

Hydropower and dam-building

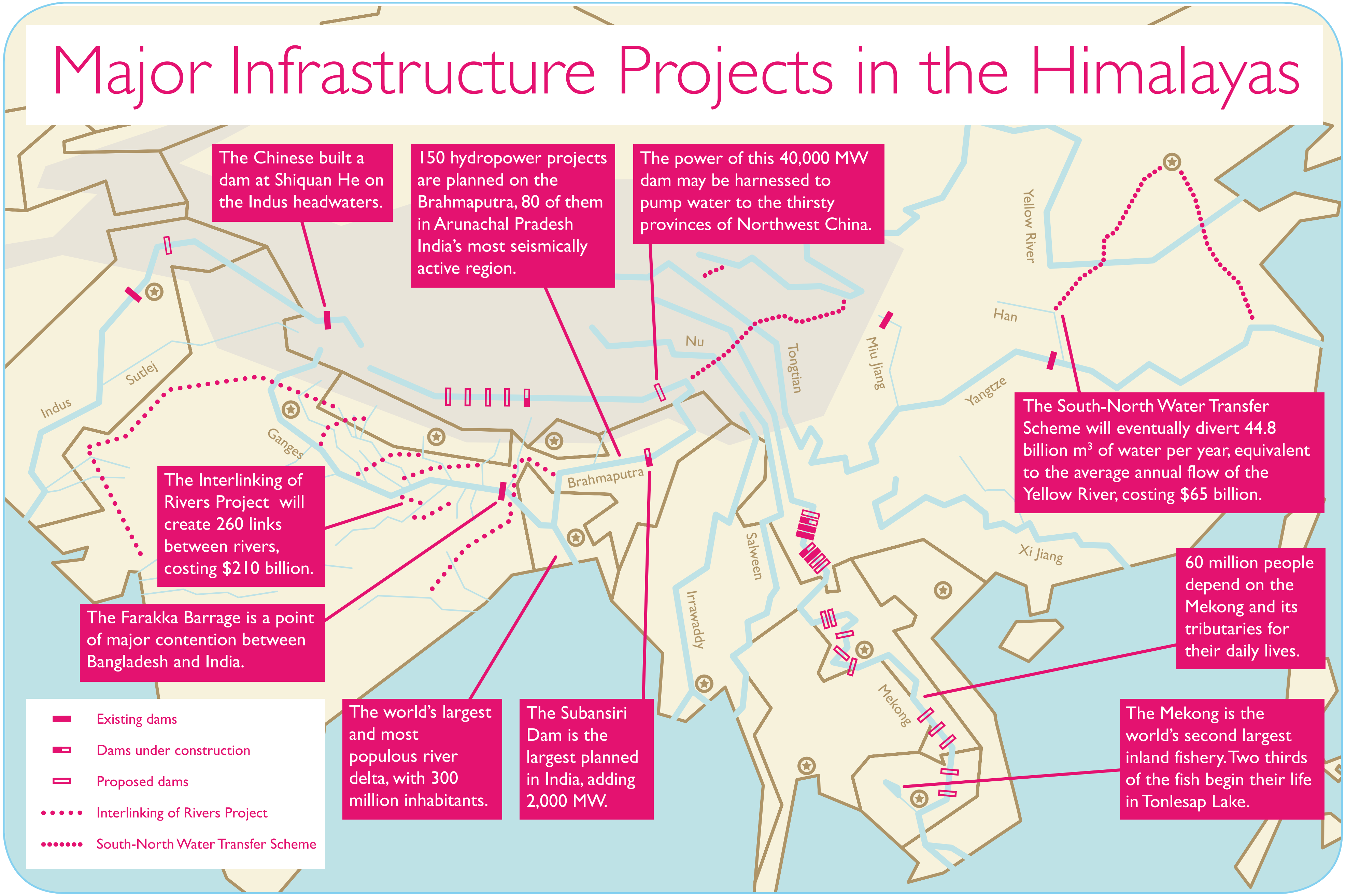
Electricity generation across the HKH region is currently undergoing a period of rapid expansion, with almost all countries aiming at least to double their generating capacity within the next ten years. North of the Himalaya, China is currently balancing supply and demand, but plans to expand its capacity in line with continued high rates of GDP growth. By contrast, the electricity sector across much of South Asia is still struggling to keep pace with rapid economic growth.

With governments anxious to avoid energy supply becoming a constraint on growth, there are plans to install vast amounts of capacity very rapidly. India has stated that it will need to expand its generating potential more than five-fold by 2030 in order to sustain current levels of growth.[98] Figure 10 shows some of the existing and planned infrastructure projects in the Himalayan region.

New hydropower projects are integral to the planned capacity development of all countries in the region, with the exception of Bangladesh, accounting for between 20% and 100% of all expansion. Given the urgency of these plans, the implications of this trend are serious. There is a real danger that questions about environmental and political impacts, and even the ultimate efficacy, of new dam projects will be overlooked as governments and suppliers struggle to meet ambitious targets. Smaller countries such as Bhutan and Laos are hoping to capitalise on their untapped hydroelectric resources, and to export electricity to energy-hungry neighbours. Problems such as severe seasonal stream-flow variation in Vietnam have already highlighted how unreliable such projects can be.[99] Should climate change or the obstruction of cross-border waterways substantially alter regional hydrology, this could have severe effects on many countries' capacity to provide power to their citizens.

The rivers that originate in the Himalaya provide sustenance and livelihood to hundreds of millions of people across South Asia, from the Indus Basin plains of Pakistan in the west to Bangladesh in the east. Massive plans are underway in Pakistan, India, Nepal and Bhutan to build several hundred dams in the region, with over 150,000 Megawatts (MW) of new projects proposed over the next 20 years.[100] If these plans are realised, the Himalayan region will have the highest concentration

Figure 10: Major infrastructure projects in the Himalaya



Source: *Adapted by Walker, Beth from Pomeranz,*. 2009 of dams in the world, with far-reaching implications for the landscape, ecology and economy of the region. As forests, fields and settlements are submerged with the displacement of hundreds of thousands of people, the wider impact of such mammoth development would be felt all the way down to the river deltas.

The changes in flow regime and sediment load imposed by new dams are likely to have substantial ramifications for agriculture and ecosystems downstream. Silt trapped in reservoir lakes not only has the potential to render dams inoperable, but also deprives farmland of valuable nutrients. The cumulative effect of several major dams in the upper reaches of a river on water provision downstream remains largely unknown, especially where the rivers cross national boundaries and while there is no effective means of jointly coordinating flow management. This is even more significant in the ambitious water-transfer projects planned in India and China, which are set to involve the re-routing of enormous volumes of water between different river basins.

Because the Himalayan region is seismically active (see Section 1 above), there are inevitably dams at risk of failure during a major earthquake. In addition, the pressure of the water in lakes of several square kilometres locked behind a large dam may even contribute to an increase in the seismic activity beneath it, especially if the dam is built directly over a fault. As highlighted in the recent controversy over the Zipingpu dam's contribution to the 2008 earthquake in Sichuan, dams could end up becoming agents of their own demise.

Climate change is also likely to have a significant effect on the safety, viability and overall impact of new dam projects. The effects of changing temperature and weather patterns are already being acutely felt in the Himalaya, resulting in an increase in extreme weather events, as well as a general trend of accelerating glacial melt. In light of plans for massive and widespread dam construction, the potential impact of such changes gives even more cause for concern. As glaciers melt, dams could be subjected to much higher stream flows, which could increase the possibility of major flooding as dams are forced to open their gates in order to release pressure. Also associated with glacial melt is the possibility of increased risk from glacial-lake outburst floods (as discussed in Section 3). The suddenness and intensity of these events raises questions about the increased risk of cascading dam failure downstream. High sediment loads in glacial meltwater could also clog up dam reservoirs, as could landslides from slopes destabilised by melting permafrost. Both would reduce energy-generating capacity and, again, augment flood risk.

Longer-term, continued glacial retreat may eventually lead to a drop in river flows once meltwater volumes have peaked. This trend may be accompanied by more exaggerated peaks and troughs in seasonal flow variation.[101] Both could directly affect the capacity of new dam projects to generate electricity. For countries

Case study 4: China's dam-building

China has built almost half of the world's estimated 45,000 large dams and remains one of the most active dam-building countries in the world. As a result, China has also been responsible for correspondingly large amounts of human displacement and river alteration. A recent study by a research team under the Chinese People's Political Consultative Conference (CPPCC) found that more than 3,000 hydropower plants operating or planned along the Yangtze's upper reaches and its tributaries suffer from weak management or supervision, and that several new dams on the Yellow River had cracked within three years of construction.

In recent years, China has shown an increasing interest in developing the hydroelectric potential of its transboundary watercourses. This could increase the potential for tension with neighbouring countries downstream worried about the security of their own water supplies. In addition to two existing dams, China is building at least eight more on the Mekong, while the future of several half-built projects on the upper reaches of Myanmar's Salween River is uncertain. The increasing number of dams built by Laos, Vietnam and Cambodia are also causing concern. Several Chinese projects in west-central Tibet also have a bearing on river-water flows into India.

The South–North Water Transfer Project is particularly controversial. In addition to drawing water from tributaries of the Yangtze, China has also discussed the rerouting of water from the Brahmaputra northwards to the Yellow River. This proposal has been described by some Indian experts as a declaration of 'water war' on the lower-riparian states of India and Bangladesh. While China's water resources minister described this ambitious project as not viable during a speech at Hong Kong University in 2006, the director of the Yellow River Water Conservancy Committee has stated publicly that the project has official sanction and could be underway before the end of 2010.[102]

like Laos and Bhutan, with development strategies depending on dam construction and historical river flow, the impact could be severe. In energy-starved Pakistan and India, rushed hydropower construction could likewise turn out to be a false saviour.

Transboundary water management

In the Asian region, water resources are already over-stretched by increasing demands from growing populations, rapid industrialisation and intensifying agriculture. At a national level, existing water-management systems are ill prepared to surmount this impending water crisis, due to ineffectual regulatory mechanisms and fragmented institutions. India and China both face serious internal and cross-border pressures over water resources.[103] At a regional level, institutional mechanisms for governing transboundary water resources remain limited. The Mekong River Basin Commission (MRC) has failed to live up to expectations largely due to China's refusal to join and engage in binding dialogue on integrated watershed management. China's dam-building projects (as discussed in Case Study 4 above) have taken precedence over ecological concerns.[104] Intensive dam construction by Vietnam and Laos is already seriously affecting downstream populations, exacerbating regional tensions. The largest and most controversial of Laos' 30 potential dams became fully operational in early 2010 despite violations of legal obligations to affected communities.[105]

At the bilateral level, the Indus Waters Treaty negotiated between India and Pakistan in 1960 with the help of the World Bank is a rare example of a successful resolution of a major dispute over international waters.[106] As a consequence of partition in 1947, the basin was divided between the two countries – headwaters in India and the lower basin in Pakistan – creating the potential for major conflict. Both sides accepted a proposal to divide the Indus waters equally between the two countries and at the same time enhance water.. The fact that the treaty has endured for four decades despite a nuclear stand-off between the two counties is testament to the high value attached to water resources for domestic agricultural production. However, in this case the agreement works on the basis of a separation of waters rather than a shared arrangement, and is not without tensions.

A bilateral agreement between India and Bangladesh also exists for sharing dry-season flow in the Ganges, but this has not proven to be very effective. At best, it has forced the two countries to establish a dialogue on flood management and hydropower generation. The Mahakali Treaty between India and Nepal has served a similar purpose by paving the way for the construction of the Pancheshwar multipurpose hydropower project.

Critically, multilateral agreements that encourage water-sharing on the basis of a common regional framework have yet to develop. While official recognition of the impending crisis now exists – in recent years governments have moved water issues higher on their national agendas – mutual distrust hinders effective action, and sovereignty concerns over-rule regional interests. Environmental cooperation generally lags far behind economic cooperation in the HKH region.[107] Currently there is a general lack of policy direction and political will in tackling these issues because states continue to regard the management of water resources as a sovereign prerogative.

However, there is evidence that water issues have the potential to drive cooperation and facilitate conflict resolution. In 2002 China and India signed a memorandum of understanding that enables the sharing of hydrological data on the Brahmaputra.[108] Such information will be instrumental in instituting early warning systems and better flood management in the future. Annual Joint Expert Level meetings on Trans-Border Rivers have been held since 2008. India and China have also begun to discuss co-operation over monitoring the melting of glaciers in the Himalayas, a border region crucial to both countries' water supplies and one over which they have gone to war.[109]

Although uncertain information and knowledge about glacier melt processes have fuelled a wider debate about the nature of climate science, one positive outcome of the debate has been the immense awareness generated among politicians, the media, and the general public. In this context, the Indian government has taken a decision to establish a specialised glacier research centre.[110] Similarly, the concept of the HKH region Environment initiated by the Chinese Academy of Sciences will have a positive impact on minimising the gaps in understanding.[111] Recent Indian and Chinese media reports have speculated that a formal agreement on bilateral cooperation in glacier research will be made in 2010.[112]

In response to claims that its dam construction has been responsible for alarming declines in Mekong River flow, China has agreed to partial sharing of hydrological data with downstream countries.[113] This is a positive step towards regional collaboration amid a water crisis, but a stronger data sharing arrangement is critical. China's transparency and willingness to allay fears may motivate India to share Himalayan river data with Nepal, Pakistan, and Bangladesh. This would lead to better management of water resources in an integrated manner.[114]

The International Centre for Integrated Mountain Development (ICIMOD) is playing a key role in facilitating increased cooperation in the HKH region. In December 2009 a project was launched to establish a regional flood information system in the Ganges-Brahmaputra-Meghna and Indus river basins. It is hoped that this will create a regional framework for information sharing and improve overall cooperation amongst participating countries in areas such as disaster preparedness.[115]

3 Emerging vulnerabilities and crisis drivers of the future

Overview

The hazard profile of the HKH region drainage basins generally varies with height. The mountainous upper reaches are more prone to earthquakes (eg. the Kashmir event in 2005), mass movements (eg. the giant failure of part of the west side of Nanga Parbat in 1841) and floods arising from the failure of natural dams and the boundaries of glacial lakes (eg. Dig Tsho in Nepal in 1985 and Lugge Tsho in Bhutan in 1994). Flatter downstream sections, deltas and coasts are more likely to experience floods (eg. the Bihar event in India in 2008), droughts (eg. as in South-East Asia in 2005), windstorms and storm surges (eg. Cyclone Sidr in Bangladesh in 2007 and Cyclone Nargis in Myanmar in 2008), and groundwater contamination (eg. the ongoing arsenic problem in the Bengal basin). However, any of these events in one part of the region could also affect other parts of the region through, for example, loss of agricultural production and livelihoods, and migration and possible intra and inter-state conflict.

