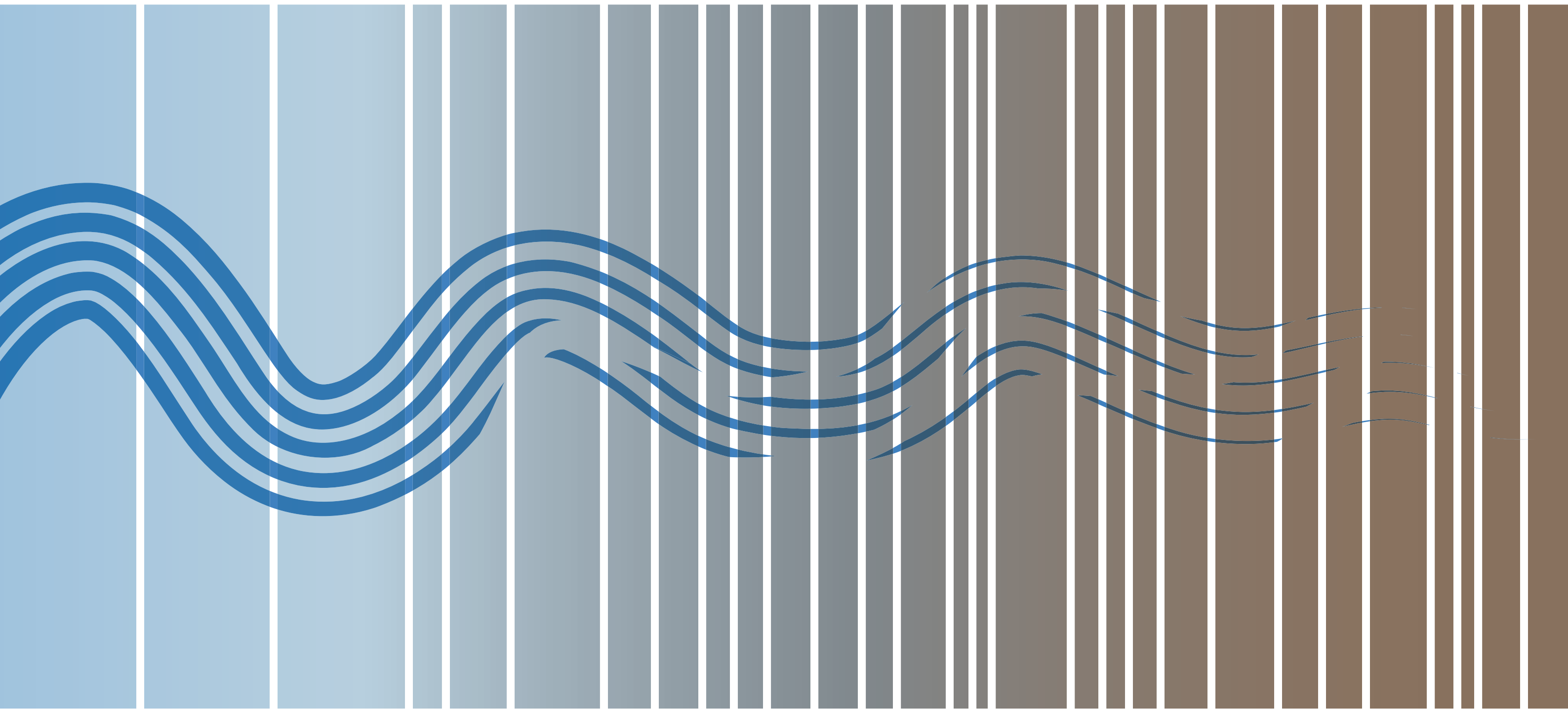
The Himalayan Challenge

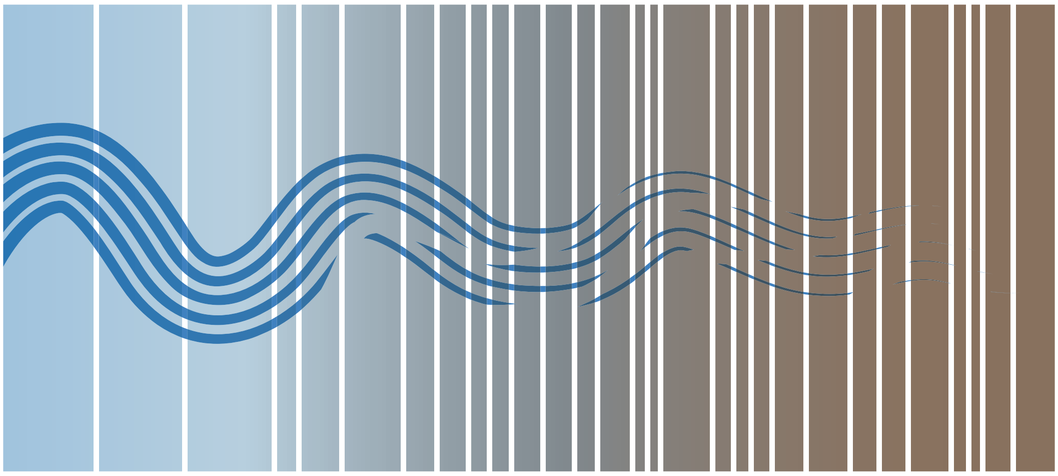
Water Security in Emerging Asia



Strategic Foresight Group

The Himalayan Challenge

Water Security in Emerging Asia



With support from

John D. and Catherine T. MacArthur Foundation

Strategic Foresight Group

Strategic Foresight Group

C-306, Montana, Lokhandwala Complex, Andheri West, Mumbai 400 053, India
Email: info@strategicforesight.com

Project Leader : Ilmas Futehally
Research Advice : Sundeep Waslekar
Research Team : Sahiba Trivedi, Rohit Honawar, Anumita Raj, Sowmya Suryanarayanan
Creative Head : Preeti Rathi Motwani

This publication has been supported by the John D. and Catherine T. MacArthur Foundation. The Foundation does not necessarily share the views expressed in this material. Responsibility for its contents rests entirely with the Strategic Foresight Group.

ISBN 978-81-88262-13-7

Processed by : Excel Computer Design Centre
Printed at : Lifon Industries, Mumbai

CONTENTS

PREFACE

I am pleased to present this report on long-term implications of water security in the Himalayan River Basins. The report covers the habitat of 1.3 billion people, about one fifth of the world's population. Moreover, this sub-region is part of emerging Asia, which is expected to provide stimulus for growth in the twenty-first century. The resilience shown by the Asian economies in the financial crisis of 2008-2010 has raised the expectation of the world.

The prospects of economic growth in Asia depend on geopolitical stability. The drivers of geopolitics, peace and conflict are changing all the time. They are difficult to foresee. In the 19th Century, territory was the main driver for geopolitics, peace and conflict. In the beginning of the last century, if anybody had predicted that oil would become important, people would have dismissed it.

By the end of the century, oil did become important. After World War II in the 1950s, if any one had predicted that climate change would become important, they would have been dismissed. But climate change has already become an important factor in this decade. Similarly, while various research institutions have projected that water will become an important driver of geopolitics and global security, this is given marginal importance.

This paper is prepared from a geopolitical and security point of view and not from the point of view of sectoral expertise in water. It demonstrates that in the next 30-40 years, water will be one of the key drivers of the Asian political and security agenda.

The idea for this project came from an international conference on Responsibility to the Future, organized by the Strategic Foresight Group jointly with the United Nations Global Compact. It was inaugurated by the President of India and attended by delegates from over 25 countries. It took place in Mumbai in June 2008. The conference recommended that SFG should address the issue of water security, particularly as it relates to the problems arising from the melting of glaciers and flow of Himalayan rivers, from the position of a think tank that looks at geopolitical and strategic future, not from a sectoral perspective.

However, it is extremely important that the examination of this issue takes place with participation and leadership of experts in the field. Therefore, SFG convened expert workshops at Kathmandu in August 2009 and Dhaka in January 2010. We benefited tremendously from the deliberations at these workshops, as well as private consultations with experts and leaders in the region.

This report looks ahead at the world in 2050 which will be bereft of many bounties of nature and concepts of social stability that we are used to. This is not just a question of environmental degradation. This is also a question of the erosion of political and security concepts that we are familiar with. Already, many water deficit but financially rich countries are purchasing millions of acres of agricultural land in other countries, under the protection of their own security. Thus, sovereignty is no longer what we have traditionally understood.

Countries sharing basins of rivers flowing across boundaries are negotiating new forms of cooperation which must involve compromise of traditional concepts of security, or risk confrontation. Refugees, pirates and criminals have grown in parts of the world directly on account of food and water scarcity. If these trends continue, the world in 2050 will be a world with excessive supply of chaos and serious deficit of sustainability.

These dangers are most evident in the Himalayan region. The report throws light on the condition of the Yellow River in China, melting of permafrost, disappearance of lakes, and the need to divert the Yangste River by artificial means. It exposes the risk to the future of the Ganges in India, compounded by the risk to the future of the

Yamuna, and the rivers flowing from Nepal. Nepal and Bangladesh suffer from the strange phenomenon of "too much water, too little water".

We have two options. The easy option is to protect our national interests disregarding the concern and interests of others in the region, and exposing the region to the possible dangers created by men or nature in the next half century. The difficult option is to engage in very honest discourse, rise above short term fears and build a shared collaborative and sustainable future in the long term. I hope that a considered debate on the analysis, and presentation in this report will help policy makers and people in emerging Asia to choose the right option.

I must thank the John D and Catherine T MacArthur Foundation for providing generous support to enable the Strategic Foresight Group to undertake such an ambitious endeavour.

I hope that this report will take the debate on Asian Security ahead in a new and constructive direction.

Sundeep Waslekar

June 2010 **President, Strategic Foresight Group**

EXECUTIVE SUMMARY

- The Himalayan River Basins in China, Nepal, India and Bangladesh are home to about 1.3 billion people - i.e. almost 20% of the world's population and almost 50% of the total population of these countries.

- Water availability on per capita cubic metre basis is estimated to decline from 2150 at present to 1860 in 2030 in case of China, from 1730 to 1240 in case of India, from 7320 to 5700 in case of Bangladesh, from 8500 to 5500 in case of Nepal.

- About 10% to 20% of the Himalayan Rivers are fed by glaciers – an important source of water in low season. According to some studies, the glaciers will be seriously affected by global warming by 2350 while other estimates suggest that it will take 600-700 years for Himalayan glaciers to deplete. Reliable estimates are not available due to the absence of meteorological stations in crucial geographical areas, lack of scientific data and collaborative studies. However, for the glaciers that have fed rivers for thousands of years, a few centuries is a short period of time. Also, some impact will be already visible by the middle of the 21st century. The Yellow River in China and the Ganges (with its tributaries) in India will be the most affected and turn into seasonal rivers by the second half of the century. They are expected to lose between 15% to 30% water due to glacier depletion. The Yangtze and Brahmaputra will also lose about 7% to 14% of the annual flow due to depletion of glaciers. Bangladesh will face the cumulative impact of these developments.

- While glacial melting will eventually reduce river flow in the low season, an increase in temperature in some areas will cause heavy precipitation concentrated for a few days during July-September. This will increase the risk of flooding. The overall pattern will be intense rain over a few days and long dry periods. Some areas like north-east China and northern parts of India will see decline in precipitation.

- In the next 20 years, the four countries in the Himalayan sub-region will face the depletion of almost 275 billion cubic meters (BCM) of annual renewable water. For comparison, this is more than the total amount of water available in one of the countries – Nepal – at present. At the same time, demand will increase due to growth of population and economic development. As a result, China will experience an annual water deficit of 50-100 BCM in 2030 at a relatively low utilisation rate of 28% in 2030 and India's water surplus will become half to 200-260 BCM despite an unsustainable utilisation rate of 61% at that time. Nepal and Bangladesh will also see their water balance shrink.

- The agricultural sector will continue to be the major consumer of water in China, Nepal, India and Bangladesh, although the industrial and domestic sectors will also need more water in the future. In China, agriculture consumes about 65% of water. This proportion will decline to 55% by 2030 before rising again slightly around 2050. In India, agriculture accounts for almost 90% of the water usage but this will decline to 70-75% by 2050. Nepal and Bangladesh presently use more than 95% of their water for agriculture and will continue to do so until 2030.

- In addition to depletion of water resources due to natural reasons, it will not be possible to use the available water resources because of pollution and losses caused by inefficient management. Yellow River Conservancy Committee estimates 34% of the river unfit for drinking, aquaculture, and agriculture. The tributaries of Yangtze River are extremely polluted to the extent of 30%. In India, Yamuna River, the main tributary of the Ganges is extremely polluted to the extent of 50%. Most of the rivers in Bangladesh are considered extremely polluted, though precise degree of damage is not available. Only the rivers in Nepal and Brahmaputra in India and its tributaries are relatively clean.

- In addition to shrinking rivers, all countries face the problem of loss of permafrost, deforestation and the disappearance of lakes. Thousands of lakes in the source region of Yellow and Yangtze have disappeared. These developments have resulted in desertification, which can further result in an increase in temperature and create a vicious cycle.

- The cumulative effect of water scarcity, glacial melting, disruptive precipitation patterns, flooding, desertification, pollution, and soil erosion will be a massive reduction in the production of rice, wheat, maize and fish. Both India and China will face drop in the yield of wheat and rice anywhere between 30-50% by 2050. At the same time demand for food grains will go up by at least 20%. As a net result, China and India alone will need to import more than 200-300 million tonnes of wheat and rice, driving up the international prices of these commodities in the world market. This will have adverse impact on the poor all over the world.

- The dire need for water, electricity and flood control has led to construction of dams. Some of the dams do not last as long as intended. Moreover, they result in displacement of local populations and have adverse impact on water flows of lower riparian countries in the case of the trans-boundary rivers. The speculation about China's plans to build a dam at the Great Bend on Yarlung Tsangpo (Brahmaputra) and India's River-Linking project are matters of concern, as they can reduce river flows in low season. Since the Himalayan region has high seismic activity, an earthquake can damage a dam and flood an entire region, causing devastation.

- Water scarcity, decline in food availability, reduction in livelihood opportunities in rural areas, desertification, soil erosion, sea-level rise and construction of dams will lead to displacement and migration of 50 to 70 million people in the four countries by 2050. Scientific estimates of potential migration figures are not available but based on past trends the risk of more than 100 million people migrating internally or to neighbouring countries will result in social conflict on communal or secular basis. Water scarcity and environmentally-induced migration will exhibit reverse pattern as compared to the conventional economic migration. For instance, people will be displaced from Nepal's Terai region, China's northern provinces and river estuaries in the south-east, coastal districts of China and Bangladesh, northern provinces of India which have hitherto been the destination for migrant population due to industrial growth in these regions. In China, the number of economic conflicts will increase as a result of all this activity. In the other three countries social conflict may find ethnic, communal or religious expression.

- Relations between India and China may become strained due to competition over expanding influence in Nepal and especially, if China decides to build a dam or diversion project at Great Bend over Yarlung Tsangpo. Relations between India and Bangladesh may become strained due to a decrease in flow of rivers from India to Bangladesh and increase in refugee flow from Bangladesh to India. Relations between India and Nepal may become strained due to plans of either party to build dams on their side of the border. Though this deterioration of relations is unlikely to result in inter-state military confrontation, it can lead to new external alliances, producing fresh alignments and polarisation in Asia and 'beggar thy neighbour' politics, which can compromise the internal options of each country. Though the problems arising from water security are essentially internal, the solutions will need to be in the form of trans-boundary and sub-regional cooperation, especially if emerging Asia wants to convert adversity into an opportunity.

- China shares flood forecasting data in the monsoon months with India and Bangladesh. This is supplied by email twice a day. It is necessary to increase its frequency since sometimes 12 hours can prove to be too long to avert a catastrophe. It is also necessary to extend this data-sharing cooperation to the full year, particularly including the low flow periods.

- China and India have institutional arrangements for cooperation on data-sharing to address climate change and related problems in the Himalayan and Tibetan regions. It is necessary to actualise these arrangements through concrete projects of high intensity, quality and magnitude. More importantly, such arrangements need to be extended to sub-regional level by including Nepal and Bangladesh since many of the issues are interlinked across the four countries. A Regional Information Sharing Network is recommended.

- The Dhaka Declaration on Water Security (Annexure 2) has proposed an expert committee to prepare a roadmap for data-sharing and scientific exchange and to prepare guidelines for introducing transparency regarding relevant data.

- Since quantitative issues are controversial, a beginning can be made with data sharing on water quality monitoring. Already a network of experts for such a purpose has been established for the South Asian countries. It can be expanded to include China.

- Nepal, Southwest China and Northeast India are landlocked areas. Water transport can provide new connectivity, opportunities for trade and tourism and employment. While India can link to its north-eastern states through Bangladesh, Nepal can connect to India through waterways. Water-based transport also tends to be more environment-friendly than other modes of transport.

- The Brahmaputra can also be utilized for navigation, though combined with multi-modal transport in some sectors where the river flow does not permit water-based transportation.

- The Himalayan sub-regional water transport can comprise of two corridors, with India and Bangladesh as transit nations. The first segment includes Nepal-India-Bangladesh connecting Karnali, Narayani and Saptakoshi Rivers in Nepal to the National Waterways-1 in India. The second segment includes China-India-Bangladesh connecting south-west of China to ports in Bangladesh through waterways in India. In exchange for navigational benefits, India and Bangladesh can secure concessions and cooperation from other countries in the region in other spheres as well. In addition, waterways in the Sunderbans can be developed further for promotion of the mangrove forests as a destination for eco-tourism and for use by smaller vessels. This will maximize the potential economic benefits of the waterways in the region.

- Nepal has a hydro-electricity generation capacity of 600 MW. Its potential capacity is 40 GW while the potential demand for current population is about 2 GW. The demand is much higher if population and economic growth over the next 2-3 decades is taken into account. Thus, Nepal has the potential to export surplus power to India and China and to a lesser extent Bangladesh. India and China are currently investing in Nepal's hydro-electricity creating scope for either cooperation or competition, depending on how they manage their relationship.

- In preparation for the Copenhagen Summit on Climate Change in 2009, India and China established a working group for cooperation. This can be complemented by a sub-regional mechanism for climate change cooperation to undertake studies on impact of climate change on the region by learning useful practices from each other and by mutually formulating policies for adaptation and mitigation.

- Once trust and confidence are established through practical cooperation, data sharing, scientific exchanges, hydro-electricity, irrigation, trade, transit, and tourism, the four countries can consider Integrated River Basin Management. The Integrated River Basin Management would require agreement on certain principles which are in conformity with the UN Watercourses Convention, Biodiversity Convention and the Ramsar Convention. If such an agreement on principles is possible, the next logical step would be to establish a river basin organisation.

- Collaboration on the management of the Ganges and Brahmaputra Rivers, under the umbrella of a Himalayan

Rivers Commission (HRC), will enable all four countries to tap expertise that might not have been available under a nationally-driven framework. The establishment of consultative bodies working on different aspects of river management will also facilitate basin-wide water development. The ability to seek scientific and engineering advice at the highest level, for the collection of hydrological and climatic data, flood forecasting, environmental management, water quality monitoring and design and implementation of water projects are essential for a better understanding of the river basins. The idea of learning from the experiences of other countries and gaining an insight into how they are adapting to climate change and growing water insecurity could also be mutually beneficial. The onset of more erratic monsoons for instance, is a problem which will affect all the countries. This will necessitate research and development of hybrid crops as well as that of more sustainable water utilization practices – the former of which is currently being researched and implemented in India and China, and could be shared with Bangladesh and Nepal under the provisions of Himalayan River Commission.

Cooperation on the water issue should be looked upon as a means to a peaceful co-existence. Joint water management offers the scope for people-to-people and/or expert-to-expert connections, thus creating a channel for peaceful dialogue irrespective of political and military developments.