The HKH region offers an extraordinary panoply of future crisis drivers. The permutations of interlocking natural hazards and human interventions suggest crisis drivers unusual for both their complexity and their unpredictable dynamics. When these are placed in the context of a region of high population density and severe socio-economic pressures, the numbers of people affected by the impact of future crisis drivers could possibly overshadow some of the worst calamities that have befallen the continent of Africa in the previous two decades.

The analysis in this section focuses on the potential consequences of six types of natural phenomena: floods, earthquakes, mass movements, hazards in deltas and coastal zones, arsenic contamination, and fires and atmospheric brown clouds. When combined with the effects of human activities, these phenomena could plausibly lead to severe humanitarian crises in the HKH region over the next two decades. These six hazards, as discussed below, could trigger crises resulting from food insecurity, mass migration, destruction of human habitats and infrastructure, damage to industry and livelihoods, and exponential increases in disease and conflict. These crises are discussed in the second half of this section.

Environmental hazards and their impacts

Floods and lake outbursts

The most severe and widespread flooding in the HKH region arises during the summer monsoon, with heavy precipitation causing huge increases in both peak discharge rates and sediment loads of rivers. Where rivers are steep and flow rates are high, the sediment-rich water is highly erosive, which creates a positive feedback between erosion and sediment transport. In flatter and calmer downstream sections, the sediment is deposited, which results in silting of river channels, floodplains and deltas, irrigation channels and reservoirs, and changes in the course of river channels. The sediment load is dominated by material derived from natural mass wasting, which includes soil erosion. In mountainous and hilly terrain, soil erosion generally increases from west to east in the HKH region and is most pronounced along the southern flanks.

This pattern largely reflects trends in precipitation in the region, being highest where precipitation is high.[116] There are arguments that downstream flooding is being exacerbated by human activities upstream, such as forest clearance and livestock grazing, but these have only small local effects compared to the massive scale of natural mass wasting. Nevertheless, societies living in flood-prone downstream sections of rivers may blame communities located farther upstream for the worsening flooding.[117]

As noted in Section 1 above, there is considerable evidence that many of the HKH region glaciers are melting. As glaciers melt and retreat, lakes commonly form behind the newly exposed terminal moraine (a ridge of stony deposits). The rapid accumulation of water in these lakes can lead to a breach of the moraine dam.[118] The resultant rapid discharge of huge amounts of water and debris is known as a glacial-lake outburst flood (GLOF).[119] These sudden releases can form dangerous flood waves of water mixed with morainic materials, which can be devastating to downstream riparian communities, hydropower stations and other infrastructure. Although effects of events are relatively localised, they could eventually present an increasing cost in terms of lives, property and infrastructure in India, Nepal and China.[120]

There is also a history of such outburst floods from Karakoram glaciers. However, the problem here is caused by advancing glaciers that form unstable ice dams. More than 60 glaciers of intermediate-to-large size (10 to 65 kilometres in length) have a history of advancing into and interfering with tributaries of the upper Indus and Yarkand rivers. Not all are known to have created actual dams, but at least 30 have done so and involved outburst floods of exceptional size and destructiveness. The most urgent questions today involve some Karakoram valleys whose glaciers have created ice dams and catastrophic outburst floods in the past and that are now advancing.[121] While this issue is regarded as a "minor hazard" at present, it is an issue from a more systems perspective that might require further attention and understanding, and, hence, warrants inclusion in a list of potential environmental hazards.

Many Himalayan basins are reporting rapidly expanding lakes, as glaciers melt and retreat. A remarkable example is Lake Imja Tsho in the Dudh Koshi sub-basin (Khumbu–Everest region). While this lake was virtually non-existent in 1960, it now covers an area of almost one square kilometre, and the Imja glacier which feeds it is retreating at an unprecedented 74m per year (between 2001 and 2006). Similar observations have been made in the Pho Chu basin of the Bhutan Himalaya, where the change in size of some glacial lakes has been as high as 800% over the past forty years. At present, several supraglacial ponds on the Thorthormi glacier are growing quickly and merging. These lakes pose a threat because of their proximity to other large glacial lakes in the Pho Chu sub-basin where, in a worst-case GLOF scenario, they could cascade on to these other lakes with catastrophic consequences.[122]

Figure 11: Satellite images of Beichuan before and after the earthquake of May 2008

Note: These images show the impact of the magnitude 7.9 earthquake that struck the Sichuan Province of China on 12 May 2008. The top image is from 14 May 2006, and the bottom image is from 14 May 2008. Several landslides, a collapsed bridge and a bridge submerged by a newly formed lake can be seen. Formosat *image © 2008* Dr Cheng-Chien Liu, *National Cheng-Kung University and Dr An-Ming Wu,* National Space Organization, *Taiwan. Downloaded from http://earthobservatory.nasa.gov.*

Earthquakes

Earthquakes pose a very significant hazard in the HKH region (as outlined in Section 1 and Figure 3 above). While seismic activity is frequent in many areas it is of low magnitude most of the time. For example, every year in Nepal alone there are more than a thousand earthquakes ranging in magnitude from 2 to 5. With the last major earthquake in 1934, another large event in Nepal is likely soon. Kathmandu, for example, is highly vulnerable and studies anticipate over 135,000 casualties and destruction of at least 60% of the city's buildings.[123] The city is so vulnerable because it has been built on ancient lake sediments, which liquefy under severe ground shaking, and has undergone rapid unplanned development in recent years. Earthquakes pose an especially great hazard to dams, whether these are natural or artificial. Lakes and reservoirs may burst as a consequence of dam failure or overtopping. Earthquakes can also create natural dams (e.g. in the 2008 Sichuan earthquake) which may subsequently fail.

Mass movements

Landslides induced by rainfall are common in the HKH region, and many landslides occur during the summer monsoon.[124] Earthquakes and extreme weather events combine with the mountainous terrain to generate mass movements, such as avalanches, rock falls and debris flows, which may dam rivers. These dams may subsequently fail or be overtopped, leading to catastrophic flooding. As recently as 2008, the earthquake in the Sichuan Province of China highlighted the hazard associated with such dams, particularly around the city of Beichuan (see Figure 11), which is being relocated as a consequence of the damage caused by the earthquake and associated landslides.

Debris falling from a mountainside into a lake may cause a lake surge and flash flooding downstream. In 1841 a large section of the west side of Nanga Parbat collapsed into the Indus River, the downstream material from which dammed the river and created a lake some 50 kilometres long. The subsequent failure of the dam several months later caused flooding up to a distance of 150 kilometres.[125]

Hazards in deltas and coastal zones

Coastal erosion occurs to varying degrees along the coastline of Asia because it depends largely on the regional tectonic regime, the rate of sediment supply and sea-level rise, the intensity of wind, wave and storm activity, and the extent of human modification of the environment. Wetlands have been hugely modified by sedimentation and changes in land use, often resulting from logging to make way for development projects. Of particular note is the loss of a substantial portion of the mangroves in South and Southeast Asia as a consequence of human activities during the second half of the twentieth century.[126]

Most deltas in Pakistan, Bangladesh, India and China have experienced a decline in precipitation and an increase in droughts. This is exacerbated by upstream damming of rivers and overuse of groundwater, and has resulted in the drying up of wetlands and the severe degradation of ecosystems.[127] This degradation includes mangroves being destroyed as a consequence of reduced flow of fresh water and increased sea-water intrusion in the coastal zone.[128] Saltwater from the Bay of Bengal is reported to have penetrated at least 100km inland along tributary channels during the dry season. Severe droughts and unregulated groundwater withdrawal have also resulted in sea-water intrusion in the coastal plains of China.[129] Sea-water intrusion affects the quality of both drinking and irrigation waters.

The coastlines in monsoon Asia are particularly vulnerable to windstorm and storm surges, as about 42% of the world's tropical cyclones occur in this region.[130] The frequency and intensity of tropical cyclones originating in the Pacific have increased since the 1950s, whereas the frequency of those forming in the Bay of Bengal has decreased since 1970, but their intensity has increased.[131] An increase of surface temperature of the sea of 2–4°C relative to current thresholds may cause an increase in cyclone intensity of 10–20%,[132] which is likely to amplify heights of storm surges and associated coastal inundation and damage. In 1762 the eastern side of the Bay of Bengal experienced an earthquake of possible magnitude 8.8, which was associated with the Myanmar subduction zone off the coast of Myanmar. A recent study suggests that another event of similar magnitude may occur within 200 years and that the seismically active zone may extend beneath the Bengal fan.[133] Such an event could produce tsunami associated with ground movement or submarine landslides, and these could have a profound impact on the coastlines of Myanmar, Bangladesh and India, particularly the Ganges delta where 60 million people live within 10 metres of present sea level.

Hazards in deltas and coastal zones are likely to be magnified by higher sea levels. While the IPCC in 2007 estimated that global sea levels would increase by at least 180–590 mm by the end of the 21st century,[134] more recent studies have increased these projections. More recent estimates are that sea levels will rise from 80–200cm.[135] In coastal areas of Asia, the current rate of sea-level rise is reported to be 1–3mm per year, which is slightly above the global average.[136] The 2007 IPCC projections assumed a sea-level increase of 400mm by 2100, and has been estimated that the increase in the annual number of people flooded in coastal regions of South, Southeast and East Asia would rise from 13 to 94 million, with 60% of those affected being located along the coasts of Pakistan, India, Sri Lanka, Bangladesh and Myanmar.[137] Greater impacts, using the new data, have not yet been determined, but they are likely to be significant.

Arsenic contamination

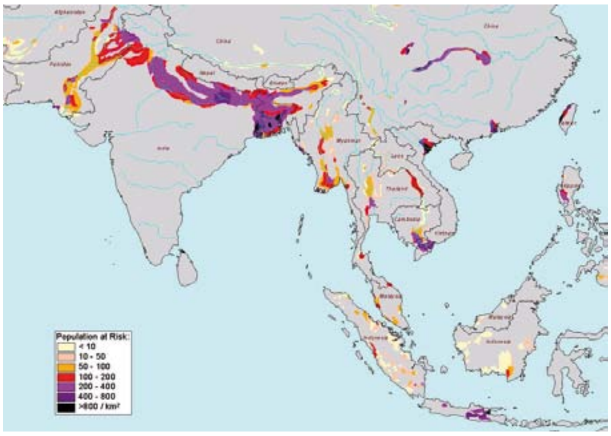
The composition of water is mostly controlled by the chemistry of the minerals that partially or completely dissolve into it. Many elements are essential to life within certain concentration limits, but otherwise represent an excess or a deficiency. Arsenic is a well-known toxin that occurs naturally in the environment. In their seminal work on arsenic pollution, Ravenscroft and colleagues[138] state that the use of arsenic-contaminated groundwater by many tens of millions of people worldwide, many of whom are now showing signs of chronic arsenicosis, represents a huge disaster.

More people are affected by arsenic poisoning in Asia than in the rest of the world combined, and possibly over 100 million people drink water containing more than 10ppb arsenic in Asia.[139] There are similar patterns of groundwater contamination in a near-continuous zone extending from the Indus River in Pakistan east to Taiwan – the South and Southeast Asian Arsenic Belt (SSAAB). Outside this belt, it is only the inland alluvial basins of Inner Mongolia, Shanxi and Xinjiang in China where arsenic pollution occurs on a similar scale.[140] As shown in Figure 12, arsenic pollution is mainly associated with alluvial deposits in the basins of the major rivers that flow south and east of the Himalaya and Tibetan Plateau. The poisoning of tens of millions of Asians with arsenic is indeed one of the greatest disasters of all time. Without widespread and sustainable solutions the problem may well increase, particularly as water stress is predicted to increase in the future in many of the regions where groundwater is seriously contaminated with arsenic.

Fires and atmospheric brown clouds

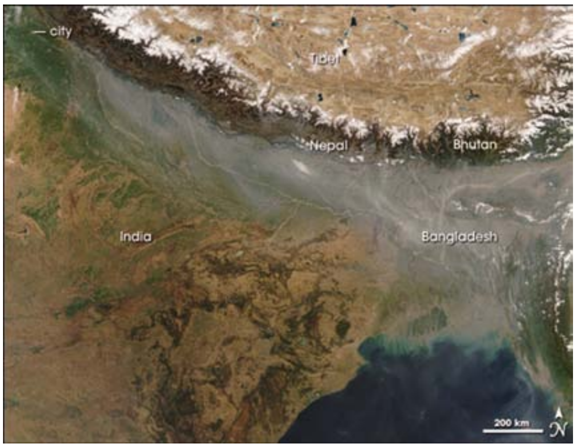
The intensity and spread of forest fires throughout Asia has increased over the past two decades, and is linked to rising temperature and declining precipitation in combination with increasingly intense clearance and use

Figure 12: Populations at risk from arsenic-polluted groundwater



Source: Royal Geographical Society; downloaded from www.rgs.org *on 4 August 2009.*

Figure 13: Atmospheric brown cloud along the front of the Himalaya and through Bangladesh



Source: Image courtesy of NASA.

of land.[141] This trend is likely to worsen in future and presents a major atmospheric hazard. Forest fires and other sources of dark particulates (such as automobiles, coal-fired power stations and wood-burning stoves) produce atmospheric brown clouds, which are most pronounced in a band that stretches from the Arabian Peninsula to eastern China. South Asia and the northern Indian Ocean are particularly affected, and a haze three kilometres thick resides here between October and May (see Figure 13).

Brown clouds may warm the local atmosphere, as they absorb solar radiation, but they generally cool the region below them by blocking and reflecting solar radiation. This cooling is problematic because it lessens the summer monsoon rainfall by reducing the amount of evaporation. India's rice harvest, for example, would be at least 10% higher if the detrimental effects of the brown clouds were removed, and higher still if the negative effects of global warming were also removed.[142] The brown clouds also deposit dark particles and aerosols on the surfaces of glaciers, which causes them to melt faster because they reflect less and absorb more solar energy. The overall increase in dark surfaces in the HKH region, because of both the loss of ice and the coating of ice with dark particulates, is one of the reasons why its high elevations are warming at an alarming rate.

From crisis drivers to crises

It is probably impossible to suggest with any accuracy the numbers of variables that could combine to trigger humanitarian crises in the HKH region, now or in future. Uncertainty surrounding the impact of climate change and future water availability makes predictions even more problematic. Nevertheless, there are indications of plausible developments that could either create large-scale humanitarian crises or reflect their consequences. These include food insecurity, mass displacement, habitat and infrastructure collapse, demise of livelihoods, changing disease patterns and a rise in conflict. These themes are considered in the remainder of this section.

Food insecurity

In various ways the interaction between natural phenomena and human activity in the HKH region could create levels of food insecurity that would directly affect the lives of at least 280 million people, and indirectly many more, in less than fifteen years. Unless there are major improvements in water efficiency and management it is likely that water shortages will in the longer term lead to major food shortages in some regions.

Salinisation of the soil may become an increasing problem, and the capacities of dams to provide water for irrigation purposes will be ever more problematic due to increased silting. Brown clouds will continue to affect monsoons potentially affecting agricultural production. Irrigation is likely to be increasingly dependent upon groundwater extraction. In turn, this extraction will depend upon fossil-fuel-powered pumps that will boost the cost of agricultural produce.

A growing proportion of the HKH region is likely to be dependent upon expensive agricultural produce coming from sources well outside the region. As dams continue to threaten the variable and complex ecosystem of the Mekong River, the future environmental and social effects could be monumental.

Mass displacement

A combination of infrastructure development, lack of potable water, the flooding of deltas, riverbeds and coastal areas, the threats of potential or ongoing conflicts, and the sale of agricultural lands for industrial purposes may result in the movement of millions of indigenous peoples in and outside the HKH region.[143]

The consequences of this potential displacement would be threefold.

1 A regional concentration of new forms of 'refugees' – mass movements of economic and environmentally induced migrants. These populations would almost certainly spread into neighbouring countries within the HKH region or outside it, and compete for resources and livelihood opportunities. There are likely to be potentially large holding areas for refugees as well as growing prospects of refugee-related conflict.

2 A rise in internal displacement which, as is already evident, could fuel internal conflict. India is but one example of this where intra-state conflict between environmentally displaced people is regarded as yet another crisis driver for the country.[144]

3 International and regional impact on urban and semi-urban conurbations. Slums of unparalleled proportions would become sources of disease and extreme malnutrition, threatening the lives of millions within them, while at the same time promoting pathogens that could spread into urban conurbations more widely.[145]

Habitat and infrastructure collapse

Dam construction and related hydroelectric power generation have in many ways become the symbol of future large-scale crises in the HKH region. The interaction between silting, the expansion of dam construction and earthquakes is but one example of how communities depending upon modern infrastructure could be faced with serious life-threatening situations.

Four of the major mega-cities in the HKH region are located near large bodies of water – rivers, the sea or deltas – leaving the insubstantial housing and infrastructure found in these cities' vast slums subject to collapse. In the wake of a flood, millions of people in Mumbai, Dhaka, Karachi or Shanghai could find themselves with no access to potable water, sanitation facilities or shelter.

The hydroelectric power that sustains a high proportion of the region's villages, towns and cities also is based on a set of precarious assumptions about the consistency of water flows. However, increasingly serious stream-flow variations, diversion of rivers and the upstream control of dam release means that the water necessary for habitats and livelihoods is by no means reliable, and can affect access to basic services such as potable water, sanitation and the most basic health care.

Livelihood challenges

Many parts of Asia have to deal with a complex paradox. While wealth creation has generated considerable wealth for many, at the same time the livelihoods of a significant proportion of people in the same societies are precarious. Across the HKH region there are serious threats to livelihoods within rural and urban areas. Increasingly, while some who migrate to urban areas may prosper and share income with families in rural areas, many of those millions of people who have abandoned the countryside for the city may struggle to gain access to employment. There are already indications that unemployment in urban areas is increasing, resulting in deep destitution with little state capacity to provide any consistent assistance. Without livelihoods in urban areas, a growing number of people are also without consistent access to clean water, as potable water remains a purchasable commodity throughout most urban areas in the region.

The situation in rural areas is equally precarious, and there is little reason to expect any significant improvement over the next two decades. Extreme climate events are likely to continue destroying crops, depleting water resources, causing losses in livestock, cropland, and agricultural productivity, and destroying the meagre infrastructure present, thus reducing market access and access to public services. Traditional livelihoods in the region have for many people depended upon migration – for agriculturalists as well as agro-pastoralists. In the future, population numbers in addition to increasing land degradation and political sensitivities mean that this form of survival strategy will be less and less available to those in search of livelihoods.

Changing disease patterns

In general, water throughout the HKH region is increasingly subject to a host of pollutants, natural and human-made. Of the former, as noted above in this section, arsenic poisoning is a potential threat throughout the region. Analysts suggest that this 'natural poisoning' is already beginning to affect tens of millions of Asians, and there is every indication that this crisis threat will intensify with growing water stress.

Yet, the admixture of collapsed infrastructure and habitat, poverty, food insecurity, non-potable water and lack of sanitation could be the source of major epidemics that would sweep through extensive areas of mega-cities across the HKH region. Traditional diseases, including cholera and typhoid, could join with new virus strains to affect millions of people in slum and non-slum environments. Such patterns of disease would be carried further through displaced communities seeking survival within and outside the HKH region. The foreseeable capacities in the region to anticipate and deal with potential epidemics would appear limited.

Case study 5: Water disputes of the future

In what may become the biggest water-diversion plan in history, China plans to divert water from the south and west to bring water to the dry North China Plain. This $65 billion plan will divert 45 billion cubic metres of water per year – roughly the average annual flow of the Yellow River – along three channels in eastern, central and western China.[146] The western route draws water from Tongtianhe, Yalongjiang and Daduhe, tributaries of the Yangtze River in southwest China, feeding the upper reaches of the Yellow River in efforts to alleviate water shortage in the northwestern regions. The central route is to fetch water from the Danjiangkou Reservoir on the border between Hubei and Henan provinces to supply Beijing and Tianjin. The eastern route draws water at Yangzhou on the lower reaches of the Yangtze, flowing northward through a section of the Grand Canal and several lakes to reach Hebei and Tianjin.

India, like China, is contemplating its own potentially disastrous schemes for water diversion. The most ambitious part of its Interlinking of Rivers Project, the Himalayan section, would move water from the upper parts of the Ganges, Yamuna and Brahmaputra Rivers westward, ending in the Luni and Sabarmati Rivers in Rajasthan and Gujarat. This would break India's formal promises to Bangladesh, including a written understanding of 1996, that no water would be diverted away from the Ganges above the barrage at Farakka, a few kilometres from the India–Bangladesh border. Official estimates for the cost of this project in total, with 260 links between rivers, are of $120–200 billion. Plans for the project have been shrouded in even greater secrecy than with China's river-diversion projects. It is estimated that the number of people displaced will be 5.5 million.[147]

Rising conflict

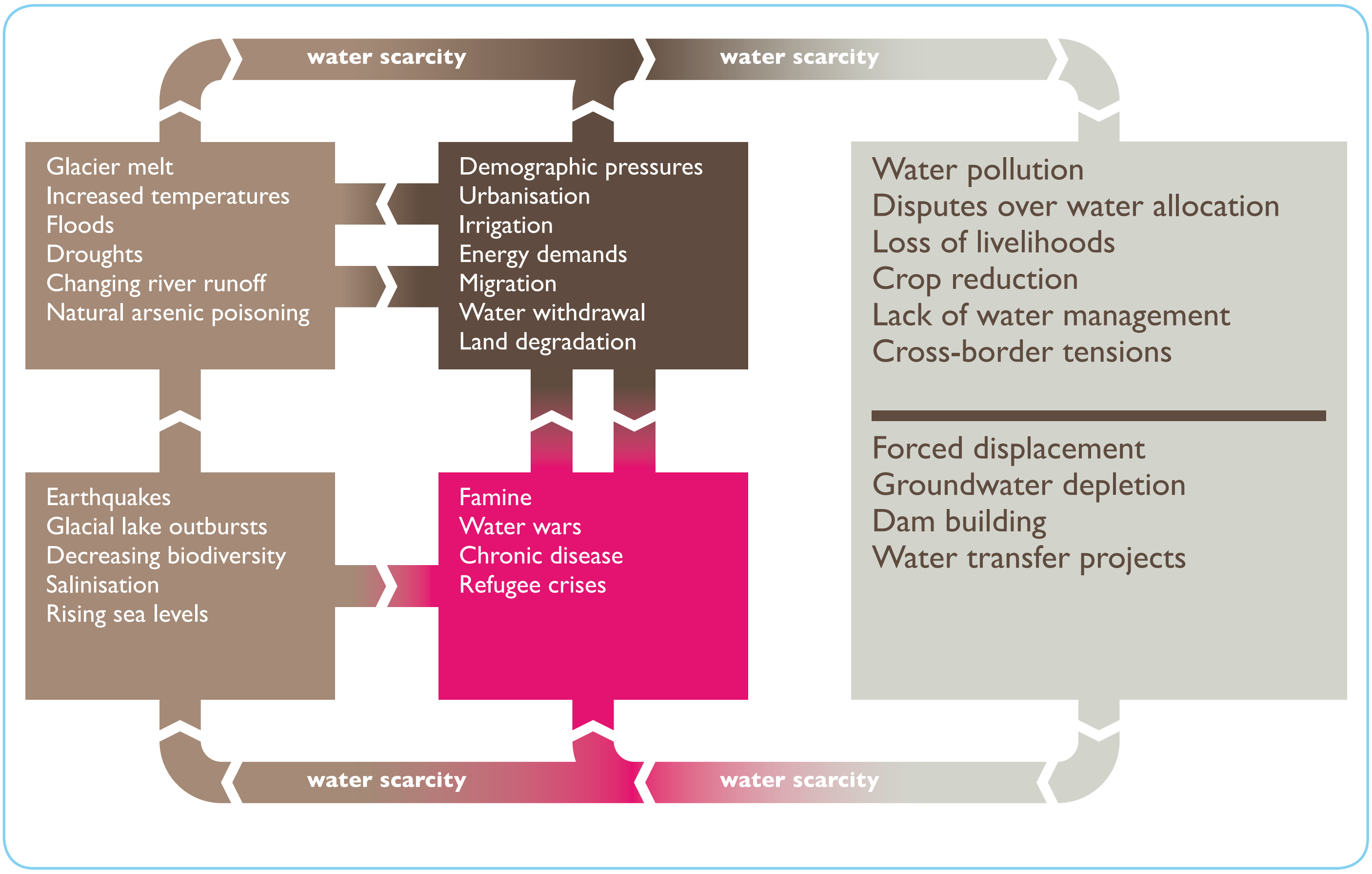
Almost all of the major rivers that originate in the Himalaya traverse several different countries. The Indus River originates in Tibet and flows through India into Pakistan; the Sutlej River rises near Mansorovar in Tibet, crosses India and Pakistan and meets the Chenab and the Indus; the major rivers of Nepal originate in the Himalaya and flow into India to meet the Ganges, which itself flows on to Bangladesh; the Tsangpo River originates in Tibet, flows into Arunachal Pradesh in India as the Siang (Dihang) River, then into Assam as the Brahmaputra, finally flowing on to Bangladesh, where it is called the Jamuna River.

The transboundary nature of the rivers, combined with the uncertain impacts of future dam construction, is likely to raise the risk of conflict in a region already fraught with cross-border tensions. Pakistan and India have already clashed over the Baglihar dam on the Chenab, while Chinese development of the upper reaches of the Mekong River and other countries projects on the lower Mekong have sparked popular outrage in South-East Asia. A more worrying long-term prospect is a possible plan by China to dam the main course of the Tsangpo (Brahmaputra) river in Tibet, which could result in serious confrontation with India. In the absence of any transboundary regulatory framework, disagreements and misunderstandings over dam construction could become flashpoints for future conflict, especially in a situation of water scarcity.

Considerable attention has been given to the prospect of inter-state 'water wars' involving in one way or another Bangladesh, Myanmar, China, India, Nepal and Pakistan.. However, far less attention has been given to the nature of intra-state conflict within these same countries. In China alone, it has been reported that domestic uprisings have continued to increase in protest about water management or water-quality issues. Xinhua News reported that more than 50,000 environmentally related protests occurred in China in 2005, slightly more than half of which were about water pollution issues.[148] Conflicts are occurring between factories and farming communities as well as between upstream and downstream water users. In India, too, many analysts also point to an increased in intra-state conflict that will lead to large-scale communal violence.

This is not to suggest that initiatives have not been taken to address such future conflicts. However, it is evident – if one takes the Mekong River Commission as a case in point – that the pressures throughout the HKH region for ensuring domestic water interests can transcend individual countries' commitments to sound transboundary water management.

Figure 14: Crisis Drivers in the HKH region



A matrix of interactions

The sorts of interactions between natural phenomena and human activities described in this section are by no means unique. They represent global phenomena with parallels elsewhere. However, in terms of potential crisis drivers of the future and their impacts, the likely consequences for the HKH region probably have few parallels in terms of the numbers of potentially affected people and the complexities of the crises that in various ways the meltwaters and declining recharge rates may well trigger. While it remains difficult to pinpoint numbers of potentially affected people, the complexities that would generate such future crises are outlined in Figure 14.

4 Humanitarian perspectives

An uncertain future

Sources of Survival – Sources of Threat poses questions about *what might be* and points to the very real possibility of disastrous humanitarian implications from the diverse types and scale of multiple disasters occurring at any one time in a highly vulnerable region of the world. It focuses on the issue of water as a vital resource and a potential crisis driver in the region. The report warns that natural hazards, particularly those relating to water quantity and quality, will continue to hamper socio-economic development and poverty reduction and could contribute to international conflict. This danger is highlighted below, **in part** II under the sub-heading, The *Changing dynamics of humanitarian crises* where one expert in water-related violence points up that the historic world hotspot for water conflict may have switched from the Middle East to Asia today. ***Sources of Survival – Sources of Threat*** is a study in humanitarian futures, and is not intended as a commentary on the science that underpins those expert views. Its objective is to energise those with humanitarian roles and responsibilities to look for greater clarity about the future and to begin preparing for potential future challenges which we can anticipate.

There is much that remains uncertain and unknown about potential humanitarian threats across the HKH region. Yet, at the same time, there is ample expert opinion to suggest that the region offers a plethora of humanitarian threats that could severely affect the lives and livelihoods of hundreds of millions of people. To date Asia experiences 37% of the world's natural disasters, 55% of the deaths they cause and estimated annual rate of US$98 billion worth of economic damage since 2000.[149] With this in mind, it is telling that in India, for example, there is a firm belief among well positioned experts that 'future types of crises [will be] fundamentally different, with the consequence that past knowledge, experience and systems of coping will no longer be relevant. In part this relates to unprecedented scale, but [also to the] difference between the nature of threats emerging, in particular from climate change and environmental degradation, and those that have previously been seen, that "we will have no wisdom from the past to rely on".'[150]

In looking to the future, it is increasingly evident that globally the types as well as the dimensions and dynamics of humanitarian crises may increase exponentially. There is every reason to assume that this spectre will also relate to the HKH region and more specifically to the issue of water. As outlined below, under *preparing for humanitarian futures*, the factors that are affecting the types, dimensions and dynamics of humanitarian threats are as relevant to the HKH as they are elsewhere. And yet, given what those experts in the region and others regard as plausible threats, it is disconcerting to note that the perspective and indeed action necessary to prepare for such longer-term threats appear to be severely constrained by what will be described under *the present state of play* by factors ranging from inadequate knowledge and knowledge sharing to institutional short-termism.