GLOSSARY

Anthropogenic	Anthropogenic refers to the environmental externalities in the form of chemical or biological wastes that are produced as by-products of otherwise purposeful human activities.
Aquifer	A geologic formation, group of formations, or portion of a formation capable of yielding usable quantities of groundwater to wells or springs.
Backwater effect	The effect which a dam or other obstruction or construction has in raising the surface of the water upstream from it.
Base flow	The term refers to that part of the stream discharge that is not attributable to direct runoff from precipitation or melting snow; it is usually sustained by groundwater discharge.
Distributary	A distributary is a stream that branches off and flows away from a main stream channel.
Evapotranspiration (ET)	Evapotranspiration comprises the simultaneous movement of water from the soil and vegetation into atmosphere through evaporation (E) and transpiration (T).
Glacial lake outburst flood (GLOF)	A glacial lake outburst flood (GLOF) occurs when a large portion of a glacier breaks off and massively displaces water in a glacial lake at its base. This can happen due to erosion, a buildup of water pressure, an avalanche of rock or heavy snow and an earthquake or cryoseism (sudden cracking action in frozen soil or rock saturated with water or ice).
Glacial meltwater	Glacial meltwater refers to water from glaciers that have receded over time. Meltwater is the water released by the melting of snow or ice, including glacial ice and ice shelfs over oceans. Meltwater is often found in the ablation zone of glaciers, where the rate of snow cover is reducing.
Greenhouse gases (GHGs)	GHGs refers to any of the atmospheric gases that contribute to the greenhouse effect by absorbing infrared radiation produced by solar warming of the Earth's surface. They include carbon dioxide (CO2), methane (CH4), nitrous oxide (NO2), and water vapor.
Groundwater	The term refers to water that flows or seeps downward and saturates soil or rock, supplying springs and wells.

Overlap between surface and groundwater	Part of the internal water resources which is common to both surface water and groundwater. It is the part of river runoff which originates from groundwater (baseflow) and/or the part of the groundwater recharge that comes from losses from water courses (particularly in arid areas or in karstic environment) and is thus accounted for both as surface and groundwater.
Peak Discharge	The maximum instantaneous discharge of a stream or river at a given location. It usually occurs at or near the time of the high flow period.
Permafrost	Layer of soil or rock, at some depth beneath the surface, in which the temperature has been continuously below 0 °C for at least some years. It exists where summer heating fails to reach the base of the layer of frozen ground.
River discharge	The rate at which water passes a given point. Usually expressed in cubic feet per second.
River runoff	River runoff includes all the water coming in directly to the hydrological network during rainfall or snowmelt, plus groundwater from the upper aquifers feeding rivers more or less evenly throughout a year.
Salt water intrusion	The movement of salt water into fresh water aquifers.
Surface runoff	The runoff that travels overland to the stream channel. Rain that falls on the stream channel is often included with this quantity.
Topography	The term refers to the features on the surface of an area of land.
Transboundary	The term refers to crossing or existing across national boundaries. The term "transboundary waters" refers to sources of freshwater that are shared among multiple user groups, with diverse values and different needs associated with water use.
Vector-borne disease	A disease that is transmitted to humans or other animals by an insect or other arthropod.
Water scarce	A per capita water availability of below 1000 m3 per year
Water stress	A per capita water availability of below 1700 m3 per year
Water table	Water table refers to the top of the water surface in the saturated part of an aquifer.

ABBREVIATIONS

ABCs	Atmospheric Brown Clouds
ASEAN	Association of Southeast Asian Nations
BIISS	Bangladesh Institute of International and Strategic Studies
BIMSTEC	Bangladesh, India, Myanmar, Sri Lanka and Thailand Economic Cooperation
BIPSS	Bangladesh Institute of Peace and Security Studies
CMIE	Centre for Monitoring Indian Economy
FAO	Food and Agriculture Organization
GCM	General Circulation Models
GMS Cooperation	Greater Mekong Subregional Cooperation
HYV	High Yielding Variety
ICIMOD	International Centre for Integrated Mountain Development
IDPs	Internally Displaced Persons
IITM	Indian Institute of Tropical Meteorology
IPCC	Intergovernmental Panel on Climate Change
IWMI	International Water Management Institute
JCWR	Joint Committee on Water Resources
MOU	Memorandum of Understanding
NCZMA	National Coastal Zone Management Authority
NEERI	National Environment Engineering Research Institute
OECD	Organisation for Economic Co-operation and Development
ppb	Parts per billion
REDD	Reducing Emissions from Deforestation and Forest Degradation
SAARC	South Asian Association for Regional Cooperation
TERI	The Energy and Resources Institute
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WASSA	Water and Security in South Asia
WHO	World Health Organization
WWF	World Wildlife Fund
YRCC	Yellow River Conservancy Commission

Part I : Water Security

Introduction

Geography

Much like the oil crisis in the twentieth century, scientists and policy makers predict that water will be the most contested precious resource in the twenty-first century. Over the last few decades, fresh water has gone from being an abundant natural resource to one that is fast disappearing before our very eyes. Even as the fresh water resources of the earth are in danger of being depleted due to overuse, the effects of climate change have come in to play and have only served to aggravate and even complicate the issue. The situation is the bleakest in the basins of the major Himalayan Rivers in Asia. These basins are located in countries whose combined populations constitute roughly one-third of the world's population. Besides being rapidly emerging economies, they also have expanding industries and urban centres. These, along with multiple other factors, make the examination of water security in the Himalayan River Basins imperative and urgent.

The Himalayan Rivers studied in this paper are:

1. The Yellow (Hwang Ho) and Yangtze in China;
2. The Karnali, Saptakoshi and Gandaki in Nepal;
3. The Ganges, Brahmaputra and Yamuna in India and
4. The Ganges, Brahmaputra and Meghna in Bangladesh.

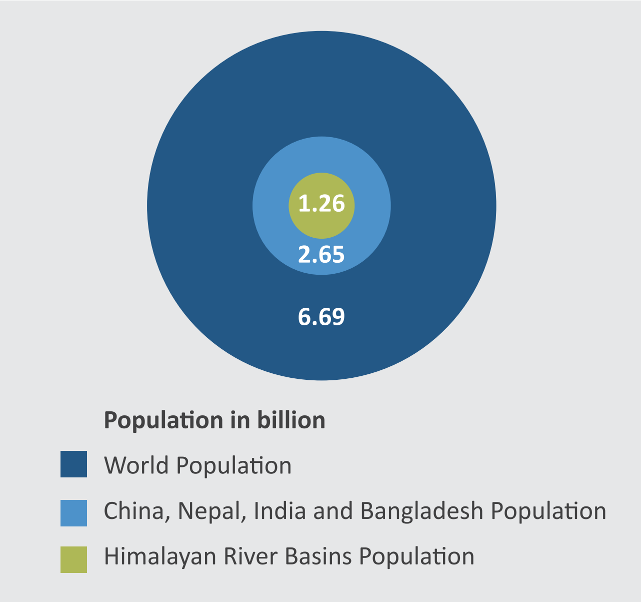
These rivers have been selected for the significance each of them holds in their country's water scenario. With the exception of the Yellow, the Yangtze and the Yamuna, all these rivers are trans-boundary, thus making their individual fate a regional issue, apart from being a serious national one.

The Yellow and the Yangtze Rivers both originate in Tibet - the Yellow in the Kunlun Mountains and the Yangtze in the Qinghai-Tibetan Plateau. While the former ends in the Bohai Sea, the latter merges with the East China Sea.

The Ganges originates in the Gangotri Glacier in Uttarakhand, although it is considered that the Bhagirathi River which rises from the glacier at Goumukh at an elevation of 7756 metres is the actual source. The source of the Yamuna River is the Yamunotri Glacier in Uttarakhand. The Yamuna is a major tributary of the Ganges with its confluence point in Allahabad.

All three of Nepal's major rivers flow into the Ganges in India. The Karnali rises in Tibet from glaciers in Mapchachungo, and enters India, where it is known as the Ghaghara. The Ghaghara joins the Ganges west of Patna. The Gandaki rises in the Tibetan Plateau in the Mustang district of Nepal near its border with Tibet. The Gandaki enters India where it is known simply as the Gandak and it joins the Ganges east of Patna. The Saptakoshi which originates in the Himalayas, flows through Nepal lying west of the Kanchenjunga Mountain, and enters India where it is known as the Kosi. The Ganges is joined by the Kosi shortly after Bhagalpur in India.

Representation of Population of Himalayan River Basins vis-à-vis World Population & the Populations of China, Nepal, India and Bangladesh



The Ganges flows into Bangladesh between the districts of Rajshahi and Kushtia. From here, it flows south-easterly for about 212 kilometres to its confluence with the Brahmaputra, where it is called the Padma. The Padma flows for about 100 kilometres to join the Meghna River at Chandpur. The Meghna River rises as the Barak River in the Manipur Hills in India, which are a part of the Sub-Himalayan ranges, at Chandpur. The Meghna then ends into the Bay of Bengal.

The Brahmaputra River, India's longest river originates in the Chemayungdung Glacier on the slopes of the Himalayas, about 100 kilometres south-east of Lake Mapan in south-western Tibet. The Brahmaputra is known as the Yarlung Tsangpo in Tibet. The river enters India through Arunachal Pradesh at which point it is known as the Siang River. From here it flows into the plains of Assam where it is known as the Dihang River. The river flows for about 35 kilometres before it is joined by the Dibang and the Lohit rivers. From here on, it is known as the Brahmaputra. The Brahmaputra enters Bangladesh from the north of the Kurigram District flowing south for about 270 kilometres to join the Ganges at Aricha about 70 kilometres west of Dhaka in Central Bangladesh.

Declining Water Availability

China, Nepal, India and Bangladesh have seen their total water resources and water availability drop steadily over the last few decades. In the next two to four decades, these numbers are expected to fall further, reaching dangerous and potentially unsustainable levels in some of the countries. According to the World Bank, per capita water availability below 1700 cubic metres per annum is considered water-stressed and a number below 1000 cubic metres is considered to be water-scarce.

All the four countries will face depletion of freshwater resources on account of climate change, disruptive precipitation and other natural factors, without considering pollution and demand management inefficiency. At the same time, they will witness growth of their population, which will stabilise in the case of China around 2030 but will continue to expand in the case of other countries at least until 2050. As a result, per capita water availability will decline. As compared to 2010, it will be substantially reduced by 2030 as follows: from 2150 at present to 1860 cubic metre in 2030 in case of China, from 1730 to 1240 cubic metre in case of India, from 7320 to 5700 cubic metre in case of Bangladesh, from 8500 to 5500 cubic metre in case of Nepal. As compared to the two large countries, Bangladesh and Nepal will still have per capita water availability at a much higher level of higher than 5000 cubic meters. As this report will aptly illustrate and assess, the water security of both these countries in the future cannot be taken for granted despite impressive statistics of fresh water availability. A combination of groundwater and river runoff forms the bulk of the water resources of China, Nepal, India and Bangladesh. Rain is vital to both, groundwater levels and river runoff. Despite the fact that the Himalayan Rivers are glacier-fed, they are also very dependent on rainwater for their sustenance. In all of

Basic Statistics of the Himalayan River Basins

	River Basin	Catchment Area (km²)	Length of River (km)	Basin Population (millions)	Mean Annual Runoff (BCM)
China	Yellow	795,000	5464	189	58
China	Yangtze	1,808,500	6300	400	925 (at Datong); 1000 (at the mouth)
Nepal	Saptakoshi	27,863	NA	6.8	45 (at Chatara)
Nepal	Gandaki	31,464	NA	NA	50 (at Narayangadh)
Nepal	Karnali	41,058	507	4.7	44 (at Chisapani)
India	Ganges	861,000	2525	370.2	525
India	Yamuna	345,850	1330	131	93 (at Allahabad)
India	Brahmaputra	580,000	916-1100	33.2	585
Bangladesh	Brahmaputra-Jamuna	46,300	270	47	630 (at Bahadurabad)
Bangladesh	Ganges	47,000	212	37	360 (at Hardinge Bridge)
Bangladesh	Meghna	35,000	160	43.9	150 (at Bhairab Bazar)

the four countries, the volume of the river runoff far exceeds that of the available groundwater. Moreover, both India and China having over-exploited and nearly depleted their groundwater reserves are now all the more dependent on river water for the daily needs of their populations.

In 2007, over 95% of China's water resources were attributed to river runoff, underground water resources accounting for only 5% of it. The total renewable water resources for China that year stood at 2800 BCM. Of this, river runoff accounted for 2711.5 BCM and the remaining 100 BCM was the volume of underground water.

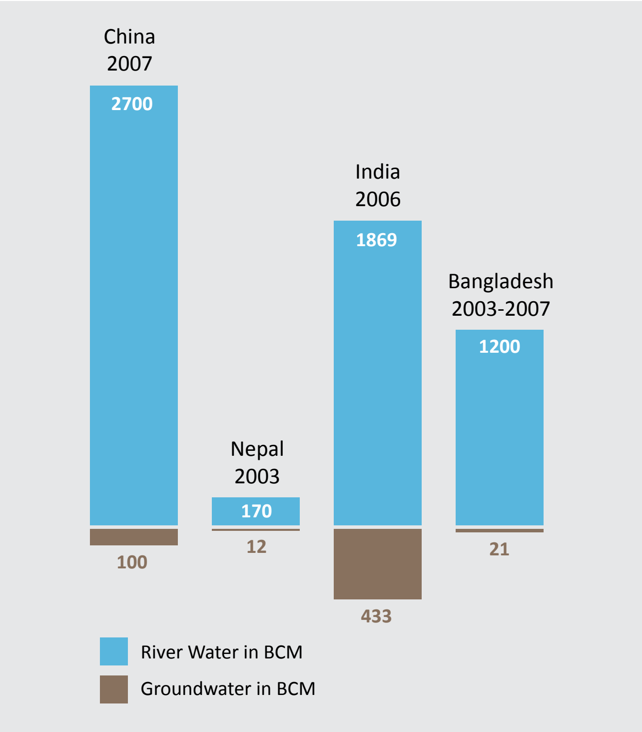
Nepal's story is similar to that of China, although its groundwater is in a comparatively better condition and is still under-utilised for lack of development and infrastructure. The total available water resources in Nepal were estimated to be at 237 BCM in 2003. This includes runoff of all rivers at 170 BCM (71%), groundwater at 12 BCM (5%) and remaining at 55 BCM (24%) made of other surface water resources including glacier water, glacial lakes, and snow melt.

The total river runoff of Bangladesh, like Nepal and China, far exceeds the underground water resources of the country. However, groundwater constitutes an important factor in Bangladesh's water resources. Close to 97% of Bangladesh's rural population depends on groundwater for daily drinking water needs, particularly in the dry summer season (November-May), when the rivers experience low water flows. It is estimated that the total annual river runoff in Bangladesh is approximately 1190 BCM (average figures for 2003-2007), while groundwater resources are only about 21 BCM. Bangladesh's groundwater is also affected by salinity due to sea water intrusion along the coastal areas. The country's total renewable water resources stood at 1211 BCM for the same time period.

The ratio of India's river runoff to groundwater is better than that of China, Nepal and Bangladesh, although due to its high population density, groundwater in the country is often over-exploited. As of 2006, India's total groundwater resources stood at 433 BCM. In the same year, the total river runoff of all Indian rivers combined was about 1869 BCM. The groundwater resources of India in 2006 were roughly one-fourth the size of the river runoff of the country, while the total internal renewable water was estimated at 1907.8 BCM per year.

India's dependence on groundwater has led to the over-exploitation of this valuable resource as tube wells are being dug deeper into the ground. According to the Ministry of Water Resources, 58% of the country's groundwater has been developed. Furthermore, a World Bank report states that 15% of all aquifers are already in a state of critical condition, a number which is expected to increase to 60% within the next 25 years. It is not surprising that groundwater resources are being overexploited, given that a large proportion of the country is dependent on groundwater acquired through tube wells. There have been reports suggesting that approximately 20 million tube wells have been set up in India and more than 50% of irrigated areas are being fed by groundwater. As a result, despite India having the best groundwater to surface water ratio compared to those of China, Nepal and Bangladesh, the country will gain little respite due to the gross overuse of its groundwater resources.

Ratio of National Groundwater Resources to National River Resources



Thus, the four countries covered within the scope of this report have varying levels of dependence on their groundwater resources. The groundwater resources have been developed to varying degrees, subsequently making an impact on their utilization rate.

Significance of the Himalayan Rivers

Of the hundreds of small, medium and large rivers of China, Nepal, India and Bangladesh, this paper focuses more on those that are fed by the Himalayan glaciers. In the case of India and China, while these river basins are significant in the overall national perspective, they do not occupy the entirety of the country. They do, however, support large populations, thereby linking their fates to the fate of almost half the populations of each of these countries. That would put the rough estimate of those affected by just the Indian and Chinese Himalayan rivers at over 1 billion people. Nepal and Bangladesh represent a different side of the spectrum. Both are small countries and the three basins combined in each of the two countries occupy almost the entire geographical expanse of Nepal and Bangladesh. The fate of the Himalayan Rivers in Bangladesh and Nepal is closely linked to that of their individual populations.

China has over 50,000 rivers, which provide close to 2711.5 BCM of water. The country's major river systems are the Yangtze, Yellow River, Huahe, Haihe, Songhua, Pearl and Liaohe. Their individual annual runoffs, the Yellow with 58 BCM and the Yangtze with 1000 BCM, together contribute 39% of the total runoff of all the Chinese rivers. The Yellow River is the second-longest river in China and its basin covers over 795,000 square kilometres of land, roughly 8% of China's total land area. The Yangtze River basin accounts for almost one-fifth of China's land area in square kilometres and covers 19 provinces. As of the year 2000, the population in the basin of the Yellow River was 189 million people, and that of the Yangtze River basin was 400 million people, which equates to 15% and 31.5% of the entire country's population respectively.

Glacial melted water and snow cover are important contributors to the flow of the Yangtze, Yellow, Mekong and Salween. The waters from these rivers are vital to China's western region especially in the dry season – sustaining approximately 23% of people in the area during this time. However, as with India, majority of the rivers in China are rain- dependent, with only a

National Groundwater and National River Water as a Percentage of Total Renewable Water Resources

Country	Total Water Resources	Groundwater as a % of total water resources	River Water as a % of total water resources	Overlap*
China (2007)	2800 BCM	3.6	96.8	729
Nepal (2003)	237 BCM	5.06	71.7	NA
India (2006)	1907.8 BCM	22.6	97.9	394.2
Bangladesh (2008)	1211 BCM	1.73	98.2	NA

* When the total internal renewable water resource of a country is calculated, the total surface water resources of the country and the total groundwater resources of the country are added together. From this number, an 'overlap' is deducted to reach the final total, i.e. the total internal renewable water resources of the country. The overlap is the volume of water resources that is 'effectively shared as it interacts and flows in both the groundwater and surface water systems'. This 'overlap' is equal to groundwater drainage into rivers (typically, base flow of rivers) minus seepage from rivers into aquifers. If this number were not deducted from the total, it will effectively result in the volume that is shared being counted twice.

For example, the total surface water of China is 2711 BCM. The total groundwater in China is 829 BCM. However, the overlap is 729 BCM, which has been counted twice. Therefore, the total internal renewable water resource of China is calculated as follows: 2711 BCM + 829 BCM – 729 BCM = 2811 BCM

Similarly, the total surface water of India is 1869 BCM. The total groundwater in India is 433 BCM. However, the overlap is 394 BCM, which has been counted twice. Therefore, the total internal renewable water resource of India is calculated as follows: 1869 BCM + 433 BCM – 394 BCM = 1908 BCM

few in the western region being snow-fed and glacier-fed. Most of China's larger rivers flow from the west to the east of the country. Those in the south, such as the Yangtze and Pearl River are defined by large water flows, small seasonal variations in water-levels, large number of tributaries and small silt loads due to heavy annual precipitation and warmer temperatures.