In no sense, however, is this to suggest that regional organisations such as ASEAN or the South Asian Association for Regional Cooperation (SAARC), governments, research institutions and non-governmental and community-based organisations in the region are oblivious to the region's water vulnerabilities.[151] To the contrary, considerable energy and efforts have been devoted in the past to address evident threats and consider the prospects for having to deal with those that are less evident. And yet, given the growing complexity, dimensions and dynamics of crises created by and affecting water, the question remains, "Is enough being done to meet such future humanitarian challenges?"[152]

Preparing for humanitarian futures: dimensions and dynamics of future humanitarian crises

The dimensions and dynamics of future humanitarian crises that are increasingly apparent in a more global context are clearly relevant to the HKH region. This would seem evident when reflecting on the changing nature of humanitarian crises and hence their consequent dimensions and dynamics.

The changing nature of humanitarian crises. Uncertainty, rapid change and complexity will increasingly be the hallmarks of humanitarian crises in the foreseeable future. The foreseeable future is likely to reflect new sets of sudden and slow-onset crisis agents, including technological systems failures, large-scale industrial and chemical collapse, pollution, nuclear seepage, water scarcity and pandemics.

In China, for example, experts suggest that "various *crises* are perceived as growing in both intensity and frequency, and are regarded as now posing serious obstacles to national economic and social development….The combined factors of climate change, rapid economic development and accelerating urbanization mean that tackling and preventing future crises has become increasingly complex."[153] Throughout the region, potential crisis drivers such as the interaction between dams, water volume and earthquakes and arsenic contamination are being added to a growing catalogue of new types of crisis drivers as well as expanded types of traditional drivers.

However, much of the analysis of new and traditional crisis drivers continues to be done in sectoral isolation, and the potential consequence of their interaction is too rarely explored.

The changing dynamics of humanitarian crises. More and more future crises will be interactive, global, synchronous, simultaneous and sequential. The inter-relationship between natural hazards and political events such as violent conflict will become more overt and probably more frequent. Growing concerns about the implications of lack of adequate water supplies in at least 40 states around the world is a clear case in point where the correlation between the depletion of a natural resource and the prospect for violence seems increasingly clear.

In the words of one expert concerned with water-related violence, "While the Middle East has the longest history of water-related violence by far, my biggest worries today are elsewhere: in Asia, where pollution, massive population growth, serious over-allocation and inefficient use of water, weak institutions, and exceedingly complex political relationships combine in a volatile mix."[154] This is not to ignore efforts that have been made by two of the largest powers in the region – China and India – to address these, nor in this context the efforts made by Pakistan and India at the declaratory level to deal with their common water problems.[155] However, it is to say that in all these efforts there appears little discussion on the emerging dimensions and dynamics of humanitarian crises.

The prospect of *synchronous failures*, or, systems collapse, for example, is increasing globally, and is a phenomenon that will also impact upon the HKH region. The more economic, infrastructural and social systems become dependent upon factors such as internet technology and globalisation, the more systems become vulnerable to temporary or permanent collapse. A crisis driver such as volcanic ash as evidenced in 2010 can undermine one system, the airline industry, which in turn can spill over into others, such as tourism and insurance, and have not only regional but global effects.

The HKH region is equally prone to such synchronous failures as a result of systems' collapse within the region and externally. Spiralling food and fuel prices due to actions outside the region could undermine the stability of many countries within the region, itself.[156] This sort of synchronous failure could in turn readily result in very high levels of starvation, breakdown of urban water sources and result in severe community violence.[157] Similarly cybernetic manipulation which takes "power stations off line" would have disastrous consequences for dams and hydro-electric facilities within countries of the region and in some instances cross-regionally.[158]

While ASEAN and SAARC among others continue to explore measures to deal with crises that might affect the region, little attention has been given to the implications of major crises that could occur simultaneously. This has at least three implications. Firstly, though the realities of regional cooperation are far more limited than the rhetoric that often precedes it, there are serious initiatives to promote cooperation.[159] If and when such regional cooperation becomes a more established reality, members will have to determine how best to deal with major crises that occur at the same time. How, in other words, would regional actors working in cooperation deal with the impact of a major flood affecting the India-Pakistan borders at the same time a cyclone hits the coastline of Bangladesh?

Secondly, for those countries that are all too familiar with multiple disasters occurring simultaneously, they may well appreciate the difficulties of prioritising response from a humanitarian perspective. In light of the types of water-driven crises that could occur in the majority of the states in the HKH region, there is little indication that either contingency planning or response reflects the prospect of the simultaneous events that could ensue in any single country in the region.

The third issue concerns the possible support role which external actors – international humanitarian organisations - might play when confronted with two competing crises in the HKH region, each of which might require substantial assistance. It is far from implausible to suggest that in the foreseeable future an intense tropical storm would strike from the Bay of Bengal at the same time as extremely heavy monsoon rains – after several months of severe drought – causing major floods inland. The total affected populations could reach the tens of millions, and it is probable that many of these people would seek refuge in neighbouring India. How and in what ways could the international community support two simultaneous calamities on that scale, with all the ensuing complexities, involving refugee movements, internal displacement and catastrophic flood?

The implications of *sequential crises* for the HKH region are considerable, and could be triggered by a range of factors, from an earthquake that destroys a dam which, causing flood waters to wreak havoc in riverine areas, in turn leading to mass migration. Indeed one speculative scenario suggests that in less than two decades time the effect of dam construction in China, Cambodia , Laos and Vietnam might well result in dramatic changes to the Lancang (Upper Mekong) River's unique cycle of flood and drought - the annual flood pulse – which in turn could wreck the area's delicate eco-system. The consequence of that threat would be to destroy the fishing industry upon which millions of people depend for their survival.

This, according to the futures scenario attached to this report, could well lead to climate refugees, resulting in desperate attempts by governments such as Cambodia to close their borders against "refugee hordes" and would stretch the capacities of cities such as Ho Chi Minh City to cope with the disease and discontent that might well ensue from mass influx.[160]

The present state of play

Many of the crisis drivers that do or could affect the region are politically sensitive. This is markedly so when it comes to the control, diversion and damming of rivers. Nevertheless, given the sensitivity that surrounds these and related issues, one also has to recognise the considerable efforts that continue to be made to come to terms with such threats.[161] So, from the perspective of vulnerability to crises, there are persistent concerns that have emerged from interviews and literature reviews about the serious gaps in prevention, preparedness and response planning. These concerns fall into five general categories:

1. **Governments short term-ism**. "The action of the Chinese government is driven by crises, rather than tackling the problem head on through comprehensive prevention and mitigation," noted the President of the Institute of Environmental Studies at Renmin University in Beijing. There is a tendency for the government to cover up the sources of problems such as water pollution, and, hence, "The more we [the Government] repress the problem, the more severe it will become in the future!...The decision making mechanisms of the Chinese government need to be greatly improved."[162]

   Such criticisms are by no means unique to governments of the region, but clearly apply in one way or another to them. The inclination of governments to pursue short-term objectives, and to think in terms of maintaining economic growth at the expense of creating secure longer-term environments is possibly understandable, but explains in part why there appears to be no long-term integrated planning for dealing with humanitarian threats on a country-wide or regional basis.

2. **Stove-piped planning processes.** In Pakistan as is often the case elsewhere, authorities' fixation on burgeoning urban populations such as those of Karachi has meant that water decisions have all too often been taken in isolation, with a lack of a holistic analysis about the intersection between urban and rural water needs. Preoccupation with dam building in 2008 had reputedly cost Pakistan over $12.6 billion dollars without improving to any significant extent the country's downstream distribution infrastructures.[163] These sorts of issues are but examples of isolated planning processes in which technocratic and engineering solutions are adopted in isolation, divorced from context as well as from other sectoral concerns.

   Governments' tendencies to stove-pipe analysis and solutions may be easy targets, but they are not alone in their compartmentalised perspectives. Regional organisations have generally moved from one issue area to another – eg, water and development, climate change and their impacts upon water – without connecting the two in terms of vulnerability analyses. Such perspectives have not been able to capture adequately the range of factors that need to be taken into account to assess potential crisis drivers and their possible impact upon vulnerability.

3. **Local adaptation and knowledge**. While international, regional and national cooperation is crucial, local levels are also central to an understanding of vulnerable populations and to ensure that those populations are able to adapt and adequately cope with the uncertainty and insecurity brought existing and emerging crisis drivers. The potential of community-led adaptation is increasingly recognised as critical for reducing vulnerability. More and more, good practice and principles emphasise the importance of empowering communities to base adaptations to current and forthcoming crises on their own knowledge and decision-making processes, with support from outsiders. For example, farmers in flood prone areas of Bangladesh build their houses on stilts. Tibet nomads have already noticed the earlier spring and moved yaks to alpine meadows earlier accordingly and Nepali farmers store crop seeds for recovery after natural disasters. The considerable diversity of local cultures and coping mechanisms are vital in the development of effective prevention, preparedness and response strategies. They as well as indigenous coping mechanisms

need to be reflected in the holistic humanitarian strategies that will be essential for dealing with future humanitarian crises.

Government policies in the region, however, tend to have a narrow sectoral focus. For example, road construction in Nepal has increased market access and thereby supported new livelihoods, but has destroyed many traditional streams and wells, reducing local ability to cope with drought. In many areas, restoration programmes following droughts have simply reconstructed buildings in high-risk flood zones. This is not to suggest that authorities should adopt a laissez-faire attitude towards addressing vulnerabilities. To the contrary, prevention programmes, for example, should involve activities such as livelihoods diversification, disaster risk reduction, improving water efficiency, and increasing local access to markets and public services. In order to succeed however, such measures must use approaches that reflect local cultures and traditions. If on the other hand such local support interventions are not integrated into wider policy making processes the effects of these policies will be short-lived.[164]

4 **Information sharing failures and knowledge gaps**. The issue of local knowledge and adaptation directly feeds into the glaring issue of knowledge gaps and information sharing throughout the region. While, for example, the global climate change debate has made a significant shift from focusing on mitigation of greenhouse gas emissions to increasing awareness of the importance of adaptation, there is still a gap in research on local adaptation processes, and the factors enabling or constraining them.[165] Issues such as the downstream effects of changing water flow regimes in Himalayan rivers require more extensive research. Few, if any studies have attempted to model the impact of a 30–50% reduction in dry season flow on, for example, downstream economic growth, livelihood conditions, and urban water use.[166]

In a related vein, policy-makers and scientists at an international, regional and national levels need to be more open to a new range of expertise informed by the insights of vulnerable communities, local stakeholders and development and disaster-risk reduction practitioners, rather than restricted to impacts-based scientific inputs arising from global or national models alone.[167] At the same time, insufficient time is spent by regional organisations and governments on developing policies based on social and natural science expertise to offset potential future humanitarian crises. Conferences and workshops within the region are plentiful when it comes to sectoral analyses – normally on a country-by-country basis – of issues that are possible natural hazards. There is, however, no established network of scientists and humanitarian policy-makers where *dialogues* can take place about ways to identify and mitigate future humanitarian threats.

The sharing of information, too, is a problem in the region. Transboundary information is deemed to be highly sensitive by governments, and sharing it all too often is as much a political signal as a perceived functional necessity.[168] At the same time, there have been an increased number of information-sharing networks, including ICIMOD (International Centre for Integrated Mountain Development) which focuses on the region's mountain areas. However, none to date put humanitarian threats or vulnerability analyses in terms of longer-term perspectives at a regional level.

5. **Disjointed and incremental planning approaches to humanitarian crisis prevention, preparedness and response**. The sorts of crises that the HKH region will have to face require prevention, preparedness and response measures that are more holistic and futures-oriented than is the case to date. While authorities in the HKH region are not alone when it comes to incremental and disjointed approaches to humanitarian crisis management, there has been little attempt to address the potential vulnerabilities of the region from a holistic, futures-oriented systems perspective.

The sorts of threats which the region will have to face will depend upon prevention and preparedness measures that focus on unfolding crises through a "vulnerability lens" over the timescale of several decades. The inter-relationships between climate trends, local coping mechanisms, agricultural and commercial initiatives, new technologies, socio-economic structures and migration patterns need to be seen in other words in a way that integrates such key factors and which analyses how holistically they could increase the exposure of people to potential humanitarian threats. Only through such a lens will development as well as disaster management effectively address prevention and preparedness.

It is also important to recognise that disaster management in the region is well established, and is supported by the longest serving and well respected research and policy institutions in the world. Technologies, too, are available throughout the region that can "map" and monitor critical vulnerability exposure, and these are increasingly accessible, for example high and low resolution satellite data.[169]

In isolated pockets, cross-border water management, for example, has generated a number of bilateral and multilateral initiatives. However, what is of concern from the humanitarian point of view is that these initiatives continue to be piece-meal, inadequately integrated from a sectoral perspective and without a coherent appreciation of the long-term perspective necessary for dealing with the sorts of complex crises one will have to face.

Humanitarian consequences

There is a clear gulf between the scale of plausible humanitarian threats that may well affect the HKH region and the present state of play for dealing with such threats. There appears to be little investment in looking at the long-term implications of such threats in a way that is holistic and regional, that looks at possible threats and opportunities to mitigate them in ways that are systematic and coherent and in ways that are based on knowledge – both local and regional – that points to vulnerabilities and ways to address them.

In noting this, the report stresses that the types of crisis drivers that human kind will increasingly confront cannot be handled at the last moment, which is all too often the inclination of humanitarian organisations. Many future threats will require longer-term analysis and systems perspectives. Prevention and preparedness measures will be complex, and require in many instances holistic, inter-disciplinary understanding of cause and effect. There are significant disparities between the way that prevention and preparedness are undertaken now, and the sorts of challenges that may well threaten the lives of hundreds of millions of people in the foreseeable future.

Conclusions and recommendations

This report seeks to point out risks that need to be considered when dealing with the HKH region. It has tried not only to identify such risks, but also to highlight the initiatives undertaken to offset them. In exploring both, this report concludes that there is a great deal that must be done with considerable commitment and urgency to offset a variety of potential catastrophes that could threaten the region in the foreseeable future.

Conclusions

1. **The HKH region is already in a state of crisis.**
While there are indicators throughout the region that humanitarian crises are already taking place, their impacts on and implications for the region are often ignored, handled in geographic or sectoral isolation or inadequately understood. This is particularly the case for water where dramatically reduced availability in some areas, inefficient use of water, pollution and water diversion are already affecting directly and indirectly food production, migration and increased levels of disease.

2 **The threat of the future**.
There are a growing number of experts in and outside the region who are concerned about the region's prospects over the next two decades. Population rates are growing while the availability of potable water is becoming more problematic, and the means that have been used to offset that scarcity, such as river diversions, dams and intensive use of groundwater, could lead to ever more serious humanitarian threats without concerted efforts to address these at a regional level.