Rivers to the north, such as the Yellow and Liaohe flow through semi-arid areas of the country, where the precipitation is limited, soil erosion is high and winter temperatures are low. This results in the rivers having low flows and large seasonal variations. Also, the northern rivers are largely over-utilized. The Yellow River's utilisation ratio is at 70% in comparison to international parameters that require the ratio to be below 40%. It is important to note that high utilisation levels are primarily due to the correspondingly high population levels. The northern part of the country hosts approximately 50% of the population, with 14% of the water resources. In such a situation, there is bound to be a lot of pressure on the already limited water resources in the country.

India has a large network of rivers, all of which are characterised by very large variations in their water discharge due to seasonal rainfall and prolonged dry periods. The country's rivers are classified into large, medium, and minor, of which 15 are considered large, 45 are medium and, over 120 minor. India's rivers are usually described according to their origin – either as Himalayan and Peninsular or, East and West flowing. The majority of India's rivers are rain-fed, with the exception of those originating in the Himalayas. The peninsular and central rivers of India are more likely to face water scarcity issues. With rising temperatures and sporadic rainfall, water quality deteriorates and the already limited water supplies are unable to meet increasing demands for water. This in turn, will increase dependence on the Himalayan Rivers.

The contribution of the three Himalayan Rivers of India, the Ganges, the Yamuna and the Brahmaputra to the annual river flows of the country is approximately 1203 BCM - 525 BCM from the Ganges, 93 BCM from the Yamuna and 585 BCM from the Brahmaputra. This equates to approximately 64% of the total 1869

China : Yellow River (Huanghe) and Yangtze River (Changjiang)

BCM of annual river flow in the country. In addition, the average water yield per unit area of the Himalayan Rivers is almost double that of the southern peninsular rivers, reiterating the importance of snow and glacier melt contribution.

Nepal has over 6000 rivers, all of which are snow-fed and originate in the Himalayas, making them perennial in nature. Most of the country's rivers drain from the north to the south into India, although a few drain from the west to the east as well. There are several rivers which flow towards the south of the country. Their shallow nature means that they invariably run dry during the lean season. Nepal's rivers are prone to flooding during the monsoon season, reiterating the notion of 'too much water too little water'. Nepal's rivers contribute as much as 71% or 170 BCM of water towards the country's total water availability of 237 BCM.

The Karnali, Gandaki and Saptakoshi have annual runoffs of 44, 50 and 45 BCM, respectively. These three major rivers of Nepal, account for most of the country, or 70% in terms of drainage area; they also account for 80% of Nepal's total river runoff. Apart from being the main and most valuable source of water for Nepal, the rivers offer a vast, and as of yet untapped potential of hydropower and irrigation. The country's profitable white water rafting industry, along with Nepal's prominent tourism industry, is also heavily dependent on these three rivers. The major rivers of Nepal are not only important to the country, but also to its neighbour India. These rivers are the largest contributors to the Ganges River when they flow into India from Nepal. Together, the three rivers, and to a much smaller extent, the other trans-boundary rivers in Nepal make up for about 41% of the annual flow of the Ganges.

Bangladesh is comprised of 230 river systems, of which 57 are trans-boundary, with three flowing from Myanmar and the rest from India. Bangladesh's rivers make an important contribution towards sustaining agriculture, fisheries and navigation, GDP growth and

India: River Ganges

employment. While Bangladesh cannot be called a physically water-scarce country, it does receive more than 80-90% of its annual fresh water supplies from beyond its borders. The two principal Himalayan trans-boundary rivers in Bangladesh are the Ganges and the Brahmaputra. These two rivers contribute about 80% of the total trans-boundary inflow of 1100 BCM. The Brahmaputra River and its tributaries contribute around 54% and the Ganges River and its tributaries contribute around 31% of the runoff.

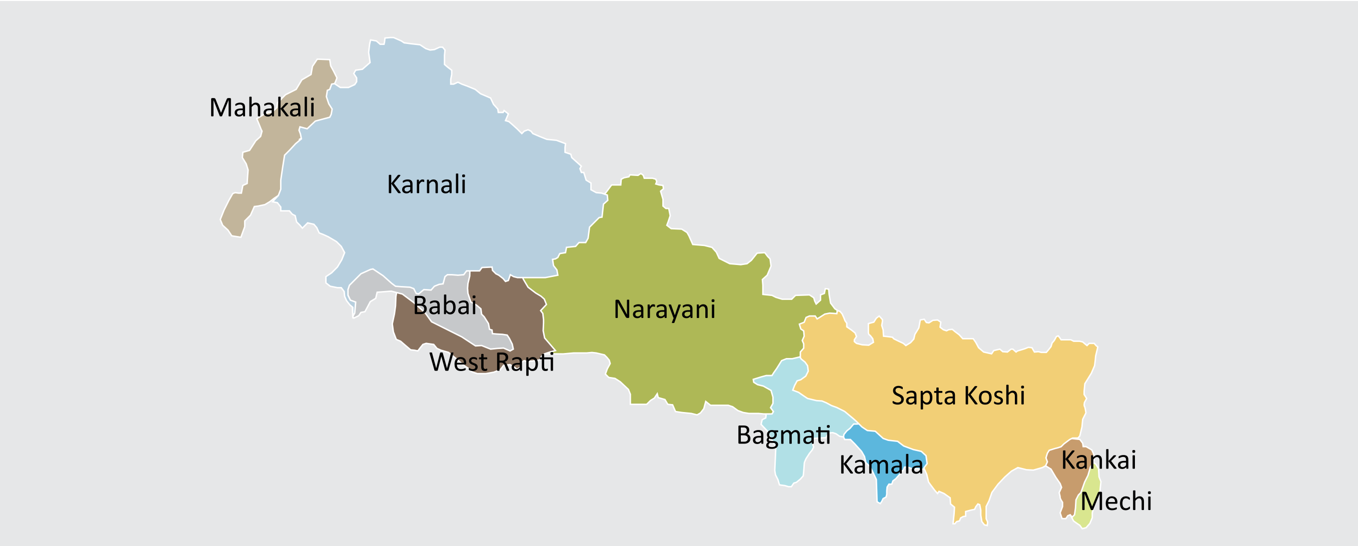
The Meghna River also contributes around 15% of the runoff along with other minor rivers. All the minor rivers with the exception of those in the Chittagong region belong to one or the other of the three major river systems. The Himalayan Rivers are also of economic importance to Bangladesh since they provide water to most of the country during the dry season. The three main sectors in Bangladesh - agriculture, fisheries and navigation - are highly dependent on the availability of the water resources. However, as with the rivers of the other Himalayan sub-regional countries, here too there are hurdles to a good water supply like considerably high levels of pollutants in the rivers, inadequate storage facilities and transportation infrastructure.

Highly variable precipitation patterns, dependence on monsoons, gaps in infrastructure development, pollution, growing water demands and climate change are various factors leading to limited water supplies and a consistent water scarcity situation.

Climate Change

It has now been established that water security in countries like China, Nepal, India and Bangladesh is intricately linked to the health of the Himalayan

Main River Basins in Nepal



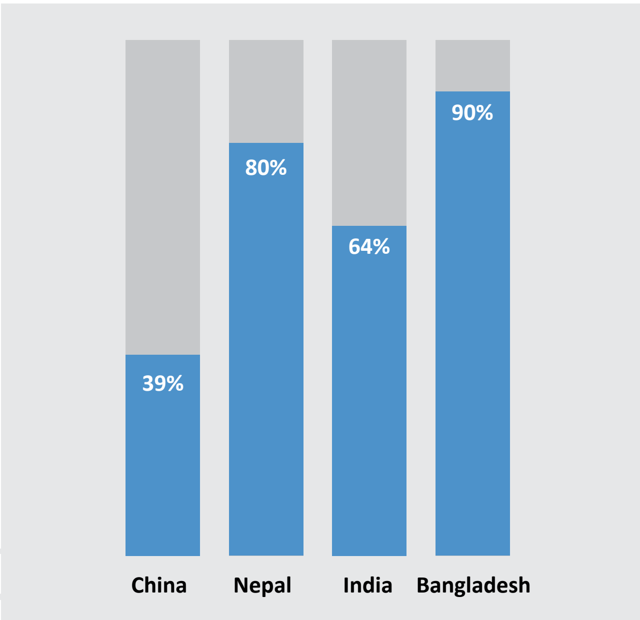
Source: http://assets.panda.org/downloads/himalayaglaciersreport2005.pdf

glacier-fed rivers in each country. Over-exploitation and in some cases, under-development pose a serious challenge to securing water resources – an issue which is further complicated by climate change. As the effects of global warming on glaciers and rainfall, become increasingly apparent, the water security of the Himalayan River basins has been compromised.

The glaciers in the Himalayas, the source region of all of the rivers are melting. There is also lack of reliable data and scientific consensus on their rate of depletion. Besides, higher temperatures have altered existing monsoon patterns making the rains infrequent, unreliable and unpredictable. The rivers, which are fed by a combination of glacier melt and rainwater, have already started displaying the effects of these new and extreme patterns. Wet season flows have become unreliable, leading to a direct and negative impact on agricultural practices. Floods have become a much more common occurrence, as have winter droughts. Rivers that were once perennial have now started to run dry several days of the year. Increasing temperatures have led to greater evapo-transpiration - the release of water from the surfaces of plants, soil, and other objects through evaporation. Salt water intrusion due to rising sea levels has caused groundwater to become saline and therefore, unsuitable for irrigation. All of these consequences can be traced back to climate change.

Issues like food security, human security, economy, health, and conflict are all related to the issue of securing water resources in the sub-region. The aim of this paper is to examine the water security in these basins and to understand how, through the convergence of various factors, including climate change, there continues to be a threat to water resources and subsequently to human security in the region.

Share of Himalayan Rivers in National River Flows



The Future of Glaciers 01

The Himalayan Rivers are perennial in nature owing to the glaciers that feed them and provide them with a constant flow of water. Various parts of the rivers receive different quantities of water from the glaciers that they originate from, depending, in part, on their distance from the source region. By the time the Himalayan Rivers enter Bangladesh, they are almost entirely rain-fed, thereby making the impact of the glacier melt indeterminate with regard to the water fortunes of the country. However, it is important to note that it is the perennial nature of the rivers that allows the water to reach Bangladesh in the dry season (November-May). In the case of Nepal, the status of the origin of glaciers is yet to be mapped clearly. This has brought about some amount of ambiguity as to the impact of warming temperatures on the three rivers. It is roughly estimated that glaciers contribute up to 10% of stream flows of the rivers of Nepal. The contribution of the glaciers to the flow of water in the rivers makes them an important aspect of this study, particularly as the perennial nature of the rivers is dependent on the security of the source region.

It is estimated that the amount of water that China receives from glaciers annually is almost equal to the amount of water that flows out to the sea from the Yellow River during the same period, that is, approximately 58 BCM. Reports suggest that about 20% of the Yangtze is glacier-fed. The extent to which glaciers contribute to the Yellow River is estimated to be relatively small, at approximately 1.3%.

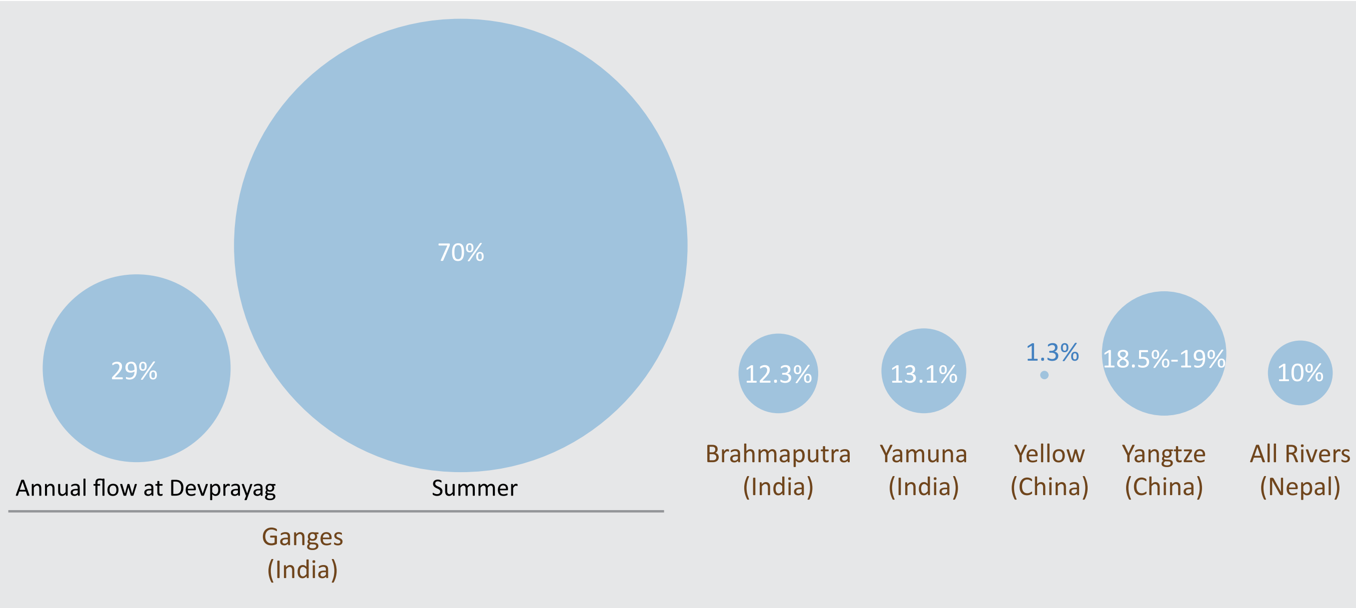
In India, the Ganges is 7% glacier-fed up to Devprayag in the upper reaches. Overall, snow and glacier melt contribute constitute about 29% of the annual flow at Devprayag. It is during the summer months (March-June), that the Ganges is most dependent on glacier melt water, with up to 70% of the river fed through the glaciers during this time.

The Yamuna, on the other hand, is fed by a cluster of 52 glaciers covering a total area of 144.47 km^2, with a total volume of 12.21 BCM. The river is dependent on the glaciers for about 13.1% of its total flow. There have been few studies conducted to assess the contribution of glaciers to the flow of the Brahmaputra River – although it is estimated that up to 12.3% of the Brahmaputra is contributed by glaciers.

Impact of Climate Change on Glaciers

The rise in global mean temperatures has resulted in the acceleration of glacier melt, a fact reinforced by the governments of China, Nepal and India, as well as by studies carried out by the IPCC and ICIMOD. The general consensus is that there will be an increased incidence of glacier melt and snow cover melt in the future, which will mean an initial increase in flow in the Himalayan glacier-fed rivers. However, over a period of time, there could be a reduction in water availability during the dry season (November-April/May), particularly on the rivers dependent on glacier melt water for water flow. Apart from decreasing dry season flows, there is growing concern that several of the glaciers could eventually disappear, if climate change continues to remain unchecked.

Percentage of the River Runoff dependent on Glacier Melt



The impact of these melting glaciers will be most detrimental to India and China in the next few years. According to China's Initial National Communication to the UN Framework Convention on Climate Change, glaciers in Western China could decrease overall by 27% by 2050. Some regions could be worse affected than others. Due to reduced glacial flows and rising temperatures, the per capita water availability is expected to reduce by 20-40% by 2080. Of all the Himalayan glaciers, the ones that are melting at the most drastic rate form the origin of the Yellow River. 17% of the glaciers at the source of the Yellow River have been lost in the past 30 years alone.

Glaciers at the source of the Yangtze, which is very close to the source of the Yellow River, are also decreasing at a fast rate. Over the past 50 years, the average annual temperature at the source region of the Yangtze River has increased by as much as 2°C; over the next 50 years, the temperature is expected to increase at an even greater rate, affecting the ecology of the area and eventually reducing the glacial melt flowing into the river. Glacial runoff is expected to increase across the Tibetan plateau by 2050. The 'Yangtze Conservation and Development Report 2009' by the China Academy of Science estimates that by 2030, the glacial area at the source of Yangtze will be reduced by 6.9% from the level recorded in 1970. The glaciated area in the Yangtze River source region has decreased from 899.13 km² in 1986 to 884 km² in 2000, or a reduction of 14.91 km² in 15 years. This area is being especially affected by global warming, retreating glaciers, melting permafrost and dying vegetation.

The Himalayan region, which is known as the "Water Tower of Asia", supports 9575 glaciers in India and covers an area of approximately 18,000 km² and a total volume of 1300 km³. Over the past few decades, the Gangotri glacier, the principal source of the Ganges, has been retreating at a rate of between 22 and 27 m/year. As with the glaciers that feed the Ganges River, the Yamuna's source of water is depleting, as the glaciers melt. However, since the rate of retreat is not available, it is not possible to determine how soon and to what extent the river will be affected.

The glaciers supplying water to the Brahmaputra River are also receding. The most significant probability of glacial melt on the Brahmaputra is on the Chinese side. It goes on decreasing from the east to the west, being lowest at Samsang, near the source of the Yarlong Tsangpo. Over the century, the flow in this area may reduce by 20-70%, depending closely on the exact increase in temperature. By the time the river enters India, the reduction is marginal around 10-30% in Singing in Arunachal Pradesh, very close to the Great Bend and the India-China border. However, when the effects of temperature are coupled with 15% less precipitation, the river flow may reduce by 30% by 2050 and 60% by 2100 at Singing.

There is disagreement among scientists about the impact of climate change on glaciers. The Government of India and the IPCC differ over their views on the rate at which the glaciers are melting and by when they will disappear. The official government stance subscribes to the belief that the IPCC assessment is 'alarmist'. The Government of India, which acknowledges that the glaciers are shrinking in volume and are constantly showing a retreating front, believes that they have not yet exhibited any abnormal annual retreat. In its 4th assessment report, the IPCC estimated the area covered by glaciers at 500,000 sq. kilometres, and speculated that this would reduce to 100,000 sq. kilometres some where around 2035. It was discovered later on that these 500,000 sq. kilometres represented glacier area in the entire world outside the polar region and that the IPCC had made a mistake in its 4th assessment report. Also, the year by when glaciers would largely deplete was actually 2350 and not 2035. Thus, IPCC was 300 years wide off the mark. However, in the history of the planet, 300 years is still a short period of time. For glaciers that have been there for thousands of years, melting in 300 or even 600 years' time would be disastrous. Research by ICIMOD reveals that the total area of the Himalayan glaciers is around 100,000 square kilometres. The ICIMOD does not share the IPCC alarmist view of the rate of glacier melting at a fast rate but it does share the view that some glaciers are indeed melting and risk depletion over the next few centuries. The main problem is the lack of data. There are relatively few meteorological stations in Tibet and other parts of the Himalayan region that are designed to track glaciers. This means that the debate on glaciers is predominantly based on assumptions and old data. While the Governments of China, Nepal and India have initiated steps to establish scientific and expert level bodies to study the glaciers and the impact of global warming, there is still considerable work yet to be done.

Under the circumstances, it would be safe to assume that glaciers would melt to a certain degree in the first half of this century and risk depletion over the next few centuries, though we do not have precise milestones. We can use the Chinese and Indian government estimates, presented by their official Climate Change Commissions and environmental bodies as approximate indicators.

Climate Change and the Himalayan Rivers

The Yellow River has been affected by global warming at its source region, with the area experiencing warmer and drier climate. About 55.6% of the Yellow River's flow is provided by the area just above Lanzhou. Lanzhou lost water at an average annual rate of 13% during the 1980s. In 2002, the water flow above Lanzhou dropped by 46% when compared with the annual volume of the water in the river.

According to a study carried out by China's Ministry of Land and Resources in collaboration with the Beijing Normal University, the stream flow of the Yellow River is likely to reduce even further, by 4.8% in 2020 and 6.4% in 2050 while annual precipitation will increase by 3.47% by 2020, and 6.42% by 2050. Glacial runoff is expected to increase by 5%-30% across the plateau; with some areas experiencing an increase as high as 50%. Eventually however, the Yellow River is expected to become seasonal in nature.