3 **Intensification of insecurity**.
In a region already sadly familiar with conflict, further conflict could result from the natural and human-made pressures facing the HKH region over the next twenty years. Assuming that the present dam development and water diversion initiatives are brought to fruition , states large and small may find water becomes even more of a life-or-death calculation for their citizens and for the industries and agriculture supporting them. Hence, there is growing concern that the competition for water and the risk of large scale displacement due to water patterns will exacerbate tensions among the nations of the region. The prospect for trans-border tensions could be further intensified as Central Asian states such as Afghanistan and Uzbekistan become engaged in the competition for water.

4 **Development catastrophes**.
This report has emphasised the nexus between natural hazards and human intervention. It has been suggested that the development initiatives being undertaken throughout much of the region could lead to major crises. Have the rate and scale of development have made the region highly vulnerable to humanitarian crises on an unprecedented scale? Will the long-term impact of the region's present approach to development be paid in searing vulnerabilities in the future through the effects, for example, of toxic waste contamination of existing waterways or the consequence of the largest number of dams in the world?

Like the other conclusions here, this is not a new idea. It is, however, all too apparent that the consequences of such vulnerabilities and direct human costs stemming from disasters, emergencies and catastrophes have not yet been adequately calculated. From this preliminary analysis, it is apparent that there have been inadequate efforts to quantify the potential types of calamities and their consequences in terms of affected and related costs regarding longer-term threats. This sort of consideration would seem to be a useful starting point for practical prevention and preparedness, as well as response planning.

5 **Lack of effective water management**.
There is inadequate water management at almost every level in the HKH region. At the national level, water management is marked by short-termism, with seemingly little attention paid to the long-term consequences of policies taken in sectoral and geographical isolation. From discussions with experts in China and India as well as in other research centres in the West, it would appear that policy all too often results from a combination of competing interests and decisions and plans taken in relative isolation. Further, the historic predisposition towards large-scale water-supply projects is deeply

embedded. This legacy, as much as short-term attitudes, constrains the political will to adopt alternative and more sustainable water management practices.

6 **Lack of systems perspectives**.
A major factor continuing to inhibit a proper understanding of the region is the failure to adopt a *systems perspective* of regional issues. In order to understand and then appropriately manage water in the vast HKH region and its drainage basins, it is essential to take a fully integrated systems approach. This requires definition and quantification of the components of the system and the linkages and feedbacks between these components. In this, both the natural and human components must be defined, and the impact of change followed through the system.

7 **Knowledge gaps and lack of understanding.**
It is evident that there are considerable uncertainties that remain unknown in the HKH region. It is evident that these knowledge gaps are due to the sheer enormity, complexity and vast diversity of the region. At the same time, these knowledge gaps are also due to gaps in technical capacities. Hence, for example, lack of knowledge of the causes of wetland degradation is due to the difficulties of gathering relevant data and accurate figures regarding amongst other things climate change impacts on precipitation levels.

Beyond the technical difficulties to be addressed to narrow knowledge gaps, there is also a considerable lack of understanding about the people of the region. As is all too evident in analyses of community vulnerability and solutions in other parts of the world, those who purport to understand threats and solutions of those in the HKH region often do not understand the linguistic, cultural and socio-economic differentiations that mark the region's diverse populations. In that sense, there really is no adequate shared understanding about the region as a whole, no 'map' of potential risks and opportunities that would serve as a useful planning instrument.[170]

8 **Lack of coordinated, comprehensive research.**
While there are considerable pools of research on various aspects of the HKH region, data gathering and interpretation have been carried out without cohesion or continuity.[171] Governments have failed to date to facilitate ways to bring together the considerable academic and policy research that is already available. At the same time, many research projects are still guilty of 'selective science', distorting findings to serve their own agendas.[172] Some projects, due to their particular bias or focus, fail to take into account a wider spectrum of factors involved in their analyses, sometimes with very serious potential consequences.[173]

Hence, an important issue to be addressed is how information flows between researchers and the information needs of those responsible for decision-making and developing solutions. In addition to addressing the current gaps in knowledge through further research, there also needs to have a better understanding of what is already there, and of the information that could be obtained through better and more systematic analysis of existing data, in particular historical records.

Recommendations

The recommendations that follow are intended to suggest ways to strengthen humanitarian crisis prevention and preparedness activities in a region that may become increasingly vulnerable to large-scale water-related disasters and emergencies. There can be no doubt that these recommendations in some instances may run up against deeply rooted political, economic and cultural constraints; there, too, is evidence that in some instances these constraints are being overcome. In any event, the potential scale of threats to lives and livelihoods compel the authors to propose steps that should be taken now to mitigate the consequences of the types of future crises suggested in this report. The recommendations are focused on functional issues, and seek to engage humanitarian policy-makers and practitioners to address the region's threats and opportunities – not in the context of individual countries, but from the perspective of an inter-related system.

1. **The HKH region must move up the planning agenda.** In a world in which the types, dimensions and dynamics of humanitarian threats are predicted to increase substantially, the attention given to the potential vulnerabilities of a region that is home to 20% of the world's population has to increase. The issues that are likely to impact upon that region – water-driven food insecurity, internal displacement, refugees, and potential conflict – all emphasise the importance of putting the region higher up on the 'humanitarian agenda'. This means that a more concerted, coherent and cross-regional effort is required to identify the range of emerging and potential threats that the region will have to face. This recommendation does not ignore the growing number of initiatives that reflect an increased awareness about the region's present and future hazards, but these in turn do not convey the urgency which many natural and social scientists within and outside the region increasingly feel is required.

2. **Develop a new planning construct.** The complexities which will underpin so many of the crisis drivers that may affect the region require

a new planning construct or framework. The proposed construct will have to have four core components: [i] *vulnerability* needs to be the main focus; [ii] a regional approach to vulnerability mapping in which natural flows of hazards and possible solutions are not delimited by national boundaries; [iii] greater attention to the interactive nature of future threats resulting in more integrated modelling; and [iv] preparedness planning based upon *futures* scenarios, including the consequence of synchronous failures and sequential and simultaneous crises.

3. **Develop a new, non-intrusive means for international support.** Over the past three decades, humanitarian organisations from the international community have become accustomed to intervening in "overseas crises" in ways that are seen in many instances as intrusive and disempowering. Governments in the region will be less amenable to such intrusive intervention – no matter how well intentioned. Concerned organisations outside the region will need to pay greater attention to non-intrusive support. This would include [i] creation of humanitarian professionalisation programmes for sharing best practices and standards; [ii] means for regular sharing of data on regional dimensions of vulnerability; [iii] regionally-developed scenario exercises to assess and test appropriate approaches for international support for regional crises; [iv] pre-response arrangements between relevant regional bodies and international counterparts.

4. **Foster cross-regional humanitarian policy-maker/science dialogue**. There is an increasing number of events that bring together experts on a wide range of issues affecting vulnerability in the region. Most in one way or another makes inroads into information and knowledge requirements needed to develop greater understanding about the nature of hazards and possible solutions for addressing future crises. And yet, there are at least five major gaps in that much needed dialogue to date that should be narrowed: [i] greater efforts need to be made to share scientific information between and amongst countries in the region; [ii] policy-makers that have direct interests in prevention and preparedness as well as response need an accessible forum – including on-line capacities -- for inter-acting with natural and social scientists; [iii] a concerted effort is needed to have such a forum focus on the interactive nature of possible threats on a regional level; [iv] greater attention needs to be made by scientists and policy-makers to make the practical outcomes of their work accessible to threatened communities; and [v] greater attention needs to be given to strengthening appropriate scientific and humanitarian research capacities in the region.

5. **Address knowledge gaps and coordination for comprehensive research.** Despite the extensive research undertaken on a range of hazards in the region, there remain many areas in which further research is required to develop effective prevention and preparedness approaches. The knowledge gaps and uncertainties have been touched upon in this report and in others. They range from the technical to the socio-cultural, and include the need for greater understanding about the effects of global activities, eg. food pricing, upon the vulnerabilities of local communities within the region. Towards this end, greater efforts need to be made through, for example, the forum proposed in Recommendation 4 to identify critical knowledge gaps for collaborative research and research partnerships.

6. **Promote innovation consortia.** Related to Recommendation 4, a watching brief on the identification, prioritisation and implementation of scientific and technological innovations needs to be established, and geared towards identified problems in the region. This is not to ignore the fact that there are already a number of scientific and technological innovations that can address some aspects of possible future crises. This recommendation calls for more systematic approaches for identifying, testing and sharing innovation that is both obviously and potentially relevant to the mitigation needs of the region. Of particular importance in this context is working with local communities to identify innovative solutions that directly relate to local needs.

7. **Initiative a vulnerability mapping exercise**. A regional mapping exercise and system are required to identify and monitor those factors that could create humanitarian crises at local and regional levels. Towards this end, a platform to undertake this mapping exercise is needed, and the exercise, itself, should in the first instance focus on how such factors interact, their dynamics and probable dimensions of impact. Based upon this initial mapping exercise, a regional mapping system could be developed to ensure that key data and knowledge are regularly incorporated.. The 'map' itself should reflect details from specific urban and rural community levels to the wider regional context. It should be a key objective of the exercise and system to ensure that localised dynamics are incorporated into the regional framework which will also require deeper investigations into community resilience at the micro level because this can affect the severity of any future crisis scenario.

References

ADB (Asian Development Bank) (2007) *New Insights on Water Security in Asia: The Changing Water Management Landscape in Asia*..

AFP (2010), 'China reveals Mekong data in boost for drought response' (http://www.google.com/hostednews/afp/article/ALeqM5hZT_RdCTG2u_on1S5c6CGl8Ozpiw , Accessed 5 May 2010).

Ageta, Y. and T. Kadota. (1992) "Predictions of changes of glacier mass balance in the Nepal Himalaya and Tibetan Plateau: a case study of air temperature increase for three glaciers." Annals of Glaciology 16:89-94.

Alam, M. (2004) 'Adverse impacts of climate change on development of Bangladesh: integrating adaptation into policies and activities', Working Paper 1, CLACC, Bangladesh Centre for Advanced Studies (BCAS), Dhaka.

Ali, A. (1999) 'Climate change impacts and adaptation assessment in Bangladesh', *Climate Research* 12, pp.109–116.

Allison, M.A., Kham, S.R., Goodbred, S.L Jr and Kuehl, S.A. (2003) 'Stratigraphic evolution of the late Holocene Ganges–Brahmaputra lower delta plain', *Sedimentary Geology* 155, pp.317–342.

Amitabh, K. (2009) *Urbanisation and Migration: An Analysis of Trends, Patterns and Policies in Asia*, UNDP research paper, June.

Archer, D.R. and Fowler, H.J. (2004) 'Spatial and temporal variations in precipitation in the Upper Indus Basin, global teleconnections and hydrological implications', *Hydrology and Earth System Sciences* 8, pp.47–61.

ASEAN (2005), *Agreement on Disaster Management and Emergency Response*, 26 July 2005. http://www.aseansec.org/17579.htm (Accessed 13 May 2010).

Asia Society (2009), *Asia's Next Challenge: Securing the Region's Water Future*, a report by the Leadership Group on Water Security in Asia, April.

Auffhammer, M., Ramanathan, V. and Vincent, J.R. (2006) 'Integrated model shows that atmospheric brown clouds and greenhouse gases have reduced rice harvests in India', *Proceedings of the National Academy of Sciences* 103, pp.19668–19672.

Bajracharya, S. R., P. K. Mool and B. R. Shrestha. (2007) *Impact of climate change on Himalayan glaciers and glacial lakes: case studies on GLOF and associated hazards in Nepal and Bhutan:* International Centre for Integrated Mountain Development in cooperation with United Nations Environment Programme, Regional Office Asia and the Pacific.

Benn, D. I. and D. J. A. Evans. (1998). *Glaciers and glaciations*: London. Edward Arnold. pp 734.

Bishnu and Gea (eds) (2007) *Himalayan Wetlands: Risks, Challenges and Opportunities*, Ramsar Wetlands Center Korea, Changwon, p.7.

Biswas, Asit K. and Seetharam, K. E. (2007) "Achieving Water Security for Asia", International *Journal of Water Resources Development*, 24:1, 145 – 176.

Black, R. (200() 'India's water use "unsustainable"', BBC, updated 13 August 2009, http://news.bbc.co.uk/1/hi/sci/tech/8197287.stm (Accessed 17 July 2009).

Black, R. (200() 'India's water use "unsustainable"', BBC, updated 13 August 2009, http://news.bbc.co.uk/1/hi/sci/tech/8197287.stm (Accessed 17 July 2009).

Chinadialogue (2009b), 'Glaciers and guesswork': Isabel Hilton interviews Andreas Schild, a director general of the International Centre for Integrated Mountain Development (ICIMOD) on Chinadialogue.net, 24 August.

Chinadialogue (2009a) 'The Tibetan Plateau- the plight of economic migrants'http://www.chinadialogue.net/article/summary/2445-The-Tibetan-Plateau-the-plight-of-ecological-migrants (accessed 30 July 09).

Christensen, J.H., Hewitson, B., Busuioc, A., *et al.* (2007) 'Regional Climate Projections' in Solomon, S., Qin, D., Manning, M. *et al.* (eds) *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge and New York.

Chossudovsky, M. (2008), 'The Global Crisis: Food, Water and Fuel. Three Fundamental Necessities of Life in Jeopardy', 5 June, *Global* Research, Centre for Research on Globalisation, University of Ottawa (http://www.globalresearch.ca/index.php?context=va&aid=9191 , Accessed 13 May 2010).

CRED (2010), CRED Crunch, February, Centre for Research on the Epidemiology of Disasters, Universite catholique de Louvain, Brussels.

Cruz, R.V., Harasawa, H., Lal, M., *et al.* (2007) 'Asia' in Parry, M.L., Canziani, O.F., Palutikof, J.P. et al (eds), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK, 469–506.

Cummins, P.R. (2007) 'The potential for giant tsunamigenic earthquakes in the northern Bay of Bengal', *Nature* 449, pp.75–78 (doi:10.1038/nature06088).

Dapice, D.(2008) *Case Study – Vietnam Electricity*, Harvard Kennedy School, Cambridge MA (http://www.fetp.edu.vn/exed/2008/HaNoi/Docs/Readings/Day%202-1-Vietnam%20Electricity%20Case-E.pdf, accessed 28 August 2009).

de Fraiture, C., D. Wichelns, J. Rockstrom, E. Kemp-Benedist. 2007. "Looking ahead to 2050 : Scenarios of alternative investment approaches". In Molden, D. (ed.). *Water for Food, Water for Life: A Comprehensive Assessment of Water management in Agriculture. Earthscan, London, and International Water Management Institute, Colombo.*.

Dharmadhikary, S. (2008) *Mountains of Concrete*, International Rivers Organisation, December.

Ding, L., Li, B.Y. and Zhang, S.S. (2004) 'Advances in researches on seawater intrusion of coastal area', *Marine Science Bulletin* 23, pp.82–87.

DSG (Desakota Study Group) (2007) *Re-imagining the Rural-Urban Continuum: Understanding the role ecosystem services play in the livelihoods of the poor in desakota regions undergoing rapid change*. Institute for Social and Environmental Transition–Nepal.