Permafrost in the Tibetan plateau is also likely to decrease between 5% -15%. This could also lead to an increase in soil temperatures over the next 30-50 years, which could then result in landslides and alterations to the ecology. More specifically, desertification in the Tibetan plateau could be a possible outcome of all this. These interdependent factors like rising temperatures, melting permafrost and drying vegetation at the source region could take a toll on the main rivers of China. This has also affected the hydrology, flow and ecosystems of these rivers downstream.

The largest impact of the retreating Gangotri glacier will be felt in the upper reaches of the Ganges River, where melt water contributes significantly to river flow. However, the impact of glacier melt towards the middle and lower reaches is expected to be negligible, as the major determinant of river flow within this sector is rainfall. At Haridwar, for example, the river is

Map of Meteorological Stations in Tibet and China's Southwest Province.

Source: Xi Chen, "Precipitation and temperature trend analyses in the last five decades for the Southwest China" presentation at Second International Workshop on Himalayan River Basins hosted by SFG - BIPSS at Dhaka on January 16, 2010

70% monsoon-fed. However, many of the river's major tributaries, like the Yamuna, Alaknanda and Ghaghra are glacier-fed. In addition, it is important to note that the biggest impact of the retreating glaciers will be felt during the dry season (October-May/June).

A World Wildlife Fund (WWF) report states that as temperatures rise and the Gangotri glacier continues to melt, there will be an initial increase of approximately 20% to the flow of the Ganges River. However, the flow of the river is eventually expected to decrease by 20%, with lesser glacier melt water being carried into the river system. The impact is likely to be detrimental to the region, with increasing demand for water at the household, industrial and agricultural level, coinciding with reduced river flows during the dry period.

Similar to the Ganges, the retreat of glaciers at the source region of the Yamuna is also likely to impact the flow of the river during the lean season (October-April/May). However, as the glaciers have not been extensively mapped, and the rate of retreat is yet to be determined, precise predictions about the quantum of river flow affected will be difficult to ascertain. To a certain extent, analysis into the future of the Yamuna River can be drawn from the Ganges, given that both rivers are experiencing glacial retreat at the source region. In the short term, there will be an increased flow in the Yamuna, a trend which will eventually break, as the river becomes seasonal in nature. Moreover, there is possibility of an increased threat of flooding as the melting glaciers send surplus water downstream, to an area which has historically been poor at flood management. In addition, given that the Yamuna is one of the major tributaries of the Ganges and that the average runoff of the Yamuna is 61% of the total runoff at Allahabad (the confluence point with the Ganges), a reduction in water flow due to a retreating Yamunotri glacier is likely to have a major impact on water flow downstream.

Studies on the impact of climate change on the Brahmaputra River predict different reactions to climate change at different sections of the river. In addition, it is important to note that most of the studies that have been conducted on the Brahmaputra, measure the impact of climate change in relation to annual flow of the river. Therefore, the findings can be misleading as the Brahmaputra has a high variability in seasonal flows.

At the point where the Brahmaputra enters India, the river is expected to reach a 30% reduction in annual flow by 2050 and a 60% reduction by 2100 because of climate change factors – in particular rising temperatures in the Tibetan plateau and predictions of 15% less precipitation. In the mid to lower portions, as the river flows through Assam and south from Pandu into Bangladesh, studies predict that the annual flow will increase up to the year 2100. Meanwhile, studies conducted by Klaus Seidel and Jaroslav Martinec use satellite imagery of the snow cover to predict that the yearly runoff by 2030 will be 25% higher than that in 1995. This would be primarily due to extreme precipitation events from June to September. The studies also indicate that increasing peak flows will largely contribute to the increase in the projected annual flow. In addition, research by the Hadley Centre for Climate Change and Research indicates that once the snow has melted, the average annual runoff of the Brahmaputra will decline by approximately 14%.

According to the Bangladesh Centre for Advanced Studies, peak discharge in Nepal is expected to shift from August to July due to the melting of snow cover on mountains sooner than anticipated. In addition, 20% of the present glaciated area above the 5000 meter altitude is likely to be a snow and glacier-free area with an increase in air temperature by 1°C. Similarly, a 3°C and 4°C rise in temperature could result in a loss of 58% and 70% of snow and glaciated areas respectively, although this temperature rise is likely to occur close to the end of the century. This development would also accelerate the forming of glacial lakes that are susceptible to bursting. According to the Bangladesh Centre for Advanced Studies, 'hydrologists in Nepal agree that runoff will initially increase as glaciers melt and later decrease as the de-glaciation progresses. In addition, decreased winter snowfall will result in less precipitation being stored on the glaciers, which would in turn decrease the spring and summer runoff. Winter runoff, however, is expected to increase due to the earlier snowmelt and a greater proportion of precipitation coming in as rain. This inter-annual variability will affect the operating efficiency of plans.'

Painting a concrete picture about the state of the Himalayan sub-regional rivers by 2050, with specific regard to their source glaciers, is a difficult prospect. Taking into account the present trends in glacial melt and predicted rise in temperatures, together with scientists' predictions of changed rainfall patterns, one can arrive at a conclusion that the Himalayan Rivers, in particular the large ones, will experience larger flows at first, due to a high incidence of glacier melt. However, this is more likely to be a short-term impact, and will be tempered by a steady decline of annual flow and more importantly, dry season flow in the long run. Unless climate change is dealt with and kept in check over the next few decades, there is a possibility that many of the glaciers that feed these rivers will completely disappear in a few centuries; permanently damaging the rivers and adversely affecting the populations that depend on them. Since many of the rivers are trans-boundary, the impact of the variable flows extends beyond just one country. Any reduction in the Ganges or the Brahmaputra will have an impact not just on India, but also on Bangladesh. Similarly, the three major rivers of Nepal flow directly into the Ganges and, any alteration to their flow will impact the Ganges in India, and subsequently the Ganges in Bangladesh.

The glaciers are closely linked to the rivers they supply water to. Likewise, the state of the rivers is also dependent on rainfall patterns and the monsoon season in each of the countries. To gain an overall understanding of the future scenario for the rivers, it is important to study the situation in its entirety, taking into account changing rainfall patterns as well as the impact of retreating glaciers. To this end, the paper will next discuss rainfall patterns in the future and also how rainfall influences these rivers.

Glacial Lake Outburst Floods (GLOF)

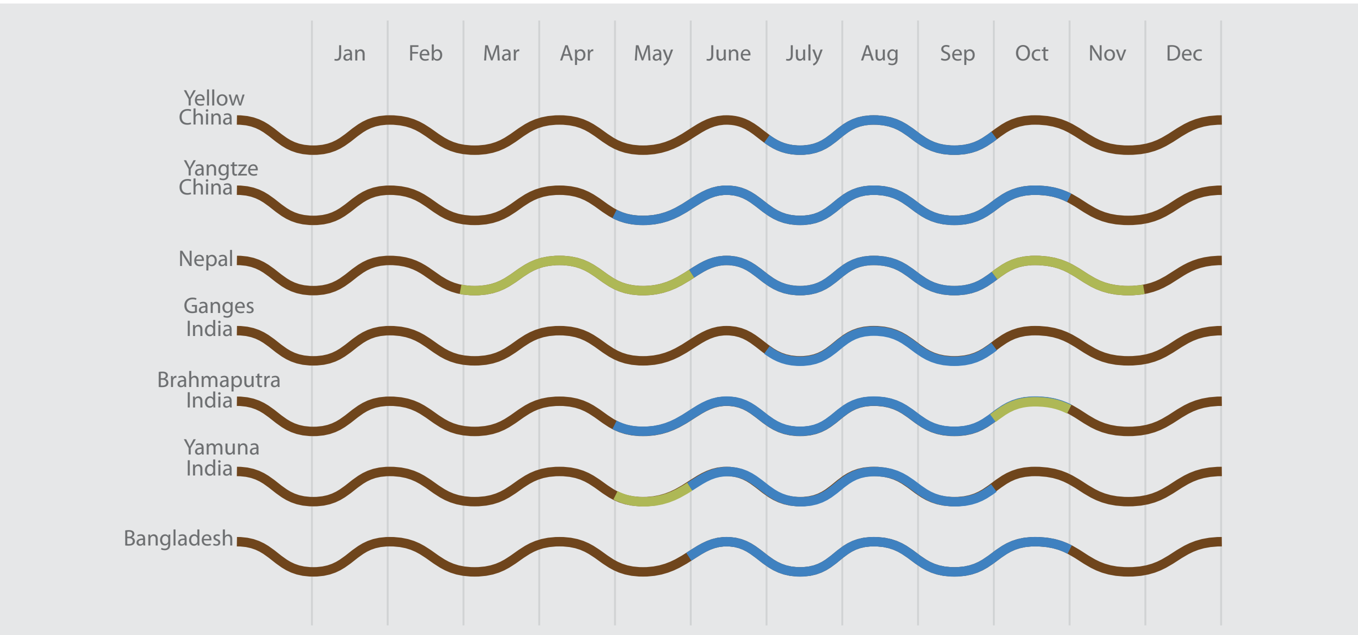
In the twentieth century, climate change has resulted in the rapid melting of glaciers, giving rise to a large number of glacial lakes. With global warming accelerating the rate at which ice and snow melts, the water level in these lakes has been rapidly increasing. At times, the lakes discharge large volumes of water and debris, resulting in floods downstream. The process due to which this occurs is commonly referred to as, 'Glacial Lake Outburst Floods.'

The melting of glaciers in the Himalayas as a result of climate change has resulted in the formation of large and rapidly swelling glacial lakes. Estimates suggest that approximately 2300 glaciers in Nepal's Himalayan region contain growing glacial lakes, which threaten the lives of people living downstream. The Arun-Koshi River basin for instance, has 229 glacial lakes, 24 of which are potentially dangerous. Similarly, of the 45 glacier lakes in the Sun-Koshi basin, 10 are considered to be potentially dangerous. The Thulagi glacier, located in the Upper Marsyangdi River basin (one of the main tributaries of the Gandaki River) is also confronted by the prospect of a GLOF occurrence. The primary cause for concern is that the number and size of these glacial lakes is increasing. While it is difficult to assess just how many and how soon these lakes could burst, it is definite that such an eventuality will be accompanied by flash floods which cause enormous damage to life and property. At present, the Tsho Rolpa and the Imja glacial lakes are among the most dangerous in Nepal. One such lake, the Dig Tsho, burst in Khumbu, Nepal in 1985, killing at least 20 people and causing great damage to property and agricultural land. The past 30 years have seen 7 major GLOF events, a number which could rise if adequate precautionary measures are not implemented. It is essential that glacial lakes are regularly monitored and mapped to minimise future losses.

Seasonal Variations

While glaciers are the determining factor in the perennial nature of the Himalayan River basins, it is rainfall that contributes a greater quantity of water to these rivers in terms of sheer volume. Seasons characterized by weak monsoons usually result in low river flows, while excessive rain often results in flooding. Bangladesh in particular, is extremely dependent on rainfall, as the Himalayan Rivers are fed almost entirely by rain by the time they flow into the country. Any alteration to the monsoon is acutely felt by all the four countries under study. The effects of climate change on rainfall have been already apparent in the first decade of the 21st century, leading to pronounced differences to the regular flow of the Himalayan Rivers.

Seasons of Himalayan Sub-region



* While all river basins receive pre and post monsoon rainfall, it is not as significant as in the case of Nepal and India. Hence, it is not shown in the table separately.

The Himalayan River basins usually experience the monsoon between June and September/October. The volume of river flow during monsoons is several times higher than during the rest of the year, with each of the Himalayan Rivers experiencing 60-85% of their annual runoff during this time.

The monsoons in China, which usually occur from June to September/October, are also associated with flooding, with approximately 70% of annual rainfall concentrated within these four months. In China, the Yellow and Yangtze River basins get 360 BCM and 1970 BCM of rainfall every year. Flood season in the Yellow basin is from July to September, during which months the average runoff is about 60% of the annual runoff. The Yangtze basin often experiences flooding between May to October, during which months the river experiences approximately 64% of its annual runoff. The dry season (November to April) in the Yangtze River basin accounts for approximately 29% of the total annual runoff.

Rainfall accounts for approximately 250 BCM of water in Nepal annually. The country's monsoon begins in June and ends in September, although there are occurrences of pre- and post-monsoon showers. The wet season accounts for approximately 75% of the annual rainfall in Nepal. Heavy incessant rains and periods of dry spells are not uncommon during these months. The amount of precipitation varies considerably across the country as a result of the non-uniform rugged terrain. The winter months from December to February are relatively dry with clear skies. The period of October and November is considered as a post-monsoon season and a transition from summer to winter. The Saptakoshi's monsoon runoff is 63% of its total annual runoff, the Gandaki's monsoon runoff is 67% of its total annual runoff and the Karnali's monsoon runoff is also about 63% of its total annual runoff.

The Indian sub-continent experiences a vast discrepancy in water availability. The country's dependence on the summer monsoons means that as one proceeds from the humid areas of the north-east to the arid west and central parts of the country, there are significant differences in water balances. India experiences two monsoons – the southwest or 'summer monsoon' (June to September) and the north-east or 'winter monsoon' (October and November), of which the former is more important on account of the rainfall potential. The south-west monsoon originates in the sub-tropical high pressure zones of the southern hemisphere and travels northwards to hit the southern-most part of India by the end of May. The monsoon then spreads into the Arabian Sea and Bay of Bengal branch to make its way across the entire stretch of the country, before finally reaching Punjab by July.

The Indian monsoon experiences varied patterns, with early withdrawals, late onsets and sudden breaks in rainfall – leading to seasonal and regional variations in the distribution of rainfall. The discrepancies in monsoon patterns exacerbates the situation in western India, which is considered an arid area, joined by an almost continuous semi-arid belt extending from Punjab in the north to the southern tip of the peninsula. In addition, India's Western and Central areas receive a higher incidence of sporadic but intense rainfall, leading to increased surface runoff. However, the ability to tap and utilize the increased runoff has not been achieved, owing primarily to the lack of facilities for storage of water.

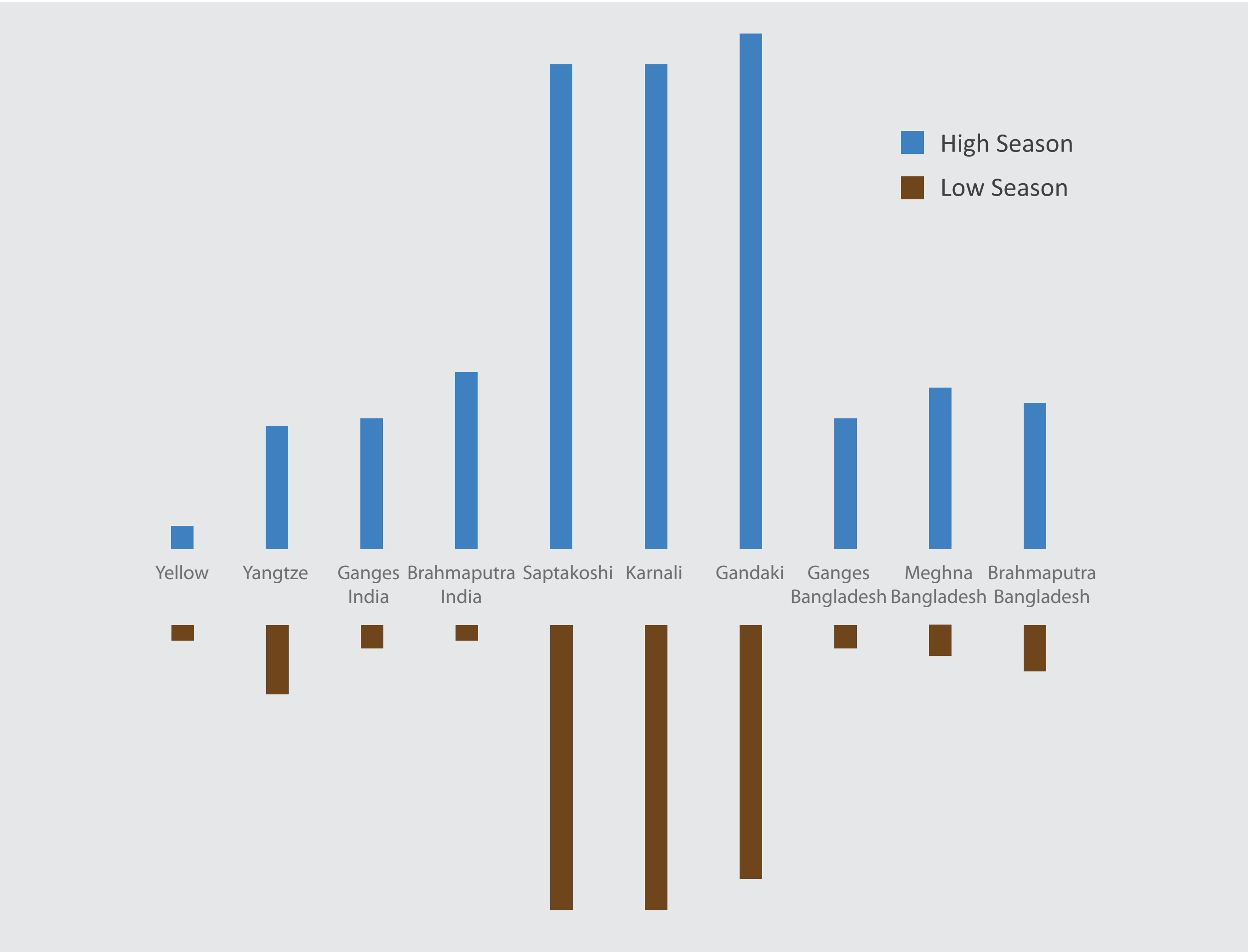
In India, the Ganges Basin receives over 1100 BCM of rainfall annually, the Yamuna basin approximately 380 BCM and, the Brahmaputra between 580 to 2320 BCM of rainfall annually. The seasonal variation of the Ganges is extremely high, with the months from June/July to September period experiencing roughly 85% of the total annual runoff of the river. At Haridwar, more than 70% of the flow is due to rainfall. In addition, as the river flows downstream it is joined by more tributaries and enters regions with heavier rainfall, thus resulting in a marked increase in volume. The Himalayan glaciers contribute to the river flow from April to June, while the monsoon season, from July to September, contributes to the river's flow by way of heavy rainfall.

Similarly, the Yamuna, which receives almost 90% of its runoff from rainwater, experiences significant seasonal variations in flow. Despite receiving a constant flow of water from its source glaciers all year round, the runoff of the Yamuna increases significantly its monsoon months (June/July to September). The seasonal variation often results in flooding at the downstream of the river because the tributaries of the Yamuna often carry large volumes of water.

In India, the Brahmaputra River experiences relatively substantial seasonal variation flows, with the average ratio between high and low season fluctuating between as much as 12:1. The variation in the upper reaches, near Singing, is approximately 1:5, which increases to 1:12 in Arunachal Pradesh and further increases in the plains of Assam. During the dry period the river relies on glacial melt, although there is a marked increase in flow during the wet months (May to September/October).

In Bangladesh, the monsoon months are from June to October. The rainfall in September, October and November is less reliable, but is occasionally very heavy and usually associated with violent tropical cyclones that develop over the Bay of Bengal. More than 80% of the total rainfall occurs during June to October. In the Ganges basin, the average rainfall is about 73 BCM. The Ganges River has an extremely high seasonal variation. The Brahmaputra basin receives about 113 BCM of rainfall. As with the Ganges, the seasonal variation of the Brahmaputra is also high with the months of June to October receiving almost 76% of the total annual runoff of the Brahmaputra. The rate of the Meghna basin's monsoon rainfall is almost twice that of the national average. From the months of June to October, the Meghna River receives almost 84% of its total annual flow.