Du, M.Y., Kawashima, S., Yonemura, S., *et al.* (2004) 'Mutual influence between human activities and climate change in the Tibetan Plateau during recent years', *Global and Planetary Change* 41, 241–249.

Dun, O. and Gemenne, F. (2008), Defining 'environmental migration', *Forced Migration Review*: 31, pp. 10-11.

European Commission 'Environmental Change and Forced Migration Scenarios' (EACH-FOR), (http://www.each-for.eu/index.php?module=main).

E.L.F. Schipper and I. Burton, Editors, *The Earthscan Reader on Adaptation to Climate Change*, Earthscan, London (2009).

Economist, The (2009) *Buying farmland abroad: Outsourcing's Third Wave*, 21 May.

Fan, D.D. and Li, C.X. (2005) 'Complexities of Chinese coast in response to climate change', *Advance in Research on Climate Change* 1, pp.111–114..

FAO (2006), *Food Security Policy Brief*, June: Issue 2.

Forsyth, T. and Ayers, J. (2009), 'Community-based adaptation to climate change', *Environment Magazine*, 51:4. July/August.

Fowler, H.J. and Archer, D.R. (2006) 'Conflicting signals of climate change in the Upper Indus Basin', *Journal of Climate* 19, pp.4276–4293.

Gautam, P. K.(2008) 'Sino-Indian Water Issues', Strategic Analysis, 32: 6, pp. 969–974.

Gleick, P., (2009) *Pacific Institute Newsletter*, 13 January.

Goodman, D. (2004) 'Qinghai and the Emergence of the West: Nationalities, Communal Interaction and National Integration', *China Quarterly* 178 (June), pp.379–99.

Grumbine, R. E. 2010. *Where the dragon meets the angry river: nature and power in the People's Republic of China*. Island Press, Washington, DC.

Gupta, S.K. and Deshpande, R.D. (2004) 'Water for India in 2050: first-order assessment of available options', *Current Science* 86, pp.1216–1224.

Gyawali D. (2001), *The Contested Terrain of Water Development and Human Rights*, May. (http://www.cceia.org/resources/transcripts/94.html).

Hewitt, K. (2010) "Understanding Glacial Change", published on www.chinadialogue.net, February.

Hoermann, B. and Kollmair, M (2009) *Labour migration in the Hindu Kush-Himalayas – A core livelihood strategy,* International Centre for Integrated Mountain Development. Katmandu..

Hong, Y., Adler, R.F. and Huffman, G.J. (2007) 'Satellite remote sensing for global landslide monitoring', *Eos* 88, pp.357–358.

Hu, Z.Z., Yang, S. and Wu, R.G. (2003) 'Long-term climate variations in China and global warming signals', *Journal of Geophysical Research (Atmospheres)* 108, D19, p.4614.

Hugo G. (2008) "Migration, Development and the environment", Draft paper for Research Workshop on *Migration and the Environment: Developing a Global Research Agenda*, Munich, Germany April.

Humanitarian Futures Programme (2009a) *Report on Crisis Drivers of the Future Project Mission to India, September* 2009.

Humanitarian Futures Programme (2009b) *Report on Crisis Drivers of the Future Project Mission to China, November* 2009, Prepared by Chinadialogue, Beijing.

Huq, S. and M. Khan (2003), "Mainstreaming National Adaptation Plans", *Tiempo*, 49: 1-8.

HWCC (2009), http://www.hwcc.com.cn/newsdisplay/newsdisplay.asp?Id=164342 (accessed 21 August 2009).

ICIMOD (The International Centre for Integrated Mountain Development) (2007) *The Melting Himalayas: Regional Challenges and Local Impacts of Climate Change on Mountain Ecosystems and Livelihoods* by Xu Jianchu, Shrestha, A. Vaidya, R., Eriksson, M. and Hewitt, K. ICIMOD Technical Paper, Kathmandu, June.

ICIMOD (2008) *Food Security in the Hindu Kush-Himalayan Region*,. International Centre for Integrated Mountain Development. Position Paper, August.

ICIMOD (2009) *Mountain Biodiversity and Climate Change*, International Center for Integrated Mountain Development, Kathmandu, p.31.

ICIMOD (2009b) *Local Responses to Too Much and Too Little Water in the Greater Himalayan Region*, International Centre for Integrated Mountain Development, Kathmandu.

ICIMOD (2009c) *Finland supports ICIMOD to establish a regional flood information system in the Hindu Kush-Himalayan region*, 22 Dec 2009 (http://www.icimod.org/?page=696).

Independent (2009), '1,500 farmers commit mass suicide in India', http://www.independent.co.uk/news/world/asia/1500-farmers-commit-mass-suicide-in-india-1669018.html (accessed 17 July 09).

International Rivers (2010), 'Laos' NamTheun 2 Dam Operation Illegal', 24 March 2010 http://www.internationalrivers.org/en/node/5191.

IPCC (Intergovernmental Panel on Climate Change) (2007) 'Summary for policymakers' in Solomon, S., Qin, D., Manning, M. *et al.* (eds) *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge and New York.

IUCN (The International Union for Conservation of Nature) (2003) *Indus delta, Pakistan: economic costs of reduction in freshwater flows,* Case studies in wetland valuation 5, Karachi, 6pp.

Jaitly, Ashok (2009) 'South Asian Perspectives on Climate Change and Policy' in David Michel and Amit Pandya (eds), *Troubled Waters: Climate Change, Hydropolitics and Transboundary Resources*. Stimson Center, Washington DC.

Jianchu, X., Shrestha, A., Vaidya, R., Erikson, M. and Hewitt, K. (2007). *The melting Himalayas: regional challenges and local impacts of climate change on mountain ecosystems and livelihoods*. International Centre for Integrated Mountain Development Technical Paper, Kathmandu, 19pp.

Jing Ma, *et al.* (2006) 'Virtual versus real water transfers within China', *Philosophical Transactions of the Royal Society*, B, pp.835–842.

Joe, T. K. and C. R. Sandeep. (2005) "An overview of glaciers, glacier retreat, and subsequent impacts in Nepal, India and China." WWF Nepal Program Report: 1-70.

Kargel, J., Armstrong, R., *et al.* (2009) *Satellite-era glacier changes in High Asia*, Background presented at NASA "Black Carbon and Aerosols" press conference associated with Fall AGU, Dec. 14, 2009. Updated and expanded Feb. 17, 2010.

Kent, R (2010), *Personal Communication*, May.

Keulertz, M (2010)., 'Water Security: Competing Discourses' London Water Research Group 5th International workshop on HydroHegemony, 8 May.

Khan *et al.* (2004), 'The environmental status of a Kashmir Himalayan wetland game reserve: Aquatic plant communities and eco-restoration measures', *Lakes & Reservoirs: Research and Management* 9(2), p.125.

Khanal, N.R. and Watanabe, T. (2006): "Abandonment of agricultural land and its consequences in the Nepal Himalayas: A case of Sikles area". *Mountain Research and Development*, 26: 32-40.

Klein, J. A., J. Harte, and X. Q. Zhao (2004) Experimental warming causes large and rapid species loss, dampened by simulated grazing on the Tibetan Plateau. Ecology Letters **7:**1170–1179.

Knutson, T.R. and Tuleya, R.E. (2004) 'Impacts of CO2 induced warming on simulated hurricane intensities and precipitation: sensitivity to the choice of climate model and convective parameterization', *Journal of Climate* 17, pp.3477–3495..

Krishnan, A. (2010), 'On rivers and glaciers, India, China walk thin ice', *The Hindu*, 10 May 2010 (http://beta.thehindu.com/news/international/article425683.ece, Accessed 13 May 2010).

Kugelman, Michael and Robert Hathaway (eds) (2009) *Running on Empty: Pakistan's Water Crisis,* Woodrow Wilson International Center for Scholars, Washington DC.

Kulkarni, A.V., Bahuguna, I.M., Rathore, B.P. *et al.* (2007) 'Glacial retreat in Himalaya using Indian remote sensing satellite data', *Current Science* 92, pp.69–74.

Lal, M. (2001) 'Tropical cyclones in a warmer world', *Current Science* 80, pp.1103–1104.

Lamont, J. (2009), 'India and China co-operate over Himalayan glaciers' *Financial Times,* 2 August 2009.

Lan Xue and Kaibin Zhong, *Turning danger to opportunities: reconstructing china's national system for emergency management after* 2003, in Kunreuther H. and Useem.M ed. 2009 Wharton school publishing.

Lei, Luo (2005) 'Analysis of Climatic Background of Wetlands Degradation in Qinghai-Xizang Plateau', *Wetland Science [Shidi kexue]* 3:3, p.467.

Liu, X. and Chen, B. (2000) 'Climate warming in the Tibetan Plateau during recent decades', *International Journal of Climatology* 20, pp.1729–1742.

Meehl, G.A., Stocker, T.F., Collins, W.D., *et al.* (2007) 'Global Climate Projections' in Solomon, S., Qin, D., Manning, M. *et al.* (eds), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge and New York.

Morton, K.. (2008) 'China and Environmental Security in the Age of Consequences', *Asia Pacific Review* 15(2), pp.52–67.

Mukherji, Aditi *et al.* (2009) *Revitalizing Asia"s Irrigation: To Sustainably Meet Tomorrow's Food Needs*, International Water Management Institute and Food and Agricultural Organisation..

National Bureau of Statistics of China, (2009) http://www.stats.gov.cn/was40/gjtjj_detail.jsp?searchword=%C9%FA%CC%AC%D2%C6%C3%F1&channelid=6697&record=1 (accessed 30 July 2009).

National Development and Reform Council (NDRC), (2010) People's Republic of China, http://en.ndrc.gov.cn/

Ooi, Giok Ling and Phua, Kai Hong (2007) 'Urbanization and slum formation', *Journal of Urban Health* 84 (suppl. 1). May, pp.27–34.

Padma, T., 'India boosts climate data contribution to IPCC', *Science and development Network,* 4 Februray 2010 (http://www.scidev.net/en/news/india-boosts-climate-data-contribution-to-ipcc.html, Accessed 5 May 2010).

Patel, S., (2009) 'Powering the People: India's Capacity Expansion Plans', *Power* May (http://www.powermag.com/nuclear/Powering-the-People-Indias-Capacity-Expansion-Plans_1858_p4.html, accessed 28 August 2009).

Pomeranz,, K. (2009) 'The Great Himalayan Watershed agrarian crisis, mega-dams and the environment', in the *New Left Review* 58 (August).

Peterson , E.R.(2005) *Addressing Our Global Water Future* by , Center for Strategic and International Studies with Sandia National Laboratories, 30 September, Washington DC, p.103.

Pfeffer, W., Harper, J., O'Neil, S. 2008. "Kinematic constraints on glacier contributions to 21st-century sea-level rise". *Science* 321:1340-1343.

Poncelet, A. 2009. "The land of mad rivers:Bangladesh Case Study Report" for the Environmental Change and Forced Migration Scenarios Project. http://www.each-for.eu/

Ravenscroft, P., Brammer, H. and Richards, K. (2009) *Arsenic pollution, a global synthesis*, Wiley-Blackwell, Chichester, 588pp.

Revenga, C., Nackoney, J., Hoshino, E. *et al.* (2003) *Water resources eAtlas: watersheds of Asia and Oceania*. The World Conservation Union (IUCN), the International Water Management Institute (IWMI), the Ramsar Convention Bureau and the World Resources Institute (WRI).

Ritter, D. F., R. C. Kochel and J. R. Miller. (2000) *Process geomorphology:McGraw-Hill Science, Engineering & Mathematics*.

Roberts, B. and Kanaley, T. ed. (2006) Urbanization and Sustainability in Asia: good practice case studies. Philippines: Asian Development Bank.

Rodell, M., Velicogna, I. and Famiglietti, J.S. (2009) 'Satellite-based estimates of groundwater depletion in India'. *Nature* Letters 08238.

Rosegrant, M., Ximing Cai and Cline, S. (2002) *World Water* and *Food* to 2025: *Dealing with Scarcity*. International Food Policy Research Institute, Washington DC.

Schipper, E.L.F. and Burton, I., ed. (2009) , *The Earthscan Reader on Adaptation to Climate Change*, Earthscan, London.

Shamsudduha, M., Chandler, R.E., Taylor, R.G. and Ahmed, K.M (2009) 'Recent trends in groundwater levels in a highly seasonal hydrological system: the Ganges–Brahmaputra–Meghna Delta', *Hydrology and Earth System Sciences Discussions* 6, pp.4125–4154 (www.hydrol-earth-syst-sci-discuss.net/6/4125/2009/).

Sharma, K.D. *et al.* (2007) 'ICIMOD's Regional Rangeland Program for the Hindu Kush-Himalayas', *Mountain Research and Development* 2(7), May, p.174.

Shrestha, M.S., Bajracharya, S.R. and Mool, P. (2008) *Satellite rainfall estimation in the Hindu Kush–Himalayan region*, International Centre for Integrated Mountain Development, Kathmandu, 10pp.

Swain, A. (2002) 'Environmental Cooperation in South Asia', in Ken Conca and Geoffrey D. Dalelko (eds) *Environmental Peacemaking*, Woodrow Wilson Centre Press, Washington DC, Baltimore, London.

UNEP (2009) 'The environmental food crisis: Environments role in averting future food crises' United Nations Environment Programme. Nairobi: Earthscan.

UNESCO (2009) *3rd World Water Development Report: water in a changing world*, London, Earthscan.

UN-HABITAT (2008) *State of the World's Cities – Harmonious Cities* 2008/2009, London, Earthscan.

UN Water (2010) http://www.un.org/waterforlifedecade/scarcity.html (Accessed 12 May 2010).

Vivekanandan, J. and Nair, S., (2009) 'Climate Change and Water: Examining the Interlinkages', Troubled Waters: Climate Change, Hydropolitics, and Transboundary Resources, Michel, D. and Pandya, A. (Ed.), Stimson, Washington D.C.

Warner, K. Herhart C. de Sherbinin A., and Adamo S. (2009) *In search of shelter: mapping the effect of climate change on human migration and displacement*. Cooperative of Assistance and Relief Everywhere (CARE)..

Wassman, R., Hien, N.X., Hoanh, C.T., Tuong, T.P. (2004) 'Sea level rise affecting the Vietnamese Mekong delta: water elevation in the flood season and implications for rice production', *Climate Change* 66, pp.89–107.

Wateraid Australia (2007) *Getting the basics right:Water and Sanitation in South East Asia and the Pacific*. World Vision Australia and WaterAid Australia. Melbourne.

Wetlands International (2009), http://www.wetlands.org/LinkClick.aspx?link=publications%2fBrochure%2fwetlands_adaptation_press19aug.pdf&tabid=836&mid=2206 (accessed 21 August 2009).

Xinhua News Agency (2005), 5 August 2005, http://www.qh.xinhuanet.com/rkyfz/2005-08/05/content_4814811.htm (accessed 30 July 2009).