Ratio of Seasonal Variation of Himalayan Rivers



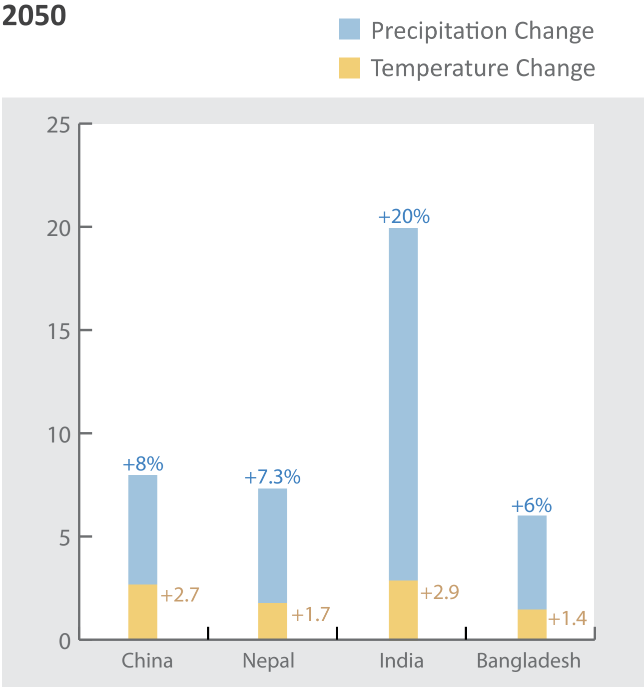
Impact of Climate Change on Rainfall

As increasing temperatures across Asia and Greenhouse Gases (GHGs) have a negative impact on the environment, scientists predict that there will be marked changes to precipitation patterns in the Himalayan sub-region. According to the IPCC Report on Climate Change and Water, '...a greater increase is expected in extreme precipitation, as compared to the mean.' The same report states that it is very likely that extreme precipitation events will increase in frequency over the coming years. This alteration of monsoon conditions will lead to a higher incidence of flooding and droughts. China, Nepal, India and Bangladesh are experiencing an increased incidence of extreme weather events, while the monsoons are becoming increasingly irregular and unreliable.

Country-specific climate change predictions state that India could experience a temperature increase of between 2.2 and 3.2°C by 2050. An increase of 2.9°C increase in temperatures could result in a 20% increase in precipitation, thus multiplying the risk of flooding, particularly given the high population densities and lack of appropriate infrastructure. In China, an increase of 1.9°C by 2030 is expected to result in a precipitation increase of 1%, while an increase by 2.7°C by 2050 could produce a precipitation increase of 8%. Although the percentage increase in precipitation is not as much as in India, it is still relatively high and can be expected to have an impact on the economic and social fabric of the country. Meanwhile, Bangladesh will experience an increase in annual precipitation of 5% for a temperature increase of 1°C by 2030 and 6% increase for a 1.4°C in temperature by 2050. Given the country's historical propensity to floods and its vulnerability to rising sea-levels, an increase in precipitation could be catastrophic for Bangladesh. Nepal is expected to face a 1.2°C increase in temperature by 2030, resulting in a 5% increase in precipitation. In addition, estimates suggest that a 1.7°C increase by 2050 will result in 7.3% more precipitation.

China, Nepal, India and Bangladesh are already experiencing alterations to the monsoon patterns, which have become increasingly erratic over the years. Rain-fed days have reduced in frequency, although they have become more intense. However, the increased intensity does not equate to an increase in volume, with an overall drop evident in China, Nepal and India. It should be noted, that despite the drop in volume, there has been and will continue to be an increase in flash floods, owing primarily to the fact that rainfall duration is compressed and more intense. The river basins of the Himalayan sub-region have a propensity to flood, meaning that shorter and more intense monsoons could have a devastating impact on people residing within the basins' areas. In addition, the unpredictability surrounding the monsoon season has meant that rainfall often arrives later and withdraws ahead of time, although Bangladesh has proven to be an exception, experiencing an increase in rainfall. However, as noted earlier, if predictions of an increase in temperature prove to be true, there is a possibility that the Himalayan sub-region could experience more rainfall concentrated in a few days.

Temperature Increase and Rainfall Patterns by 2050



Impact of Rainfall on the Himalayan Rivers

According to the IPCC, mean annual rainfall to the north-east and north of China has shown a decreasing trend, while the mean annual rainfall along the south-east coast has increased. The Yangtze basin experienced an increasing trend in the average annual rainfall from

1991-2005 in comparison with corresponding data from 1961-1990. However, 2006-2007 was marked by a drop in average annual rainfall by 10.3% and 6.9% respectively, owing primarily to an increased incidence of extreme weather events, like the drought in Sichuan province. The Yangtze Conservation and Development Report states that the basin will experience a noticeable reduction in rainfall before 2030, with the duration of rainfall becoming shorter and more intense, leading to flooding along the river. Meanwhile, variable precipitation has increased the frequency of droughts to the north of China and flooding to the south. Over the next 40-50 years, precipitation is projected to increase, with the maximum change expected in south-east China. In addition, the frequency and intensity of extreme weather events in China may increase over the next 50 years, if the trend of the last 50 years continues.

In comparison, the Yellow River is likely to experience a reduction in stream flow even as annual precipitation in the river basin is expected to increase by 3.47% by 2020, 6.42% by 2050, and 8.67% by 2080. This can be attributed to climate change and the increased likelihood of evapo-transpiration. In addition, although annual precipitation is predicted to increase, it will be more intense and fall within a shorter span of time, resulting in a greater discharge of water but represented by an overall reduction in stream flow over the entire period. The high sediment load of the Yellow River makes it vulnerable to flooding and has resulted in it being called 'China's Sorrow' – a title which it is unlikely to shed, as climate change is expected to increase the incidence of flooding.

There is a possibility of Western China being able to see a temperature rise of between 1.0-2.5°C by 2050 – of which the largest increase could be experienced in the northern areas of the Tibetan plateau. Meanwhile, rainfall in western China is expected to increase by about 5% to 25% relative to 1990 levels. By 2050 extreme weather events played out through the occurrences of typhoons, floods and droughts will affect an increasing number of people across China, while glacial lake outbursts will increase in and around Tibet. In addition, China will experience increasing temperatures, while droughts to the north of the country and flooding to the south will occur more frequently. Rainfall to the north and north-east of the country will gradually decrease, while precipitation to the west, south and south-east increases.

Nepal's monsoon season is becoming increasingly characterized by its late arrivals and erratic behaviour. As a result, the country is challenged by the intriguing phenomenon of 'too much water, too little water' – that is seen as, flooding in the monsoons and drought in the dry season. The monsoons, which are inevitably truncated due to climate change, witness excessive precipitation, which results in instances of flooding, landslides and the inundation of agricultural land. Meanwhile, the dry season (December-February) often experiences droughts.

The Saptakoshi River experiences marked variations in its river flows. This large discrepancy, and the propensity of the river to flood as it flows from Nepal to India, has earned the river the unfortunate name 'Sorrow of Bihar'. In August 2008, the river broke its embankments, resulting in the displacement of tens of thousands of people. Flooding in Nepal has now become increasingly frequent, a problem exacerbated by the Gandaki and Karnali Rivers' tendency to flood. In addition, as all three rivers are trans-boundary and eventually flow into India, there is a high risk posed to people living downstream.

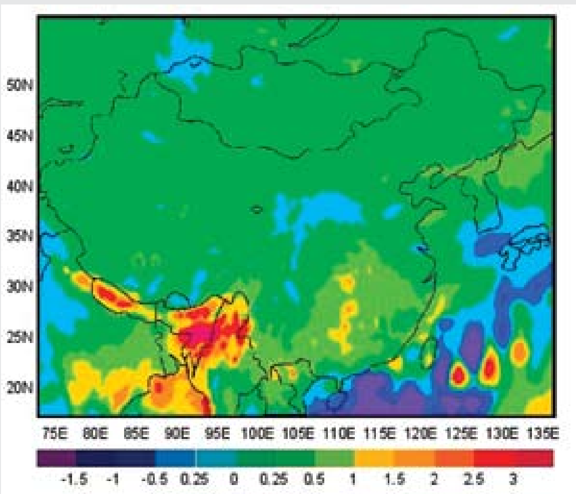
The vast landmass of India is defined by marked variations in precipitation, with the north-east of the country receiving as much as 67 times the mean annual rainfall of the water-scarce areas of western Rajasthan. Most of the country is influenced by the south-west monsoon, which falls between June and September. India's monsoon has historically been clearly marked and reliable, with the Himalayan Rivers estimated to receive as much as 80% of their total annual flow through rainwater. However, as the impact of climate change becomes increasingly prevalent, the Indian monsoon is expected to alter its pattern, becoming more irregular and arriving with varied intensity.

As weather patterns change, the Ganges basin too will receive less days of rainfall – although the intensity is expected to be greater. This, coupled with the retreating glaciers, is likely to make the Ganges River seasonal in nature. In addition, higher intensity rainfall will increase the likelihood of flash floods as surface runoff increases, making the river more susceptible to flooding. It is estimated that approximately 20 million hectares of land in the Ganges River basin is vulnerable to flooding. In addition, heavy monsoon rainfall coupled with a low lying topography results in large areas of land being inundated, particularly in Uttar Pradesh. During the monsoons, it is primarily the Ghaghra, Gandak, Kosi and Sone Rivers that flood. The main problem of flooding along the Ganges occurs in Uttar Pradesh, below the confluence of the Yamuna and the Ganges at Allahabad. As with the Ganges River, the Yamuna too flows through a relatively flat topographical expanse, which means that the areas surrounding the river and its tributaries are quite susceptible to flooding. The Yamuna River has often been flooded near Mathura, Agra and New Delhi, with rising water crossing the flood danger mark on numerous occasions.

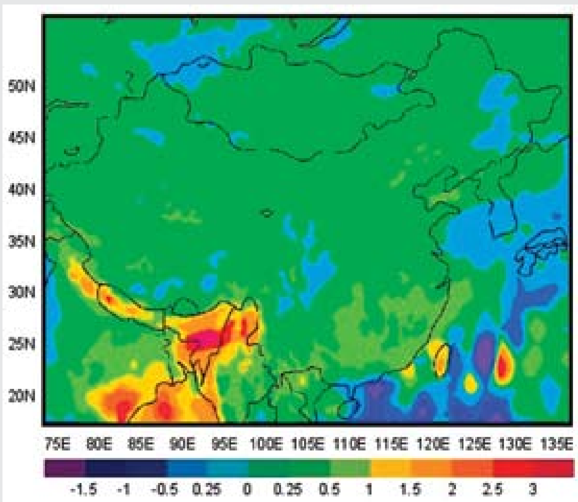
The Brahmaputra basin receives abundant rainfall and has historically had to contend with issues of flooding as opposed to droughts. The high discrepancy in rainfall results in significant variations to the average annual runoff of the river between wet and dry seasonal flows. Research into the impact of climate change on the rainfall pattern of the basin is inconclusive, with one school of thought suggesting that the south-west monsoon will increase in intensity, causing a higher incidence of flooding. Meanwhile, research by the Hadley Centre suggests that the average flow of the Brahmaputra River will decrease as the glaciers melt and as rainfall becomes increasingly unpredictable. Some climate change studies have argued that the south-east monsoon will increase in intensity causing a higher incidence of flooding in the low land plains of Assam. Interestingly, the 2009 monsoon season was marked by unusually low levels of rainfall, with several parts of the northeast receiving deficit rain.

One of the major issues confronting the Brahmaputra River is that of flooding, with approximately 40% of the land susceptible. Moreover, the river has historically suffered frequent and catastrophic flooding on account of the unique geo-environmental setting of the basin vis-à-vis the eastern Himalayas. There are also the strong monsoons, the weak geological formations of the area, massive deforestation, high population growth and the sheer fact of being in a highly seismic zone that the area has to contend with. In addition, the high intensity rainfall which occurs for the better part of the year means that the region receives little respite and, is often threatened by flash floods. Failure to reduce GHG emissions from 2009 levels could result

Simulated average change in rainfall (mm/day) for 2071–2079 under SRES A2 scenarios from PRECIS relative to baseline (1961–1990)



Simulated average change in rainfall (mm/day) for 2071–2079 under SRES B2 scenarios from PRECIS relative to baseline (1961–1990)



Source: Chandan Mahanta, "Integrated Basin Development and Management for Himalayan Sub-regional Cooperation in Water Security" presentation at Second International Workshop on Himalayan River Basins hosted by SFG - BIPSS at Dhaka on January 16, 2010

Too Much Water, Too Little Water

At first glance, Nepal's per capita water availability of approximately 9122 cubic meters, suggests that the country does not face a water crisis, as its Himalayan sub-regional neighbours - China, India and Bangladesh. However, this is not true. The monsoon season in Nepal is defined by several incidents of flooding, while almost every dry season suffers severe droughts. The vast gap in water resources between the wet and dry season, has left the country with the ominous distinction of having 'too much water, too little water'. People living in the country's hilly areas face an acute shortage of the water, having to survive on less than 5 litres of water per capita per day. Meanwhile, more than a third of the population has difficulty in obtaining water. Yet, despite the dry spells, annual monsoons continue to bring widespread flooding and landslides. The short time-span over which the monsoons occur, is highlighted by the fact that more than 80% of yearly rain falls between the months of June and September. In 2006, southern Nepal saw a 5-month long drought followed by heavy floods that swept away many villages. Unfortunately, the changing weather patterns, erratic monsoons and rising temperatures is likely to continue 'too much water, too little water' effect.

in an increase in mean wet season discharge for the Ganges and Brahmaputra by up to 15-25%, by the end of the 21st century. As a result, river discharge could increase and make the surrounding areas more susceptible to flooding.

The duration and peak flow of the Ganges, Brahmaputra and Meghna rivers in Bangladesh are highly dependent on the south-west monsoons. There is likely to be an increased precipitation from June to August, in comparison with the estimated average annual precipitation for the entire country. In addition, the higher levels of water passing through these systems as a result of monsoon variations, is likely to result in an excessive runoff in all three rivers.

Research by the Bangladesh Environment Network has shown that a 2°C increase in temperature will lead to 4.6% increase in precipitation over the Ganges River basin. In addition, peak discharge at Hardinge Bridge is also expected to increase to approximately 2259 BCM. Increased summer precipitation in the future is likely to result in a higher level of fresh water discharge in major distributaries, such as the Gorai, Madhumati and Bhairab.

Like the Ganges, the Brahmaputra River in Bangladesh also demonstrates a strong correlation between precipitation levels and river discharge. The Bangladesh Environment Network states that a 2°C increase in temperature will lead to 7.2% increase in precipitation over the Brahmaputra river basin and shows an increase in the peak discharge at Bahadurabad to approximately 2850 BCM. There are estimates that there will be an initial 10% increase in the extreme flooding in the Brahmaputra River. However, by 2050 the average annual runoff in the Brahmaputra River could decline by 14%. This is primarily attributed to predictions of the Himalayan glaciers receding, thus removing the component of a permanent flow of water. In addition, the basin is also likely to experience lower levels of precipitation in conjunction with higher levels of evaporation.

Annual and Seasonal Trends in South West China

Significant Increase ▲
Significant Decrease ▼
No significant increasing or Decreasing Trend ●

Mean Air Temperatures | **Mean Precipitation**

Source: Xi Chen, "Precipitation and temperature trend analyses in the last five decades for the Southwest China" presentation at Second International Workshop on Himalayan River Basins hosted by SFG - BIPSS at Dhaka on January 16, 2010

A 2°C temperature increase is predicted to increase precipitation in the Meghna Basin by about 10% during the monsoon season. This will lead to an increase in the runoff of the Meghna by 11% during the monsoon season. The Lower Meghna River, through which 90% of Bangladesh's river water drains into the Bay of Bengal, is likely to be affected by the 'Back Water Effect' which causes the retardation of river outflow by the rise in the level of water at the mouth of the river. Climate change is likely to worsen this effect causing increased inundation of water, resulting in more floods.

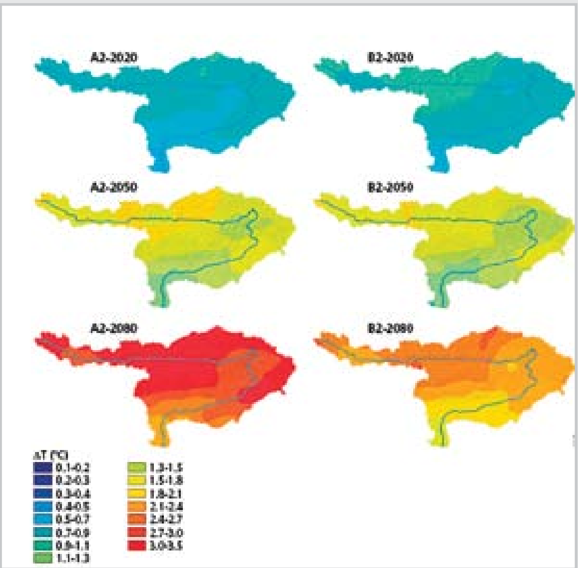
Bangladesh will experience critical changes in its climate and environment in the future. There will be an increase in the frequency and intensity of tropical cyclones. The country will experience heavier and more erratic rainfall in the Ganges-Brahmaputra-Meghna system resulting in higher river flows leading to floods, river bank erosion and increased sedimentation leading to drainage congestion. The melting of the Himalayan glaciers will lead to alternating high and low river flows. In the long run, the Brahmaputra and the Ganges are likely to become seasonal rivers. Lower and more erratic rainfall, especially in the drier north-west region, will result in increasing droughts. A rise in sea levels will lead to the submergence of coastal areas as well as saline water intrusion.

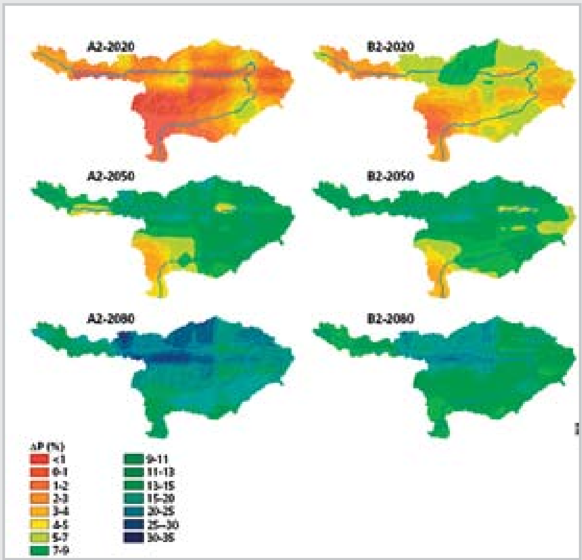
An overall increase in the temperatures is predicted to bring about an increase in net rainfall in all of the countries until 2050. It is also likely that many of the basins will have fewer and more intense rainy days. It is important to consider that an increase in rainfall might not necessarily mean an increase in river runoff, which in some cases, is on the decline. In the future, all of these rivers are likely to become more susceptible to flooding, which could have far-reaching implications beyond the issue of basin-wide water security.

Climate Change Models for the Brahmaputra Basin

Downscaled spatial temperature anomalies from the climate normal 1961-1990 based on the average of 6 GCMs for 2020, 2050 and 2080

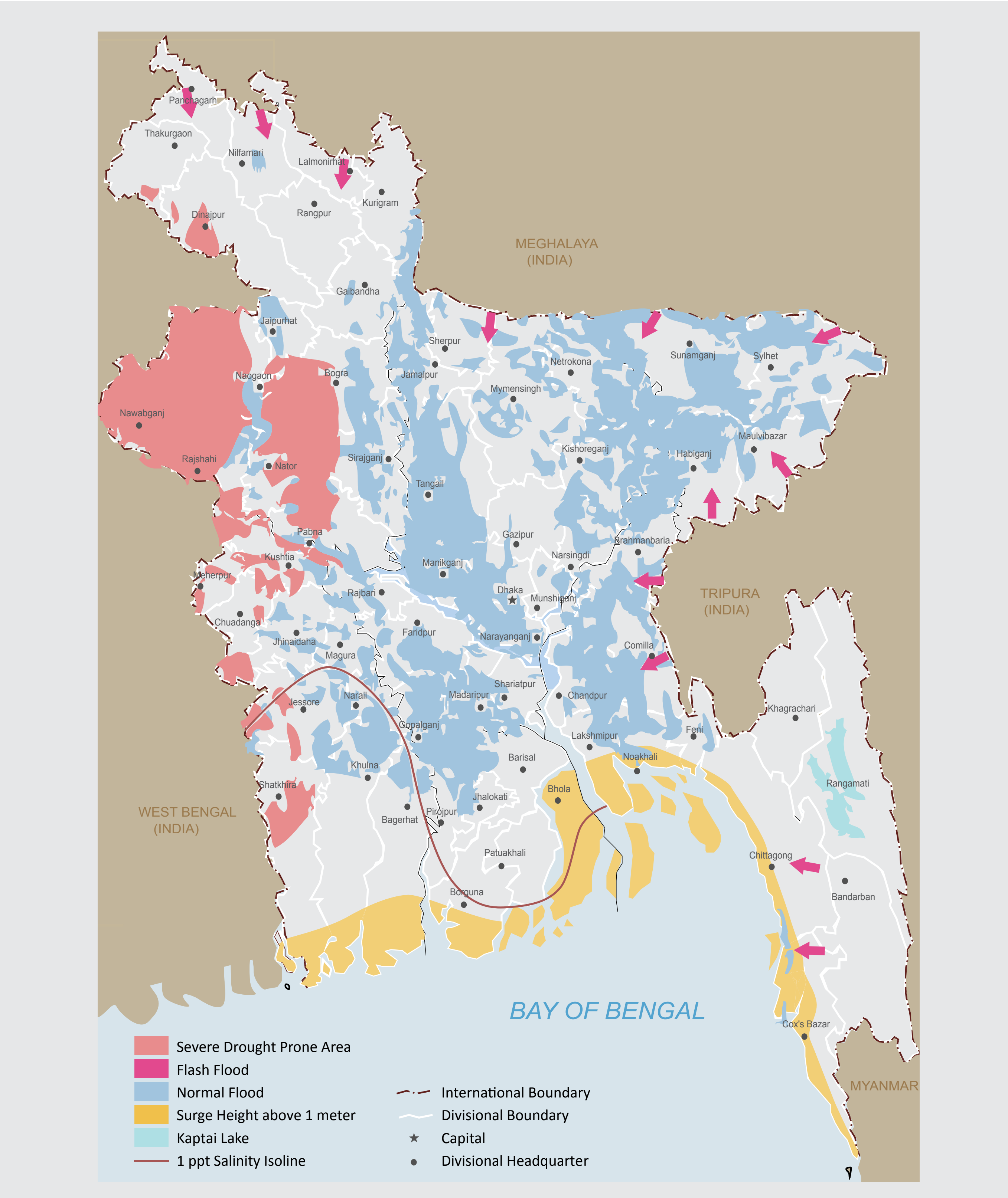
Downscaled spatial precipitation anomalies from the climate normal 1961-1990 based on the average of 6 GCMs for 2020, 2050 and 2080





Source: Chandan Mahanta, "Integrated Basin Development and Management for Himalayan Sub-regional Cooperation in Water Security" presentation at Second International Workshop on Himalayan River Basins hosted by SFG - BIPSS at Dhaka on January 16, 2010

Vulnerability of Bangladesh to Natural Hazards Associated with Climate Change.



Source: ADB, 2008

Growing Demand 03

The importance of water resources to the economic and social milieu of China, Nepal, India and Bangladesh cannot be underestimated. The industrial, agricultural and domestic sectors of all four countries are heavily dependent on a reliable and safe source of water to ensure progress and productivity. Yet, access to this resource is growing increasingly difficult, as human-induced factors and climate change threaten to affect the replenishment of surface and groundwater in these countries. As growing evidence points towards depletion of glacial melt water and more sporadic rainfall, there is concern over the state of primary water resources of all four countries with regard to its continuously depleting situation. The present water resources are very likely to fall physically and/or become economically incapable short of meeting future water demands. The challenges confronting these countries are alarming.

The water scenario for the countries in the Himalayan sub-region depends on a range of factors that could determine how well each one adapts to climate change and shifting rainfall patterns. The ability of each country to offset future challenges will depend on how well they adapt, mitigate and enforce policy changes since there are issues which are common to all, albeit to varying degrees. Historically, all four countries have largely failed in effective governance of water resources and services, which has ended in increased and unchecked environmental degradation and pollution. Groundwater resources in Bangladesh, India and China are rapidly depleting due to over-extraction as well as salinity and arsenic contamination. The groundwater resources in Nepal are in a better state due to natural replenishment and a comparatively limited usage by man and industries.

In addition, enough importance is not being given to conserving water resources in these countries. Poor funding towards water resources has resulted in a lack of infrastructure development and proper storage facilities across India, Bangladesh and Nepal. Furthermore, India's irrigation sector is grossly under-equipped due to inadequate funding towards proper channelisation of water. China is not challenged to the extent of the other three countries in this regard, having dedicated large funds towards construction projects for water resources – though many of these projects are ridden with their own set of problems. In addition, China, Nepal, India and Bangladesh have an ever-increasing demand for water at the industrial, agricultural and domestic level – a demand which will be harder to fulfill as climate patterns in the region become highly variable while populations expand at a rapid pace.

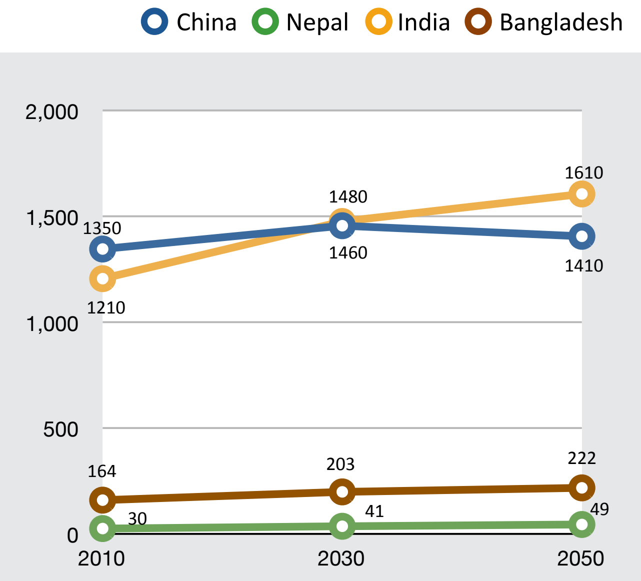
Falling River Flows

Taking into account a number of factors, including accelerated glacier melt, erratic rainfall patterns, greater evapo-transpiration and melting permafrost, it is predicted that the river runoff in the Himalayan sub-region will decrease over the first half of the 21st century. While there are estimates on how much some of the rivers will decline, others are yet to be mapped. Of the major rivers considered so far, the estimates are that by 2050, the Yellow River could decrease by about 6%, while the Brahmaputra could decline by as much as 30%. For the purpose of further examination, it is assumed that the major rivers of the Himalayan sub-region could theoretically suffer anywhere from a 5% to 30% loss in stream flows by the year 2050. Thus, 3 scenarios are expected, for a 5%, 15% and 25% reduction in annual flow, and therefore 5% reduction in dry season flow, in order to examine the impact on the low season flow of the rivers.

Population Growth

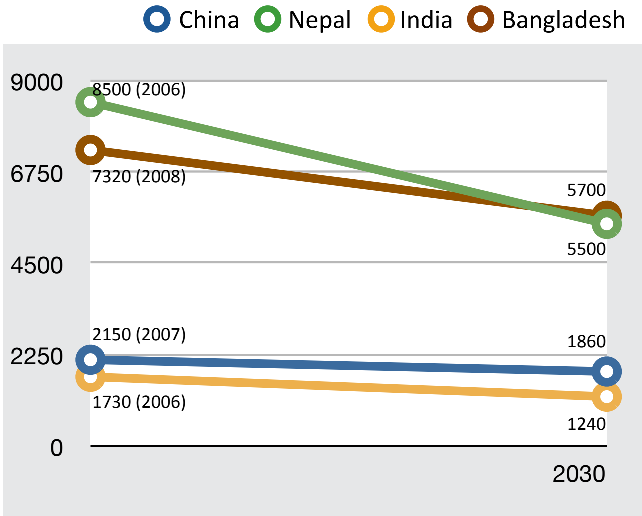
Population growth is an important determinant of whether the Himalayan countries will face physical and/or economic water scarcity in the future. As the population increases there will be an expected rise in demand for water. At the same time, on account of environmental degradation, sporadic rainfall patterns, rising temperatures, impact of humans and industrialization / urbanization, amongst others there will be increasing supply constraints.

Population Projections (in millions)

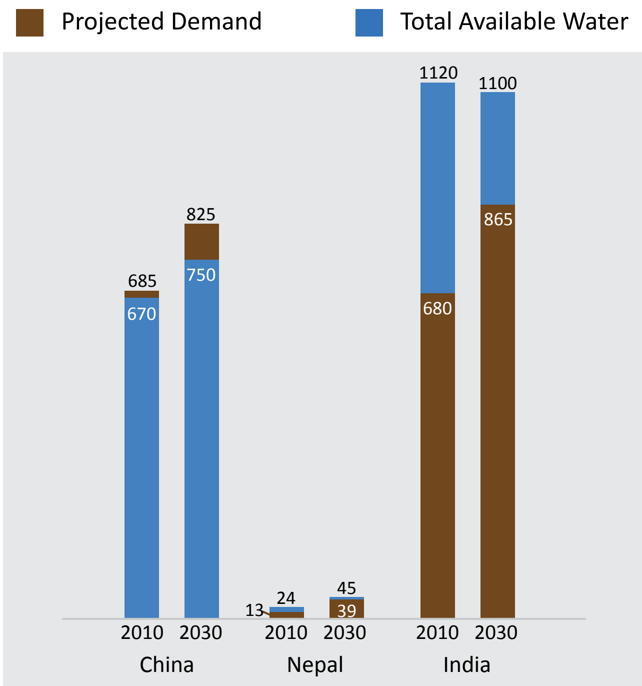


By 2030, India and China will have population somewhere between 1.45 and 1.50 billion each. However, by 2050, while India's population will increase to 1.6 billion, Chinese population will decline to 1.4 billion. Bangladesh and Nepal will also witness more than 40% increase in their population in the next 40 years. Correspondingly, per capita water availability will progressively decline in all four countries during the same time period.

Per Capita Water Availability of Water in 2030 (in cubic metres)



Water Balance in 2030 (in BCM)



The increase in demand for water will coincide with depletion of freshwater resources, over exploitation of underground resources, and fall in the real availability of water for human use due to pollution. There will be tendency to harness more water by increasing utilisation rates, though utilisation rates above 40% are considered environmentally harmful and unsustainable in the long run. Nevertheless, water balance will gradually turn negative.

China will experience an annual water deficit of 50-100

BCM in 2030 at a relatively low utilisation rate of 28% in 2030 and India's water surplus will become half to 200-260 BCM despite an unsustainable utilisation rate of 61% at that time. Nepal and Bangladesh will also see their water balance shrink. If the trend continues, China's water deficit will double by 2050 and India will turn from net surplus to net deficit by the middle of the century. This will cause significant implications for food and health security not only of the four countries but also a disruptive impact on the world food market.

China's demand for water by 2030 is expected to be driven not just by agriculture but also by industry. According to the *Charting Our Water Future* report by the Water Resources Group, approximately 32% of the demand for water in China will come from industrial requirements as well as their demand for thermal power generation, with the rest comprising of domestic needs. However, it is important to note that while China's water availability looks adequate to offset demand, the poor quality of water will render approximately 21% of the country's surface water unfit for agriculture, increasing the possibility of future food shortages.

The discrepancy in water demand projections between India and China, despite similar population levels and higher industrialization in China, can be primarily attributed to the differences in sectoral demand for water. According to the Chinese government, the country's agricultural sector is projected to consume 55.5% of water by 2030, a figure which will rise marginally to 57.5% by 2050. In comparison, International Water Management Institute projects that India's agricultural sector will consume slightly below 81% of water in 2025 and 70.6% in 2050. Industrialization in China, and a shift away from agriculture as employment opportunities rise and urbanization takes better shape, will have an impact on the water demand projections. As agriculture is typically a more water-dependent sector, and India will continue to rely heavily on agriculture for employment opportunities, the demand for water in India is expected to exceed that of China.

Himalayan Sub-region

The Ganges River basin has a total potentially utilizable water resource of 386.5 BCM and utilizable surface water of 250 BCM (2002). According to the Hydrology and Water Resources Information System for India, the groundwater potential of the basin is about 180 BCM. The utilizable groundwater is around 136.5 BCM. The Ganges basin accounts for roughly 44.19% of the country's total population (2001 Census). The total demand for water for domestic, agricultural and industrial purposes was 284 BCM in 2000. Large extraction of groundwater for domestic and irrigational purposes has worsened the water scarcity problem in the basin. The WWF report titled 'World's Top 10 Rivers at Risk' has identified the Ganges as one of the rivers facing a possibility of being severely impacted by over-extraction. The report also points out that the river is under increasing risk due to large water withdrawals for irrigation purposes. The barrages, which control all the tributaries to the Ganges in India, divert roughly 60% of the river flow for large- scale irrigation purposes. It is important to note that over-extraction of groundwater resources takes place due to the absence of adequate storage capacity of water during wet season flow. The Ganges River basin has a storage capacity of less than one-sixth of the annual flow of the river.

The total average surface water availability of the Yamuna River basin is estimated to be 90 BCM, while the total utilizable groundwater is estimated at 60 BCM, of which 85% is allocated for irrigational purposes in the agricultural sector. However, studies conducted by The Energy and Resources Institute (TERI) show that groundwater utilization has reached its limit, with little potential for irrigation in the north-west and central regions.

Unlike the Ganges and the Yamuna, the Brahmaputra River basin in India receives abundant rainfall, giving the river a high volume of water. In addition, with comparatively low population density and a lack of development, the rivers resources are yet to be fully exploited. The potentially utilizable water available in the basin is 48 BCM, which equates to 8% of the total renewable water resources. According to the draft research report published by IWMI in 2003, the Brahmaputra basin in India has a potentially utilizable groundwater resource of 25.7 BCM. Of this, 9.9 BCM is drawn for irrigation, domestic and industrial purposes. As the basin region develops, there will be more and

Map of China

Source: Xi Chen, "Precipitation and temperature trend analyses in the last five decades for the Southwest China" presentation at Second International Workshop on Himalayan River Basins hosted by SFG - BIPSS at Dhaka on January 16, 2010

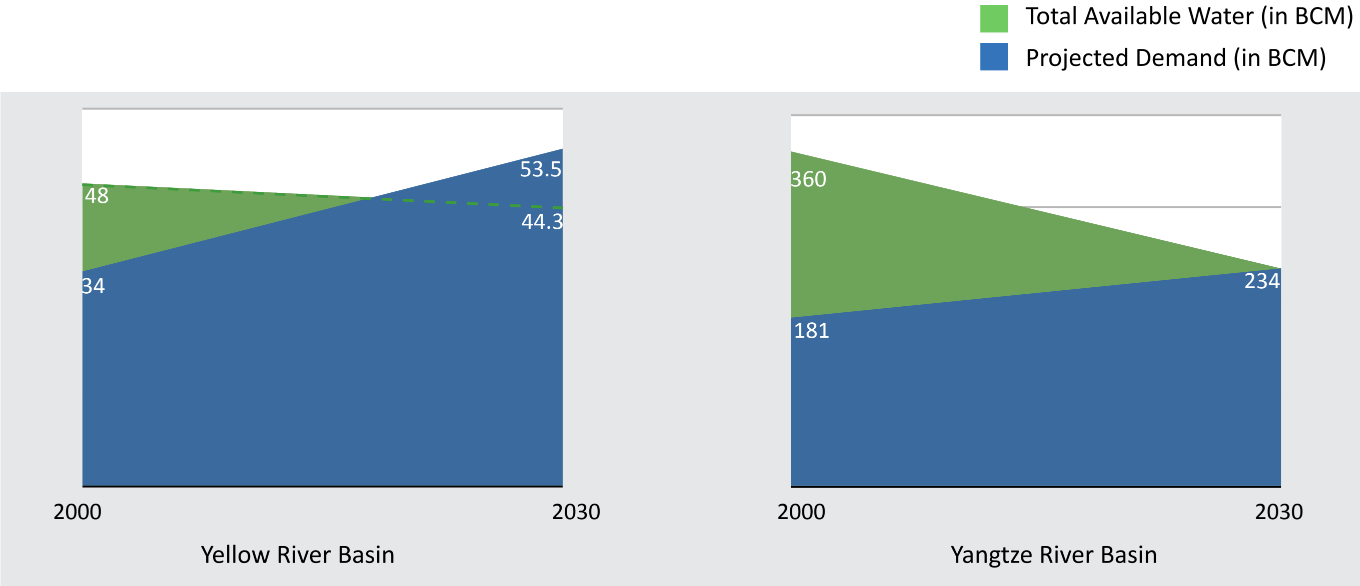
more demand for water resources. Of the three river basins in India, the Brahmaputra has the maximum potential of being further utilized in the future. Given that the Ganges and the Yamuna's groundwater resources are in a poor state, there is little scope of harnessing them further for agricultural purposes.

Surface water, by way of river runoff, will be an important contributor towards China meeting its growing water demands. In 2007, China's total renewable water resources were 2800 BCM, of which river runoff accounted for 2700 BCM and underground water storage facilities accounted for 100 BCM. As one moves across China, there are vast discrepancies in water resources, with availability decreasing from the south to the north and east to the west. The south-east of the country has abundant water resources, while the north faces water scarcity – a problem compounded by high utilization rates in the region. The dependence on surface water is further complicated by high levels of pollution, on account of industrial and domestic chemical discharge into the river system. Meanwhile, despite the comparatively better quality of groundwater, the over-exploitation of the resource has resulted in the curtailment of its use. In an effort to secure water for agricultural purposes, groundwater extraction is being carried out at a greater depth, a process which could result in the eventual imbalance of the water table.

In 2000, the total potentially usable water in the Yellow River basin was 48 BCM, while the Yangtze stood at 360 BCM. The water demand for the same year was 34 BCM in the Yellow River basin and 181 BCM in the Yangtze. This indicates that approximately 70% of the utilizable water was consumed in the Yellow River basin and around 50% of the utilizable water was consumed in the Yangtze River basin.

In addition to the surface water, groundwater resources are extensively used in the Yellow River and Yangtze River basins for domestic, agricultural

Water Supply and Demand in the Himalayan River Basins in China (2000 and 2030)



Source: Amarasinghe, UA, Giordano, M, Liao, Y, & Shu, Z. "Water Supply, Water Demand and Agricultural Water Scarcity in China: A Basin Approach". IWMI. December 2005

and industrial purposes due to easy accessibility. It is important to note that lack of adequate surface water, especially in the Yellow River Basin, has led to excessive groundwater utilization, a point highlighted by the fact that approximately 60% of the total water supply to the North China Plain is from groundwater due to inadequate surface water.

The Yellow River flows through semi-arid and arid regions of China resulting in high levels of evapotranspiration. The region supports almost 50% of China's population, resulting in high utilization rates of water. A combination of these factors has resulted in acute water scarcity and increased droughts in the Yellow River basin. The stream flow in the lower reaches of the Yellow River has been declining and has dried almost 30 times since 1972. In 1997, the river ran dry for 226 days of the year. Only timely releases of water from reservoirs have prevented the river from drying up completely since the turn of the 21st century.