Xinhua News Agency (2006a), 4 February 2006 http://www.xinhuanet.com/english2010/

Xinhua News Agency, (2006b) 'China to Address Urgent Environmental Issues' 4 May 2006. http://english.peopledaily.com.cn/200605/04/eng20060504_263042.html (Accessed 5 May 2010).

Xinhua News Agency (2010a) ,'International scientists to launch environmental studies on "HKH region"'8 March 2010 http://news.xinhuanet.com/english/2010-03/09/content_13129540.htm (Accessed 5 May 2010).

Xinhua News Agency (2010b), 'China, India to jointly research Himalayan glaciers', 26 March 2010 http://tibet.news.cn/english/2010-03/25/c_13224615.htm (Accessed 5 May 2010).

Xu Jianchu (2009) 'The Trend of Land Use and Land Cover Change and its Impacts on Biodiversity in the Himalayas', 3–4 (www.icimod.org/resource.php?id=63 (Accessed 21 August 2009).

Jianchu Xu *et al*, 2009, The melting Himalayas: Cascading effects of climate change on water, biodiversity, and livelihoods. *Conservation Biology* 23(3) pp. 520-530.

Yamada, T. (1991) "Preliminary work report on glacier lake outburst flood in the Nepal Himalayas." Water and Energy Commission Secretariat Report 4/1/291191/1/l Seq. No. 387.

Yardley, J., and Huang Y, (2007) 'Choking on growth: water and China's future', *New York Times*, 28 September.

Yao, T.D., Guo, X.J., Lonnie, T. *et al.* (2006). 'd18O Record and temperature change over the past 100 years in ice cores on the Tibetan Plateau', *Science in China: Series D Earth Science* 49, pp.1–9.

Zafar, A. (2005) 'Training and capacity building for managing our mangroves resources –UNU's role to meet regional challenges', Environment and Sustainable Development Programme, Technical Notes of United Nations University, Tokyo, Japan, 5pp.

Zhang, P.Z., Yang, Z.X., Gupta, H.K., Bhatia, S.C. and Shedlock, K.M. (1999) 'Global Seismic Hazard Assessment Program (GSHAP) in continental Asia', *Annali di Geofisica* 42, pp.1167–1190.

Zhao *et al.* (2007) *Opportunities and challenges of sustainable agricultural development in China*, published online by State Key Laboratory of Urban and Regional Ecology, Research Centre for Eco-environmental Sciences, Chinese Academy of Sciences.

Zurick, D., Pacheco, J. Shrestha, B. and Bajracharya, B. (2005) *Atlas of the Himalaya*, International Centre for Integrated Mountain Development, Kathmandu, pp.96.

Endnotes

1 Planning from the future– the 'from the future' perspective seeks to guide policy-makers and strategy-makers to speculate about 'what might be' rather than trying to envision the future by extrapolating from the past (ie. trends). Speculating from the future requires people to go beyond the sectoral bounds where they feel comfortable, and into situations where roles, innovations, threats and opportunities introduce new perspectives about what the organisation needs to consider.

2 Vivekanandan and Nair, 2009.

3 Zhang *et al.*, 1999.

4 For example, see Kulkarni *et al.* 2007; ICIMOD, 2007.

5 Gupta and Deshpande, 2004.

6 UN Water, 2010.

7 Zurick *et al.*, 2005.

8 *Ibid.*

9 *Ibid.*

10 Archer and Fowler, 2004; Fowler and Archer, 2006.

11 Bajracharya *et al.*, 2007.

12 Hewitt 2009/Kargel 2009.

13 Ageta and Kadota, 1992;Yamada, 1991.

14 Bajracharya *et al.*, 2007.

15 *Ibid.*

16 *Ibid.*

17 Hewitt 2010., Kargal and Armstrong *et al.*, 2009.

18 Hewitt, 2010.

19 *Ibid.*

20 ICIMOD, 2007.

21 Sharma *et al.*, 2007.

22 ICIMOD, 2007.

23 Klein *et al.* 2004.

24 Xu Jianchu, 2009..

25 Revenga *et al.*, 2003.

26 ICIMOD, 2009a, p.31.

27 HWCC, 2009.

28 Khan *et al.*, 2004, p.125.

29 Lei, 2005. P. 467.

30 Bishnu and Gea, 2007, p.7.

31 Wetlands International, 2009.

32 Conventional wisdom (especially in China) has often laid the blame for degradation on overgrazing by nomadic herders. This has resulted in a set of resettlement and enclosure policies designed to help grassland recover. However, while 'over-stocking' by herders has probably contributed to some extent, it has been argued that enclosure simply further intensifies over-grazing on already vulnerable land. One recent study has further suggested that appropriate levels of grazing can actually help shield rangeland biodiversity from the shock of temperature increases. Whatever the case, continued reduction in rangeland area is only likely to put further pressure on the grazing land that remains unless sustainable management strategies are successfully applied.

33 Yao *et al.*, 2006 (Du *et al.*, 2004; IPCC, 2007).

34 On Tibet and Nepal, see Shrestha *et al.*, 1999; Liu and Chen, 2000; Jianchu *et al.*, 2007. On seasonal variations, see: Cruz *et al.*, 2007..

35 On the Karakoram and Hindu Kush, see Fowler and Archer, 2006; on fluctuations in summer temperatures and the Hengduan in southwest China, see Hu *et al.*, 2003.

36 Meehl *et al.*, 2007.

37 See, for example, the summary in Cruz *et al.*, 2007.

38 Christensen *et al.*, 2007.

39 UNESCO, 2009.

40 Amitabh., 2009.

41 UN Habitat, 2008.

42 *Ibid.*

43 Roberts and Kanaley ed. 2006.

44 ADB, 2007.

45 This phenomenon of mixed economy regions between 'rural' and 'urban' has been caught by the Bahasa Indonesian term 'desakota' (meaning village-town), where trends in water stress can be best observed (see DSG, 2007).

46 *Ibid.*

47 UNESCO, 2009.

48 Roberts and Kanaley ed. 2006.

49 Hoermann and Kollmair 2009 p2.

50 Warner *et al.* 2009.

51 Environmentally induced migration is a attracting growing attention worldwide. Despite recent moves to reach a consensus on a definition for the term, controversy remains both on the scope of the issue and on how to address it. Estimates of the total number of environmentally induced migrants are divergent and controversial, ranging from 200 million to 700 million by 2050. The most widely quoted estimate is 200 million by 2050.That is 10 times the number of refugees and internally displaced people in the world today. As Dun and Gemenne note 'Just as most classical theories on migration tend to ignore the environment as a driver of migration, most theories on environmental governance ignore migration flows.' (Dun,and Gemenne 2008).

52 National Development and Reform Council of People's Republic of china, 2010.

53 National Bureau of Statistics of China, 2009.

54 Warner *et al.* 2009, and EACH-FOR.

55 Field researchers have noted that even activities like shrimp farming may be too expensive for farmers to take up (Poncelet, 2009).

56 Xinhua News Agency, 2005.

57 Hugo, 2008. pp.21, 27.

58 Xinhua News Agency, 2006a.

59 Hugo, 2008. p.35.

60 Chinadialogue, 2009a.

61 Goodman, 2004.

62 The FAO defines food security as a 'situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life'., FAO, 2006.

63 de Fraiture *et al.*, 2007.

64 Mukherji, *et al.* 2009.

65 *Ibid.*

66 ICIMOD (2008). The food grain sector has become financially less remunerative due to competition from global markets from cheap food grain produced by developed counties with high subsidies.

67 Khanal and Watanabe, 2006.

68 ICIMOD 2008.

69 Economist, 2009.

70 Dharmadhikary, 2008.

71 Mukherji *et al.*, 2009.

72 UNEP, 2009.

73 *Ibid.*

74 The Chinese predict 112% food sufficiency by 2050 (see Zhao *et al.*, 2007). These predictions are based on dangerous assumptions of the continued availability of water and arable land.

75 Rosegrant *et al.*, 2002.

76 Mukherji *et al.*, 2009.

77 Black, 2009.
78 Yardley and Huang , 2007.
79 Kumar *et al.* 2005; Mal *et al.* 2006.
80 Shamsudduha *et al.*, 2009.
81 Rodell *et al.*, 2009.
82 Shamsudduha *et al.*, 2009.
83 Cruz *et al.*, 2007.
84 Alam, 2004.
85 Shah *et al.* 2006.
86 Independent, 2009.
87 Jaitly, 2009.
88 Pomeranz, 2009.
89 *Ibid.*.
90 Jing Ma *et al.*, 2006.
91 ADB, 2007.
92 UNESCO, 2009.
93 ADB, 2007.
94 UNESCO, 2009.
95 UNICEF, 2008.
96 Wateraid Australia, 2007.
97 Biswas and Seetharam 2007.
98 Patel (2009).
99 Dapice, 2008.
100 Dharmadhikary, 2008.
101 Asia Society 2009. The magnitude of effect will vary between rivers depending on the glacial melt % of river flow (see Table 1).
102 Jaitly, 2009.
103 Peterson, 2005.
104 Grumbine 2010.
105 International Rivers, 2010.
106 Swain, 2002.
107 Morton, 2008.
108 Ashok, 2009.
109 Lamont 2009.
110 Padma, 2010.
111 Xinhua News Agency, 2010a.
112 Xinhua News Agency, 2010b.
113 AFP, 2010.
114 Gautam, 2008.
115 ICIMOD, 2009c.
116 Zurick *et al.*, 2005.
117 *Ibid*.
118 Benn and Evans, 1998; Ritter *et al.* 2000.
119 Benn and Evans, 1998.
120 Joe and Sandeep, 2005.
121 Hewitt 2010.
122 Bajracharya *et al.*, 2007.
123 Zurick *et al.*, 2005.
124 On precipitation-induced landslides, see Hong *et al.*, 2007; on relationship to summer monsoons, see Zurick *et al.*, 2005.
125 Zurick *et al.*, 2005.
126 Zafar, 2005, p. 5.
127 Cruz *et al.*, 2007.
128 IUCN, 2003, p. 6.
129 On saltwater penetration, see Allison *et al.*, 2003; on sea water in the coastal plains of China, see Ding *et al.*, 2004.
130 Ali, 1999.
131 Fan and Li, 2005; Lal, 2001.
132 Knutson and Tuleya, 2004.
133 Cummins, 2007.
134 IPCC, 2007.
135 Pfeffer *et al.*, 2008.
136 Cruz *et al.*, 2007.
137 Wassman *et al.*, 2004.
138 Ravenscroft *et al.*, 2009.
139 *Ibid*.
140 *Ibid*.
141 Cruz *et al.*, 2007.
142 Auffhammer *et al.*, 2006.
143 Kugelman and Hathaway, 2009. The authors in this volume note the sale of farm lands to foreign investors, including the Government of Pakistan's reported decision to make 6 million acres of farmland available for international investment.
144 Humanitarian Futures Programme, 2009a.
145 One billion people, or one third of the world's urban population, are estimated to be living in slum or squatter settlements. The largest proportion of the population living in slums is in the Asian region, which is also urbanising at the fastest rate. (See Ooi and Phua, 2007).
146 Draft Outline of the Tenth Five-year Plan for National Economic and Social Development (2001–5).
147 Pomeranz 2009.
148 Xinhua News Agency, 2006b.
149 CRED 2010.
150 Interview with Shekhar Singh, Delhi, September 2009 (Humanitarian Futures Programme 2009a).
151 Addressing the 37th session of the standing committee of the South Asian Association for Regional Cooperation (Saarc) in Thimphu (Bhutan), the Pakistan Foreign Secretary, Salman Bashir, said on 25 April 2010 that South Asia had become a water-stressed region and should adopt a regional, cooperative approach to address the issues of glaciers, water management and pollution on an urgent basis.
152 Annex I: Future Stories suggests scenarios about future types of crisis driver interactions and their possible consequences from a two decade perspective.
153 Humanitarian Futures Programme, 2009b.
154 Gleick, 2009.
155 One observer noted in the aftermath of an April 2010 conference in Australia which included Indian and Chinese representatives that "the transboundary issue remains terribly sensitive. [In a recent conference], both Chinese and Indian participants attested to the poor sharing of information. Alas it is now pretty clear that China is intending to dam the Yarlung Tsangpo, thus furthering igniting tensions. India now refuses to allow China to have full membership with SAARC, so options for building trust at the level of pre-existing institutions is slim. However, there is also widespread recognition that vulnerability concerns cannot be ignored and slow efforts are underway on the research side to build cooperation." (Kent, 2010).
156 'The troubled global economy has brought about an unprecedented international phenomenon in the area of food and water security and injection of money from external sources into arable land. The food price spikes in 2008 alerted governments to strategic uncertainties. Many Western governments, international institutions, development agencies and NGOs are now paying increasing attention to the political, social, environmental and economic impacts of inward investment in land. [It is important to discuss] the possibilities in the developing world of a secure means of accessing strategic food supplies independent of the uncertainties of global food commodity trade.' (Keulertz, 2010).
157 Chossudovsky, 2008.
158 The DCDC Global Strategic Trends Programme: 2007-2036, Ministry of Defence, England, p83
159 See, for example, ASEAN,2005.In Annex D of the agreement, there is even an outline framework for using the military of ASEAN nations to provide response support in the region. .
160 See Annex I: Future Stories.
161 In a recent interview, the Minister of State for Environment and Forests Mr Jairam Ramesh remarked that there was no water-sharing agreement with China to regulate any future use of the river's waters. "We don't

have a water- sharing treaty," he said. "But we have now begun the process of discussions on the exchange of hydrological data. This is the first step forward." India needed to continue discussing the water issue with the China, he said, adding the process was "going to be slow-going." (Krishnan, 2010).

162 Interview Professor Ma Zhong, professor of economics and President of the Institute of Environmental Studies at Renmin University in Beijing, November 2009 (Humanitarian Futures Programme, 2009b).

163 Kugelman and Hathaway, 2009.

164 Huq and Khan, 2003.

165 Schipper and Burton, 2009.

166 ICIMOD, 2009b.

167 Forsyth and Ayers, 2009.

168 Krishnan, 2010.

169 The satellite initiative – Sentinel Asia – began in October 2006 under the Asia Pacific Regional Space Agency Forum based in Japan. It uses remote sensing data from Japanese satellites to provide disaster information across Asia.Low resolution satellite data covers large areas, and is useful for disaster surveillance and monitoring, while high resolution data helps in localised disaster mitigation efforts, India, Thailand and other Asian countries with space programmes have shown interest in adding their own satellite data to the initiative. Australia is also providing data from its wildfire monitoring system. (http://dmss.tksc.jaxa.jp/sentinel/contents/SA-intro.html , Accessed 13 May 2010).