Acute surface water shortages have led to extensive groundwater utilization to meet the growing water demand, especially in the down-stream areas of the Yellow River basin. The total volume of groundwater available in the Yellow River basin is 17.2 BCM. In 2000, groundwater abstraction was 10.7 BCM, which is about 62% of the average total renewable groundwater resources available in the basin. Extensive use of groundwater for food-grain production such as wheat in the Yellow River basin has depleted the groundwater levels. In some parts of the basin, the wheat farmers have to pump water from a depth of 300 meters. Studies have shown that groundwater tables are shrinking at the rate of 3 meters a year in the Yellow River basin. In about 65 locations, the groundwater levels have dropped significantly due to overexploitation. In addition, five-sixths of the wetlands in this region have dried up.

As for the Yangtze River, water availability is not a problem in the river basin. The basin accounts for 35% of the water resources in the country with the per capita water availability of around 2400 m^3 per year. The basin area receives higher rainfall when compared to the Yellow basin. However, the water supply in the Yangtze River basin is ridden with problems, mostly man-induced, primarily pollution. This is one of the important causes for higher water utilization rate in the basin. In addition, groundwater in most parts of the Yangtze River delta has been contaminated due to industrial and agricultural pollution. The surface water is likely to reduce in the future due to the melting of glaciers and changing rainfall patterns, which will further reduce the already depleting groundwater levels.

The two Chinese river basins are constrained by different factors, both of which have negatively impacted the water security of these basins. While the Yellow River basin suffers from physical scarcity of both surface and groundwater resources, the Yangtze River basin's pollution levels have rendered water resources dangerous for use of any kind in many places. Considering the sizable populations that live in these basins, the future of water security in the Yellow and Yangtze basins looks bleak.

Nepal's issues regarding water scarcity are different from those of India and China. The country does not have a water deficit at present or even until mid-way through the 21st century. Nepal's Initial National Communication to the Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC) stated that the country has adequate resources to last till the end of the century. However, lack of infrastructure development, over-utilization of water resources and a growing economy threaten to deplete the water resources at an unprecedented rate. In addition, Nepal is confronted by the 'Too much too little water' syndrome, whereby the dry season experiences considerably less water than the monsoons. The large discrepancy has prompted the attention of the government, which believes that the situation in the dry season could become progressively worse.

In Nepal, the Himalayan Rivers such as the Karnali, Gandaki and Saptakoshi contribute around 80% of the total annual runoff of all Nepalese rivers. The country's water demand was less than 10% (as of 2001) of the available surface water resources, which was around 225 BCM (2003). The available groundwater in Nepal is estimated to be 12 BCM or 5% of the total water resources, of which 5.8 BCM - 9.6 BCM can be safely exploited. Changing rainfall patterns due to climate change factors is likely to increase the dependence on groundwater in the future, especially during the dry season. As of 2007, around 42% of the 2.6 million hectares of cultivated land in Nepal was irrigated. The potential for irrigation is actually closer to 85% of the total cultivated area. In 2007, groundwater accounted for approximately 18% of irrigation for the land, with the remaining contributed by surface water. Though only a small proportion of the groundwater resources is used at present, there is considerable potential for further exploitation in parts of the Terai and Siwalik regions in Nepal for drinking and irrigational purposes.

While Nepal has yet to utilize the full potential of its water resources, particularly its groundwater resources, there is a need to check against the kind of over-development that exists in countries like India and China. Despite the appearance of abundance, Nepal's water situation is in reality more fragile, a fact that has been complicated considerably due to the impact of climate change.

Multistage Relief Map of China

Note: Topography - The terrain of China is high-elevated in the west and of low altitude in the east. The highest area is Qinghai-Tibet Plateau with elevation higher than 4,000 m down to the coastal plain areas being below 50 m.

Source: Xi Chen, "Precipitation and temperature trend analyses in the last five decades for the Southwest China" presentation at Second International Workshop on Himalayan River Basins hosted by SFG - BIPSS at Dhaka on January 16, 2010

The position of Bangladesh vis-à-vis water scarcity is similar to that of Nepal. The country's surface and groundwater resources are replenished annually, ensuring that there is no physical scarcity of water.

However, the country will have to face the economic scarcity of water – an outcome of industrial, agricultural and domestic growth. The country's infrastructure will be insufficient in satisfying growing demands and will be unable to provide by way of storage facilities and transportation of the valuable resource. In addition, the rapid environmental degradation has left several of Bangladesh's water bodies in a precarious position, as they become increasingly threatened by deteriorating water quality.

Around 95-97% of the Bangladesh's population depends on groundwater resources for domestic purposes since the surface water requires primary treatment to remove sediments before it can be utilized. In addition, surface water is being contaminated due to discharge of human excrement and industrial waste being dumped directly into the rivers, making the water unsafe to drink. The absence of diversion structures and storage facilities due to the flat topography of the country has resulted in a heavy reliance on groundwater. This has resulted in a decline of groundwater levels at an alarming rate, especially in urban areas. The water table in Dhaka alone has declined at a rate of 2 to 3 meters per year between 1999 and 2009. The wells in rural areas too are drying up due to the over-utilization of groundwater.

The demand for groundwater exceeds its availability by 30 BCM in the period from February to April. According to the Food and Agricultural Organization (FAO), the total groundwater available is 21 BCM. The recharge of groundwater tables occurs primarily through direct infiltration of rainfall. Naturally the groundwater tables reach their maximum capacity during the monsoon months, from August to October. The lowest potential recharge occurs in the Ganges River basin, in districts such as Rajshahi, Kushtia and Pabna. The level of recharge is lower than the eastern parts of the country since it receives approximately 50% of the annual average rainfall of 2300mm in the country. In addition, the surface water contribution to the aquifers is limited by the restricted flow of the Ganges River due to the upstream diversion. Large parts of the groundwater in coastal regions of the river basin have saline rather than fresh water in the upper aquifers.

In comparison to the Ganges basin, the Brahmaputra and Meghna River basins in Bangladesh receive higher precipitation, exceeding the national average of 2300mm in some parts of the basins. The maximum groundwater recharge occurs in these basins in districts such as Dinajpur, Mymensingh, Sylhet and Noakhali. However, the north central region, which is highly urbanized and industrialized, uses groundwater extensively for domestic and industrial purposes. Groundwater here can be found at a depth of 10-15m from the surface. On the whole, the groundwater is a fast depleting water resource in most parts of Bangladesh because of overdependence, especially during the dry season.

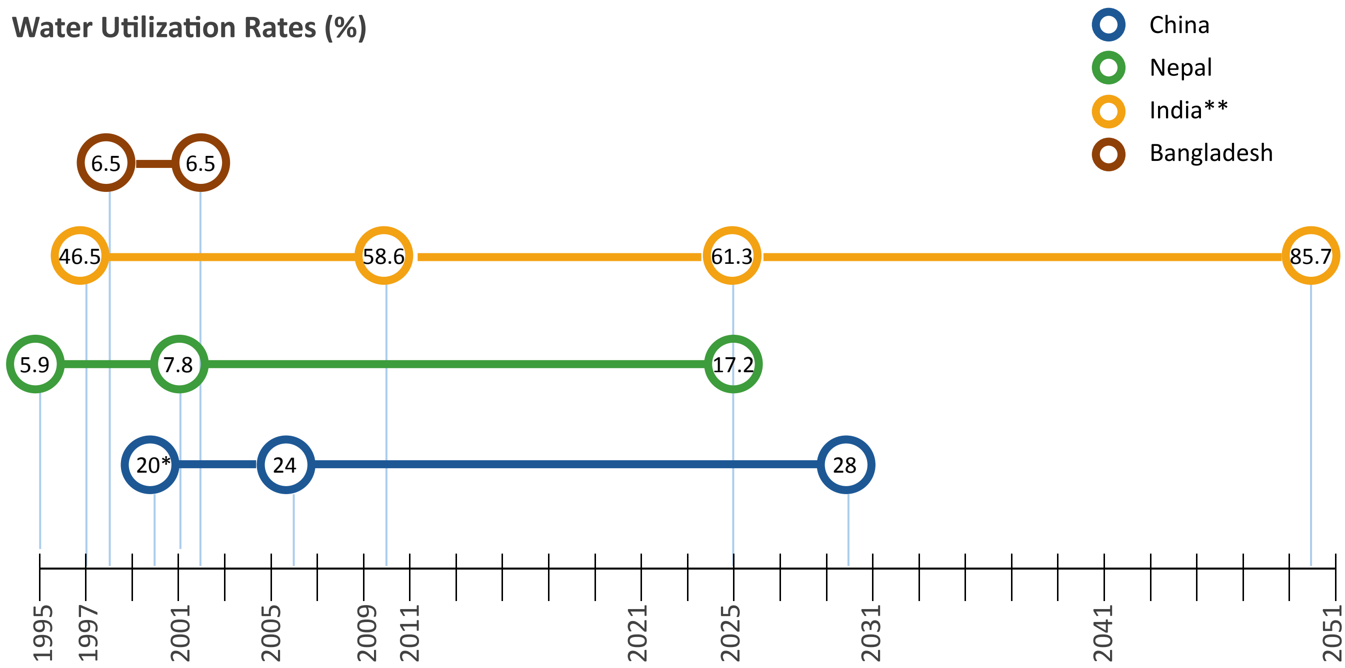
The impediment that Bangladesh faces with regard to its water security is the lack of storage facilities in the river basins, for the excess surface water resources in the country. As the country receives more than abundant rainfall, its inability to store the rainwater is the basic reason for its over-dependence on groundwater resources. The groundwater in the country is compromised not only by over-utilization, but also by pollution and contamination. Apart from this, extraneous factors such as frequent extreme weather events and seal-level rise are affecting an already stressful water situation in Bangladesh.

Sea Level Rise

The problem of water scarcity in the Himalayan River basins will be worsened by rising sea levels as well as salt water intrusion into fresh water. Moreover, the unrestrained exploitation of surface and groundwater will draw salt water into the aquifers along the coastal regions. In China and Bangladesh, as the sea levels rise, the salt water intrusion into groundwater tables will increase further thereby reducing the utility potential of the groundwater. It is important to note that the process of salinity intrusion into groundwater tables is irreversible and will therefore further restrict the freshwater availability in the river basins.

The low-lying coastal regions in China are mainly distributed along the Yellow, Yangtze and Pearl River deltas. The seawater infiltrates 62 square kilometres of groundwater annually in the eastern Bohai Gulf region in the Yellow River basin. At present, the higher runoff of the Yangtze River has helped in keeping the

Water Utilization Rates (%)



*Source: Ministry of Water Resources, China.

**Source: Briscoe, John & Malik. R.P.S. 'India's Water Economy – Bracing for a turbulent future'. The World Bank 2008.

saline water away from the land. However, rising sea levels and low flow of the Yangtze River due to climate-induced factors, will allow salinity to penetrate far inland, thus affecting the groundwater resources negatively. The sea level is expected to rise by 26cm around the year 2050 in China. This will impact the freshwater availability of about 70% of China's large cities such as Shanghai and Tianjin and over half the population that lives in China's coastal areas.

In India, the growth of mangroves along the Ganges River, which represents the extension of 'salt wedge', has resulted in salinity intrusion in the groundwater tables, especially in Kolkata. Any further rise in sea levels will render large tracts of agricultural land unusable, with the immediate impact being a reduction in food production.

In Bangladesh, 12 of the country's 64 districts meet the sea directly. Coastal cities such as Jessore and Faridpur are already being severely hit by varying degrees of salinity in the soil and groundwater tables. During the winter months, with predicted decrease in precipitation and greater use of water resources, the salinity levels is expected to increase further in the coastal districts. The flow of the Ganges, Brahmaputra and Meghna Rivers is predicted to increase during the monsoon season. However, a simultaneous sea level rise would result in back water effect in the Lower Meghna basin, pushing saline water further inland. Salinity intrusion therefore, will have a negative impact on agricultural land leading to food and livelihood insecurity in the future.

Utilization Rates: Up, Up and Up

The fresh water resources, both surface and groundwater, are under constant pressure due to a combination of climate and human-induced factors. The unrestricted and inefficient use of water has led to severe pollution in most of the Himalayan Rivers in these countries. With regard to India, the water utilization rate is predicted to increase from 59% in 2010 to around 61% and 86% in 2030 and 2050 respectively. India has already crossed the 40% water utilization threshold considered sustainable for a country by the World Bank.

In India, over a period of 15 years from now, i.e. from 2010 to 2025, the water utilization rate is estimated to increase by 2%. However, from 2025 to 2050 the water utilization rate is likely to increase by 25%, which means an average increase of roughly 1% every year. This increase in water utilization can be largely attributed not only to the increase in population density but also to the change in consumption patterns. On the whole, India's water utilization rates will reach unsustainable levels in the next 20 to 50 years.

On the other hand, it is estimated that China's water utilization rate that was 24% in 2006 will increase to 28% by 2030, an increase by 4% in a period of 24 years. This shows that unlike India, China's water utilization rates will be well within the sustainable level. However, the basin-wide statistics show that the present utilization of water is roughly three times more than the national utilization rate, thus indicating high regional disparity in water utilization. It is estimated that some cities in the country will not be able to extract groundwater by the end of the next decade.

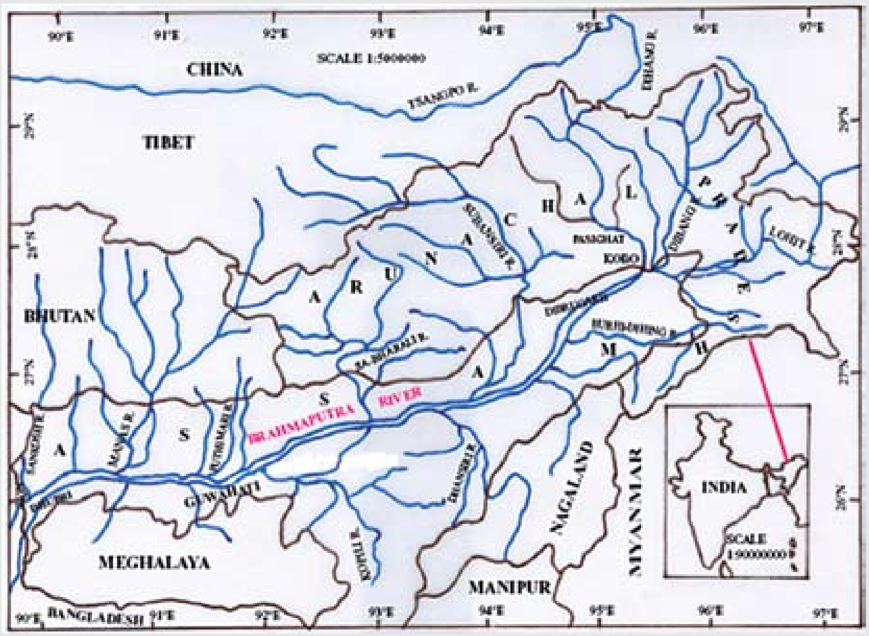
According to the International Water Management Institute (IWMI), countries that are unable meet the estimated water demands in 2025, even after accounting for future adaptive capacity, are considered to be "physically water-scarce". The Ganges and Yamuna River basins in India and the Yellow River basin in China will be 'physically water scarce' by 2030. As noted earlier, the per capita water availability in these river basins is likely to drop much lower than the 'water stress index' benchmark. It is important to note that the water stress indicator threshold does not indicate that water is becoming scarce for domestic purposes, but that the water is becoming scarce for food production since the water consumed for domestic purposes occupies a small proportion of the total water withdrawals.

Nepal and Bangladesh have sufficient renewable water resources. The estimated per capita water availability in 2030 will be roughly 3.5-4 times more than the World Bank benchmark index for measuring 'water stress', which is 1700 m^3 per person per year. Hence, these two countries are not going to face water scarcity in physical terms, though they are likely to face 'economic scarcity' of water due to mismanagement of water resources and poverty. This implies that unless the two countries make considerable investments in the water sector, the available water resources will not be able to meet the water demand of the population in these countries.

Shifting Sectors 04

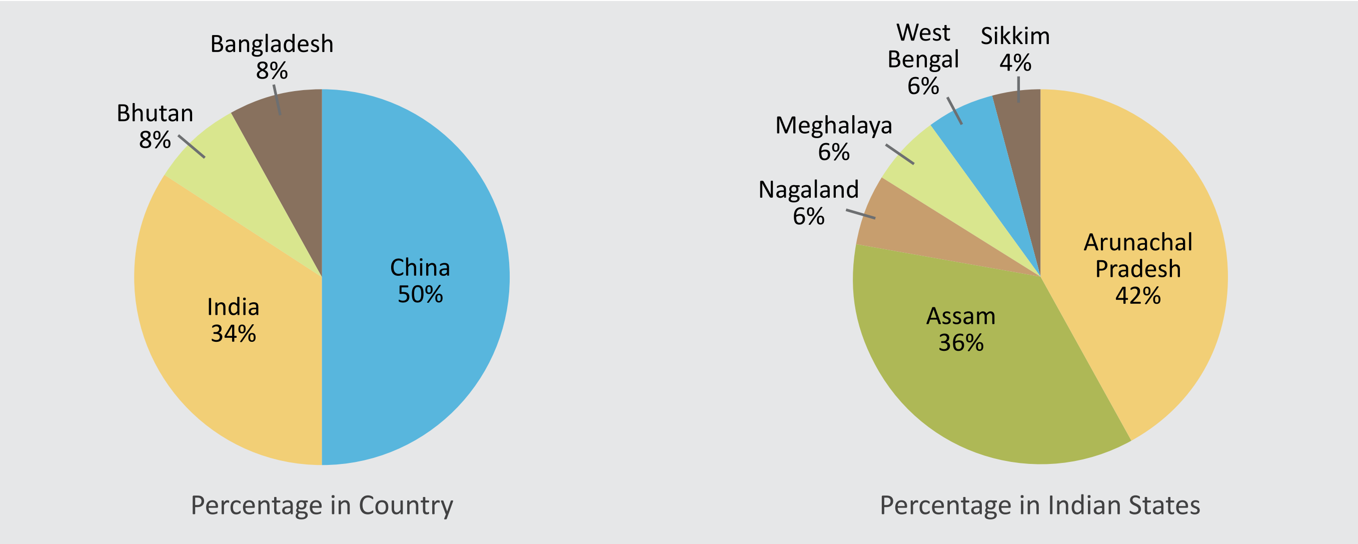
Water allocation in the Himalayan sub-region is done primarily between the agricultural, industrial and household sectors. The agricultural sector, which is a predominant employer within the sub-region, utilizes the largest quantity of water to support farming activities. However, as societies urbanize, there is likely to be a shift towards the industrial and domestic sectors. Urban populations have traditionally used larger quantities of water in comparison to their rural counterparts. Similarly, a shift away from primary to secondary sector will result in an eventual re-allocation of water, with the industrial sector receiving a larger proportion. China, Nepal, India and Bangladesh are fast developing and are largely agrarian societies, with large rural populations. However, China and India's larger economies and comparatively advanced development have ushered in a period of transformation in both countries. The domestic and industrial sectors in these two countries are also expected to require much more water in the future. In addition, it is important to note that India and China are significantly more populous than Nepal and Bangladesh. A combination of all these factors has resulted in different combinations of sectoral allocation of the total water resources in these four countries.