170 Jianchu Xu *et al*, 2009.

171 Chinadialogue 2009.

172 Gyawali, 2001.

173 Examples of projects led by misguided data with serious consequences include the World Bank funded Arun II Kulekhani Reservoir in Nepal and the building of river embankments in the Bihar region of Northern India.

Annex 1: Future stories

The following stories are not necessarily intended to approximate reality, but this approach can be used to challenge conventional thinking and to enable policy- and decision-makers to think 'out of the box'. In this instance, however, the accounts that follow are not merely an exercise in exploring alternative approaches to policy formulation. While they are indeed intended to stimulate thought about how to deal with complexity and uncertainty, they also offer descriptions of the sorts of future crises that those responsible for crisis prevention and preparedness will have to consider.

China's water, 2020–2025: scarcity, pollution and conflict

Over the past decade, the Chinese government has failed to address underlying structural issues in domestic water allocation, develop adequate systems of water pricing and rights, curb waste or allow water trading. Instead, government response has been to rely on water-transfer projects and to limit water allocations to provinces, rather than to promote conservation through regulatory or market mechanisms. By 2020, unregulated economic activity and over-exploitation of limited or contaminated water sources had combined to push China's water crisis into catastrophic proportions.

Groundwater tables under the northern plain have dried up, or at least sunk so deep that farmers are unable to extract the remaining water. Continued erratic rainfall and rising temperatures have rendered the Yellow River and its major tributaries seasonal resources. The Shiyang River in Gansu has completely disappeared. The oases of the northern plains are particularly reliant on glacier meltwater, and many, like that of Minqin County, have been completely evacuated. The early 2020s saw the water availability per person in the Hai, Huai, and Yellow (Huang) river basins fall well below 500m^3/year, less than the minimum for human existence. In this former breadbasket, desertification continues to overwhelm arable land. Dwindling glaciers have caused the Gobi desert to encroach further upon the oases in the Xinjiang Uygur Autonomous Region. Desertification now affects 600 million people, nearly half the country's population.

Policies of state-directed environmental migration have now relocated 3 million farmers and nomadic herders in Qinghai, Ningxia and Gansu to Xingjiang and Inner Mongolia. This is having enormous environmental and social repercussions since these now-arid destinations themselves are unable to provide adequate support for increasing populations and there is not enough arable land for migrants to sustain new livelihoods. Ethnic tensions have been escalating in China's western hinterlands, with increasing violence. These incidents culminated in a series of savage riots that spread from Hohot, Lhasa and Urumqi throughout urban centres in the region in June 2020.

Conflict driven by water stress

As the summer of 2020 progressed, severe droughts, worse even than in 2019, threatened to drive the 200 million inhabitants of the North China plain into potential starvation, and the army is enforcing water rationing in the overrun cities of Beijing and Tianjin. In the run-up to the National People's Congress in October 2020, the Chinese Premier Li Keqiang announced the launch of the construction of the western section of the South–North Water Transfer Project (SNWTP), aimed at increasing crop production in the Gobi desert and easing over-crowding in the east. In an attempt to gain popular support as the national water crisis accelerated, the Chinese leaders disregarded international agreements and abandoned any effort to carry out an Environmental Impact Assessment – despite the serious pollution associated with construction of the central section of the project.

India–China relations have been at an all-time low since the completion of the 40,000MW dam at the 'Great Bend' of the Tsangpo-Brahmaputra River in 2019, harnessing the power of the deepest canyon in the world. This far exceeds the scale of projects such as the Three Gorges Dam, and the Indians claim that maximum river flow has already been reduced by 20%, while the Chinese refute such accusations. On 1 October 2025, Chinese National Day, Chandra Singh, the Indian President announced that, unless China discontinued water-transfer plans, India would make an official declaration of war. In the first weeks of October, India deployed an extra 60,000 troops in the border area and strengthened air defence in Ladakh. Seemingly, uncontrolled skirmishes broke out between troops on the border, resulting in casualties on both sides. Chinese internal conflicts over water allocation and pollution were so widespread that the threat to national security provided a useful focus for the government as it aimed to encourage patriotic unity against a common enemy.

Chinese troops were deployed to quell rising dissent within Tibet about environmental damage caused by mega-infrastructure projects. Chinese nuclear missile deployment in Haiyun and Da Qaidam in Qinghai province was confirmed, but the international community remained powerless. No bilateral agreement was ever reached between India and China after the memorandum of agreement to share hydrology data in 2002 degenerated into a means for China to exhort payment from India in return for often-dubious information. Attempts by NGOs to establish an international dialogue and roadmap towards a 'benefit-sharing' agreement have failed, and the international community can only watch and wait.

In the face of these Chinese actions, India has pursued its own grand plans. By 2019 a canal had been constructed to move water from the upper parts of the Ganges, Yamuna and Brahmaputra Rivers westward, ending in the Luni and Sabarmati Rivers in Rajasthan and Gujarat. This diverts water away from the Ganges, a few kilometres from the India–Bangladesh border. The immense levels of construction along the river severely affected the flow of water downstream in Bangladesh. Stagnant reservoirs have led to high levels of toxic algae and bacteria that Bangladesh claims are now poisoning hundreds of thousands of people.

Destruction of ecosystems and livelihoods

In order to complete the western water-transfer route, China has also diverted water from the Lancang (Upper Mekong) River, and a series of 15 cascading dams has been completed. The 292-metre Xiaowan dam is now the world's tallest, as high as the Eiffel Tower. The reservoir behind the dam has grown to 102 miles long. At the same time Laos, Vietnam and Cambodia have all been pursuing their equally destructive dam projects, violating international standards concerning both environmental and social issues. The Mekong River Commission dissolved in 2015, after failing to play any role in regional facilitation or to prevent dangerous dam-construction projects.

Dramatic changes to the river's unique cycle of flood and drought – the annual flood pulse – have wrecked the delicate ecosystem of the region. In the waters of the Mekong that used to sustain the world's second-largest inland fishery, most fish species are now threatened with extinction and the 60 million people who use the river as a source of food or livelihood are struggling for survival. Cambodia's great central lake, Tonle Sap, the nursery of the lower Mekong's fish stocks, used to fill up in monsoon season with a fifth of the Mekong's waters. In 2025 it has become barely seasonal, and the loss of livelihood pushes another 15% of Cambodians below the poverty line and endangers many more.

On 7 September 2030, severe monsoon floods deluged 1.4 million hectares of land in the Mekong Delta, affecting 14.2 million people in Laos, Cambodia and Vietnam. The Vietnamese government's 'living with floods' programme of the 2010s, to resettle people living in vulnerable zones, has failed due to lack of funding. Thus 5.3 million people in An Giang, Dong Thap and Tien Giang provinces have been driven out of the Mekong and the Red River Deltas. Climate refugees have swelled the population of Ho Chi Minh City, and Cambodia attempted to shut its borders in panic.

As regional dialogue reached a deadlock over dam building, there are no regional mechanisms in place to cope with a humanitarian disaster of this massive scale. Moreover, hugely expensive construction of dams and reinforcement of thousands of miles of dikes built after the Commission collapsed in Laos, Cambodia and Vietnam will exacerbate the disaster in its aftermath. Barriers inhibit the self-cleansing mechanism of rivers and trap millions of cubic yards of industrial waste, hundreds of thousands of tonnes of industrial rubbish, and millions of tonnes of pesticides and fertiliser from fish and shrimp farms. The livelihoods and lives of the approximately 30 million inhabitants of the Mekong Delta are under long-term threat.

Mega-flooding in Bangladesh, 2028

Introduction

The Ganges, Brahmaputra and Meghna Rivers converge in central Bangladesh to form the massive GBM delta, a region corresponding roughly to the Bengal Basin, and which occupies most of West Bengal and Bangladesh. The basin is mostly flat country, between the Himalaya to the north and the Bay of Bengal to the south, and is filled with kilometres of alluvial sediment that form one of the most productive aquifers in the world. The delta has a tropical monsoonal climate and receives 1–3 metres of rainfall per year, normally with extensive flooding. The low-lying and flood-prone GBM delta is predicted to be one of the world regions most susceptible to changes linked to climate warming.

The GBM delta overall was home to 130 million people in 2000, with an additional 28 million predicted by 2015.Such growth is also reflected in the mega-city of Dhaka, where population is predicted to expand from the current 14 million to 22 million by 2025. Within the Asian mega-deltas, the abstraction of groundwater is greatest in the GBM delta, which also experiences very severe arsenic contamination of its groundwater. Consequently, the lives of millions of people, many living in poverty, are already highly vulnerable. The scenario developed here illustrates how a number of factors interacting simultaneously may lead to a magnified disaster – a flood in this case.

A future for Bangladesh: increasing vulnerability

The 2010s and 2020s were mixed for the people of Bangladesh. The population continued to grow, as did food production and inflation-adjusted per-capita GDP. Dhaka became the fourth largest city in the world as its population hit 22 million in 2025, and it remained the most densely populated city in the world. The growing population of the mega-city was partly due to in-migration from r ural areas, a trend seen throughout Asia. The population increase put great stress on the environment and its resources. Water remained the main focus of attention, with grave concern about the depletion of groundwater, which in many areas was being drawn down at a rate of over 1m per year and not annually recharged during the summer monsoon. Consequently, many sources of groundwater become unproductive, making farming impossible in many areas. The demand for domestic and industrial water in Dhaka and other cities has also grown fast.

The quality of groundwater remains problematic, despite nationwide efforts to introduce filtration systems. Severely affected communities have largely broken down, with women showing obvious signs of arsenicosis being shunned, and the birth rate declining as a result. Consequently, there are fewer young people to help sustain these communities. Starvation and suicide have become widespread. In coastal and estuarine zones, land and groundwater have become increasingly saline. The death of many mangroves in the Sundarbans has left much of the coastal zone highly vulnerable to storm surges. Loss of coastal habitat has also led to increased coastal erosion. Shrimp farming in many places has been decimated by increased salinity of surface water. Power supply in Khulna and other cities has become limited by the availability of fresh water to cool the boilers in power plants.

After the climate conference in Copenhagen in 2009, Bangladesh was designated a 'natural laboratory' for scientists mapping and monitoring the impacts of climate change on low-lying regions. As temperatures continued to rise, and summer glacial meltwater flows increased, the summer monsoon became more variable and tropical cyclones and extreme rainfall events intensified. Flooding became more extensive, and sea level in the Bay of Bengal continued to rise faster than the global average.

The flooding of 2028

The 2028 flooding in the GBM delta, mainly in Bangladesh, started off as nothing unusual, but culminated in a mega-flood, which developed over several weeks in August and September. After several months of severe drought, extremely heavy monsoon rains arrived later than normal. As the rivers swelled and broke their banks inland, an intense tropical cyclone developed in the Bay of Bengal. The storm made landfall on the night of 15 September and coincided with a rising tide. Winds reached up to 250km per hour and a storm surge up to six metres high pushed inland. As the river water and the surge met, water backed up and spread out to engulf vast area of land. Over the following days, an estimated 50 per cent of Bangladesh flooded, including many parts of Dhaka, and some 80 million people were affected. From the air, the country looked like a drowned world and people could be seen crammed onto areas of raised land and floating on boats and pieces of debris.

Hundreds of thousands of people displaced by the flooding died of starvation and disease in the days and weeks following the flood. Maintaining delivery of essential services was largely impossible, with hopelessly impaired communications and many power stations unable to function. Several other factors contributed to the severity of the flood. Reports indicated that Indian farmers or paramilitaries had opened many dam gates and barrages in order to prevent them from bursting as water levels rose. This periodic release of water led to flash flooding in some areas of Bangladesh. This was been compounded by high flows of meltwater from Himalayan glaciers. As the rate of glacier retreat has risen considerably since 2021, many reservoirs upstream of the GBM delta have been unable to hold the extra water in summer, especially given their reduced capacity due to silting. Across many parts of Bangladesh, land has sunk as a consequence of the over-abstraction of groundwater and many areas that once lay above the flood level were submerged in 2028.

The scale of the flood and the continued high flow of water through the GBM delta meant that the floodwaters took well over two months to recede. People were therefore displaced and without food or clean drinking water for many weeks. They could not work and ran out of money. An entire harvest was lost across much of the country and much agricultural soil near the coast was saturated with saline water. Even the most basic sanitation facilities all but disappeared, and so clean drinking water was largely unavailable. Consequently, food shortages and waterborne diseases reached an unprecedented scale across much of the country.

Relief operations

Although the government had issued warnings of the flood and cyclone, it was completely unprepared for the scale of the disaster. Emergency supplies quickly ran out and there was no food, safe drinking water or medical supplies across much of the country. The Bangladeshi military mobilised, although naval and air force bases near the coast were badly damaged. The army divided its efforts between helping flood victims and patrolling the 3400km fence between India and Bangladesh. Some of the most desperate flood refugees opted to risk being shot by trying to escape Bangladesh through the fence along the Indian border. In several instances, groups of thousands of Bangladeshis charged the fence, attempting to break it down. The Indian army regularly dispersed crowds by firing tear gas across the border.

National and international aid agencies poured relief into the country, but found it impossible to move food, water and medical supplies effectively. Water filtration kits were deployed to some areas in the hope that some communities could survive by purifying their own water. Aircraft and boats were required, as many roads and bridges had been destroyed or were still under water. Despite substantial international resources, starvation, dehydration and infections were widespread, and the death rate increased dramatically. Initial estimates suggested that well over one million people died during and immediately after the floods.

The aftermath

The people of Bangladesh are some of the most resilient to poverty, ill health, hunger, dehydration and disasters, especially floods, but the effects of the 2028 flooding were unprecedented. The massive cost in terms of lives, and damage to infrastructure and the economy, set back development in the country by two decades. Tension between India and Bangladesh remains high, with the Bangladeshis calling both for the removal of the fence between the two countries and for joint water management. India, however, continues to refuse either of these demands, despite international pressure, and the two countries have come close to war. In protest, several million Bangladeshis have established refugee camps along the border, and the UN has deployed peacekeepers there. The refugees have attempted to discard their waste on the Indian side of the fence in protest. To date, in 2030, war has not been declared, but there have been several shooting incidents.

The flood catalysed the international community into new climate talks, but still the rhetoric continued with no obvious long-term benefit for Bangladesh and similar regions. Bangladesh claimed environmental compensation from high-income nations but without success. There are national and international calls for the Bangladesh government to re-vegetate the coastal zone, but funding for this is absent.

Despite the renewed talks, and worldwide concern about the situation in Bangladesh, there are no significant new initiatives two years after the mega-flood. The other hard truth is that the demands of population and development growth in Bangladesh since the 1970s have permanently altered the environment and depleted its resources, pushing the country into a new era of increased vulnerability and poverty. Such is the severity of the enduring devastation that there have been calls to abandon many parts of Bangladesh. However, other countries have not agreed to accommodate the estimated 50–100 million people who would have to re-locate.

Ultimately, as before, the people of Bangladesh have been left to adapt to a situation that will probably worsen with time. They remain effectively fenced into a massive flood zone.

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