The Brahmaputra Basin



Source: Chandan Mahanta, "Integrated Basin Development and Management for Himalayan Sub-regional Cooperation in Water Security" presentation at Second International Workshop on Himalayan River Basins hosted by SFG - BIPSS at Dhaka on January 16, 2010

Brahmaputra Basin



Source: Chandan Mahanta, "Integrated Basin Development and Management for Himalayan Sub-regional Cooperation in Water Security" presentation at Second International Workshop on Himalayan River Basins hosted by SFG - BIPSS at Dhaka on January 16, 2010

Agriculture, the Greatest Consumer

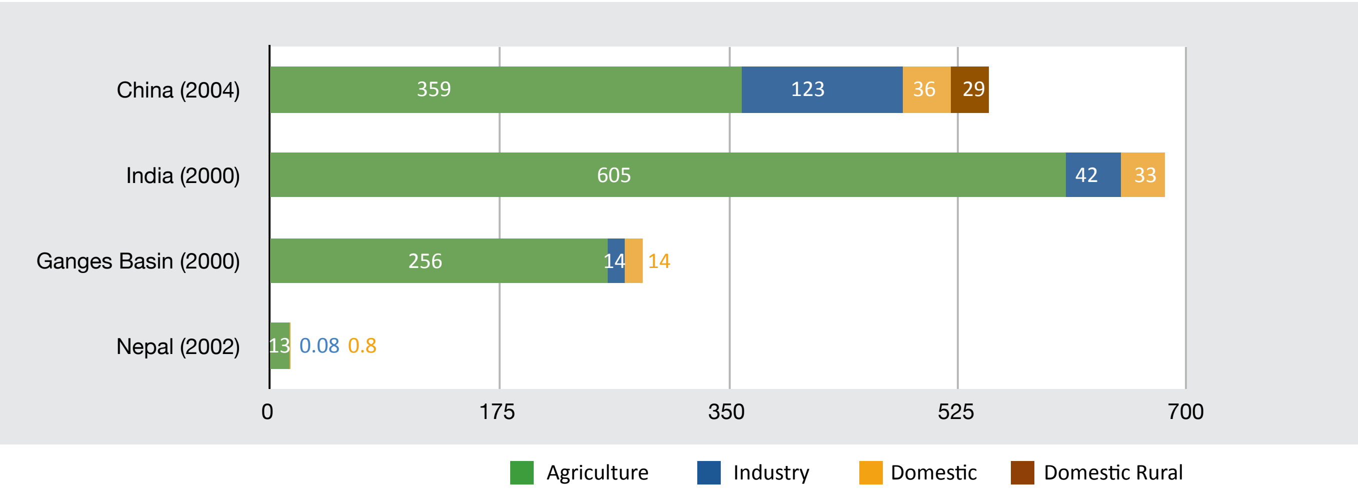
Being predominantly agrarian countries, China, Nepal, India and Bangladesh require the largest percentage of their water resources for agriculture. The primary crops of the region, such as rice, are water-intensive – further fuelling the demand for the resource and skewing water allocation towards the agricultural sector. The rapid pace of industrialization in both India and China has also created substantial demand, making industry the second largest sector in terms of water consumption. Concurrently, the volume and percentage of total water resource used for agriculture has been steadily decreasing. On the other hand, Bangladesh and Nepal's demand for water is dominated by their agricultural requirements, much more so than either India or China.

Among the four countries, China's agricultural sector consumes the smallest percentage of water, owing to the rural-urban migration that has been occurring in recent decades. In terms of sheer volume, China's agricultural sector utilized 358 BCM of water in 2004. Furthermore, when expressed as a percentage, China's agricultural consumption takes up a sizeable amount, at 65.6% of 556 BCM. However, as China is turning increasingly industrialized, people look for employment opportunities in urban centres and, there is greater utilization of HYV seeds, the amount of water consumed by the agricultural sector is expected to taper down.

As of 2005, the agricultural sector of the Yellow River basin consumed approximately 74% of total water resources while industry accounted for 17% and the domestic sector 9%. In comparison, the Yangtze River basin consumed 63% of available water for agricultural purposes, while the industrial and domestic sectors consumed 28% and 9% respectively. At a national level, the industrial sector required 22% of total water resources in 2004, with the domestic sector utilizing 11.9%. However, it is interesting to note that the urban domestic sector required 6.5% of the resources, while the rural domestic sector consumed 5.3%. This discrepancy, despite the urban population constituting 40.5% of the total population can be largely attributed to wasteful practices and varying consumption patterns in China.

As with China, India's agriculture sector also consumed a large proportion of water resources in the year 2000, accounting for 88.9%, in comparison to the 6% and 5% utilized by the industrial and domestic sectors respectively. However, as India's economy grows, there may be a gradual shift away from employment in

Water Demand by Sector (BCM)



Sources: Chinese Academy of Sciences, Institute of Geographic Sciences and Natural Resources Research.
International Water Management Institute.
Bhattarai, Damodar & Goutam, Sagar Raj. 'Water Resources of Nepal: Opportunities and Challenges'. Department of Water Induced Disaster Prevention, Nepal

the agricultural sector and towards the industry sector with more and more people moving towards urban centres. As a result, there will be a corresponding shift in sectoral allocation of water, with the industrial and domestic sectors consuming a larger percentage of the pie. It is important to note however, that while there will be a re-allocation of water between the sectors, agriculture will continue to dominate the demand for water in the not-so-far future.

The importance of the agricultural sector to India is highlighted by the sectoral allocation of water resources in the Ganges River basin. In the year 2000, the agricultural sector required over 90% of total water resources, while 4.8% was consumed by the industrial sector and 4.9% by the domestic. From a national perspective, the Ganges basin accounted for 42% of the country's total water consumption in the year 2000 – reinforcing the fact that the basin's population forms a sizeable wedge of the country and, could potentially face a problematic future with regards to securing water resources.

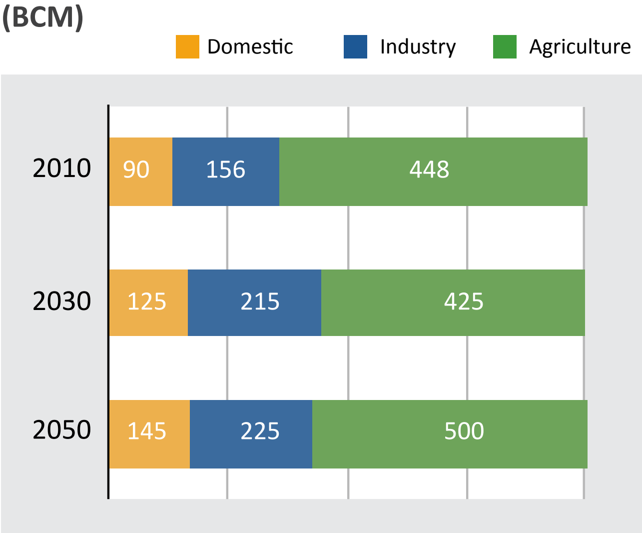
The agricultural sector in Nepal is the largest form of employment, with an overwhelming proportion of the country living in rural areas. As a result, the sector consumes the largest percentage of total water resources, with industry and domestic requirements being significantly smaller. In 2002, Nepal's agricultural sector utilized 93.6% of water in the country, while the domestic sector used 5.7% and, the industrial sector 0.6%. Nepal's water scenario is unlikely to undergo any significant changes in the immediate future, with a majority of the population confined to the rural areas, while the pace of urbanization and industrialization remains negligible.

Water consumption in Bangladesh follows a similar pattern to that of Nepal, with the agricultural sector requiring over 96% of total water resources in 2000. In comparison, the domestic sector utilized only 3% of resources and the industrial sector approximately 0.6%. Although Bangladesh's experience is similar to that of Nepal, the country is expected to industrialize and urbanize at a marginally quicker pace, leading to a slight re-adjustment in sectoral allocations in the future – with the industrial and domestic sectors consuming more water, although still significantly lesser than agriculture.

Future Shifts

In 2010, China's agricultural sector is expected to consume approximately 64% of the total water resources, while the industrial and domestic sectors will utilize 22.5% and 13% respectively. The shift away from a large consumption of water by the agricultural sector is projected to continue until 2030, with forecasts suggesting a jump in industrial water consumption to 28% and domestic consumption to 16.3%. By comparison, the agricultural sector is predicted to utilize 55.5% of water resources – a significant drop of almost 10% when compared to 2010 estimations. However by 2050, the agricultural sector is projected to record a slight increase in water consumption at 57.5%, while the industrial and domestic sectors will utilize 25.8% and 16.6% respectively. In addition, overall water demand is expected to jump by a little over 100 BCM between 2030 and 2050, rising from 765-800 to 870-950 in the span of 20 years. However, agricultural water demand is expected to drop by 2030, before increasing again around 2050, while the industrial sector is predicted to experience a marginal increase in water consumption. Consumption in the domestic sector will increase by 20 BCM over the 20 year period. It is important to note that China's moving away from agriculture will reverse itself at some point to suffice the nation's requirements.

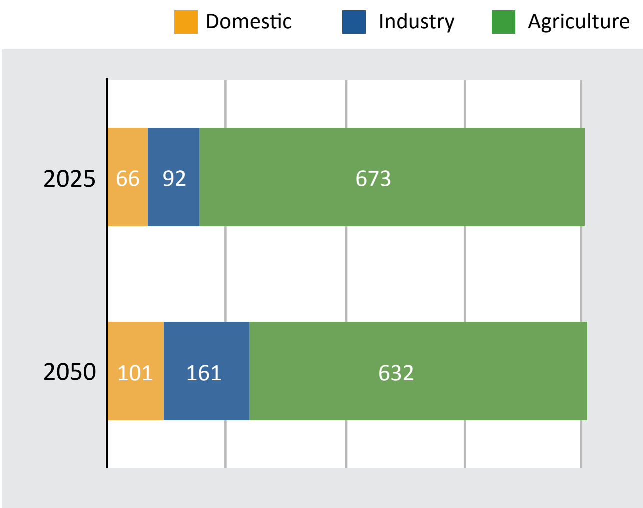
China Water Demand Projections Sector-wise (BCM)



Source: China Statistics Bureau 2007
Courtesy: World Agroforestry Centre

Sectoral demand for water in India has and will continue to be dominated by the agricultural sector, though there could be a slight decrease to approximately 83% by 2025. Water utilization requirements for the domestic and industrial (includes energy and other) sectors are expected to marginally increase to 6.67% and 10.06% respectively. However, it is interesting to note that the slight increase for the domestic sector is actually representative of a more than doubling in volumes from the year 2000. The agricultural sector is projected to require 74.08% of India's total water resources by 2050, indicating a drop in sectoral demand. Meanwhile, the domestic and industrial (includes energy and others) sectors will require 7.04% and 18.86% respectively. The lower water projections for the agricultural sector by 2030 and 2050 can be attributed to greater industrialization, loss of cultivable land, greater level of urbanization and better employment opportunities at the national and regional levels. In addition, it is likely that the trends which are present at the macro or national level will be evident at the micro or regional level, as is clear from the Ganges River basin trends.

India's Water Demand Projections Sector-wise (BCM)



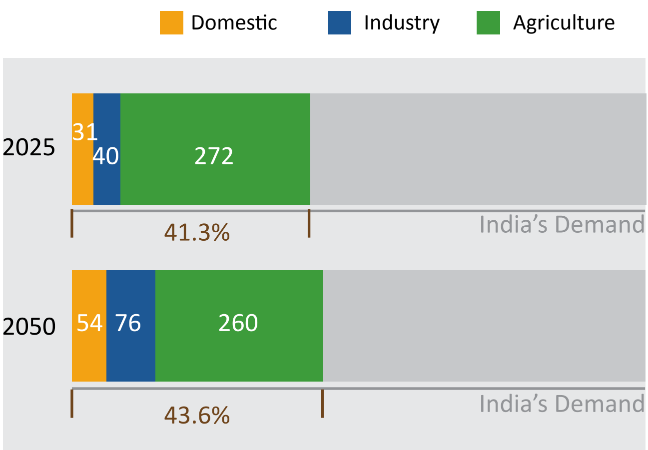
Source: International Water Management Institute

India's agricultural sector is expected to experience a dip in the demand for water between 2025 and 2050, in terms of percentage share of the total water resources as well as in terms of sheer volume. This trend is projected to occur at the national level and within the Ganges basin.

Reflecting India's national sectoral water demand projections, the agricultural sector in the Ganges basin is forecast to require 77.9% of water, while the industrial and domestic sectors will require 11.5% and

8.9% respectively by 2025. Similarly, there will be a further drop in agricultural consumption by 2050, with the sector requiring approximately 66.7% of water, in comparison to the industrial demand of 19.4% and the domestic demand of 13.8%. Projections for the Ganges basin indicate greater industrialization and urbanization, coupled with a trend to move away from a primarily agrarian economy at the regional level. As a result, water demand for the agricultural sector is expected to fall, while the industrial and domestic sectors record slight increases.

Ganges Basin Sectoral Water Demand Projections (BCM)



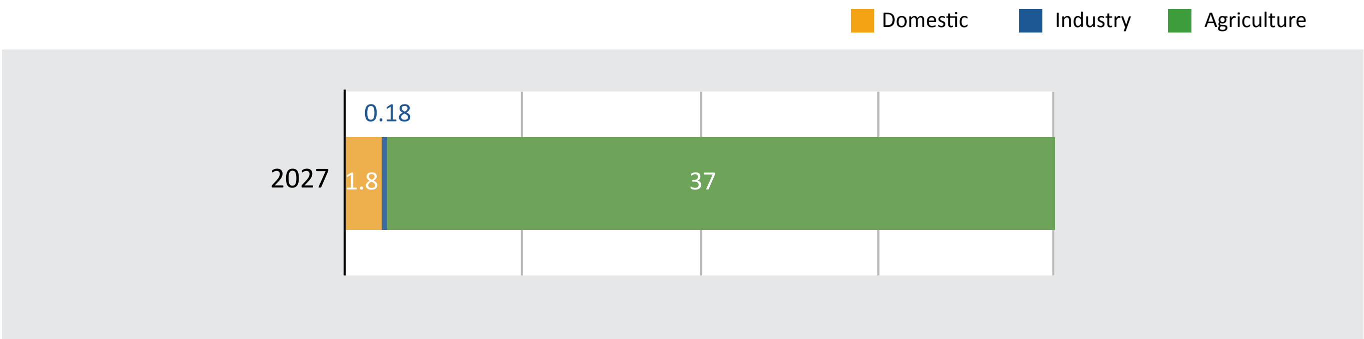
Source: International Water Management Institute

Water demand projections for Nepal indicate that the agricultural sector will continue to remain the country's largest consumer of water in 2027, requiring approximately 95% of the resource. The industrial sector will require the least water, with a demand projection of 0.5%. While the projected industrial demand is less than the required percentage in 2002, it will have almost doubled in terms of sheer volume. The domestic sector follows a similar trend to that of its industrial counterpart, and will double its water demand from 2002 levels in terms of volume. By 2027, the domestic sector is projected to require approximately 4.5% of Nepal's total water resources. Sectoral allocation of water for Nepal remains virtually unchanged as a percentage, although in terms of volume it doubles across all three sectors. Despite greater industrialization and urbanization in Nepal, the country is expected to remain largely agrarian, resulting in the high water demand for the agricultural sector.

Although there are presently no figures to predict future water resources allocation in Bangladesh, it is likely that the trend in Nepal will be closely mirrored in Bangladesh due to similarity in their slow rates of industrialization and urbanization, as well as the large rural populations in both the countries that are principally agrarian. Therefore, it is possible to predict agriculture as the dominant sector in the country, while both the industrial and domestic sectors will start making small inroads into the water resources of the country, growing slightly larger in the coming few decades. However, it is likely that the make-up of the sectoral allocation of water resources in Bangladesh will remain more or less the same in the next 15-20 years, unless some radical changes occur.

The agricultural sector will continue to be the major consumer of water in China, Nepal, India and

Nepal Water Demand Projections Sector-wise (BCM)



Source: Bhattarai, Damodar & Goutam, Sagar Raj. "Water Resources of Nepal: Opportunities and Challenges". Department of Water Induced Disaster Prevention, Nepal.

Bangladesh, although the industrial and domestic sectors will require more water in the future. Meanwhile, agricultural water demand in China and India, despite remaining the dominant consumer, will experience a slight decline in terms of volume and percentage, up until 2030. Thereafter, while India's agricultural water demand will continue to decrease, China will experience a slight increase up to 2050. The decrease in agricultural water utilization is likely to be an outcome of purposeful development policies in both countries, which seek to promote industrial growth and urbanization.

Nepal and Bangladesh will continue to experience higher demands for water especially for the agriculture sector vis-à-vis the industrial and domestic sectors. Lack of industrialization and urbanization will be partially responsible for this trend, though nationally- driven investment policies and foreign capital injections could also potentially spur growth and alter the demand for sectoral allocation of water.

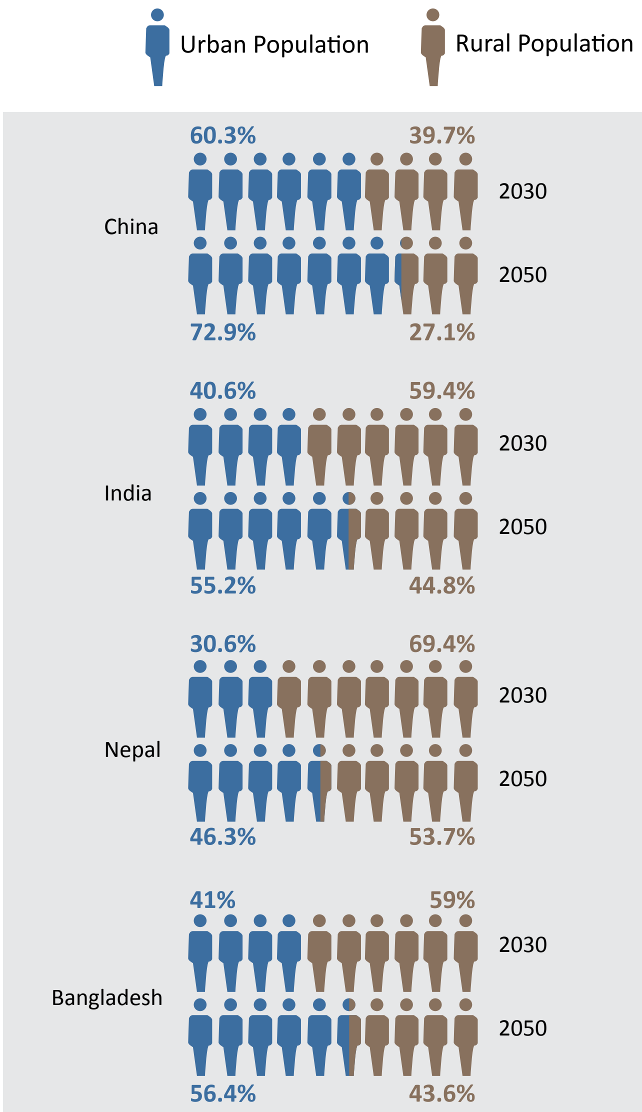
Industrialization and Urbanization

Rapid industrialization in China, Nepal, India and Bangladesh will determine the nature of demand for water in all four countries, albeit to varying degrees. The growth of highly water-intensive industries and inefficient water usage will increase requirements. Water- intensive industries such as jute, steel and textiles dot the river basins of India and China, and will push demand for water in the years to come. The growth of such industries is expected to increase in the future, resulting in an adjustment of water demands across the sectors. While Nepal and Bangladesh will experience industrial growth in the future, it is likely to be negligible, resulting in less water requirements for the sector in comparison to that of China and India.

Development in the four countries will be complemented by urbanization. Given that urban centres traditionally demand more water than rural areas, there is likely to be an increase in domestic water demand across the Himalayan sub-region. In addition, increasing populations in all four countries will drive further demands for water at the household and domestic level.

The rapid pace of urbanization will primarily drive the increase in water demand in the domestic sector in China by 2050, with over 70% of the population expected to reside in urban centres. While the rural-urban population divide will not be as pronounced as in India, the country's urban centres will account for more than 55% of the population by 2050, thus driving the domestic water demands. Within the Ganges basin, estimates suggest that over 32% of the population will live in urban centres by 2025 – a number which is expected to increase to 47.3% by 2050. In addition, over 54% of India's population will reside in the Ganges basin by 2050, reflecting national and basin-wide water demand projections.

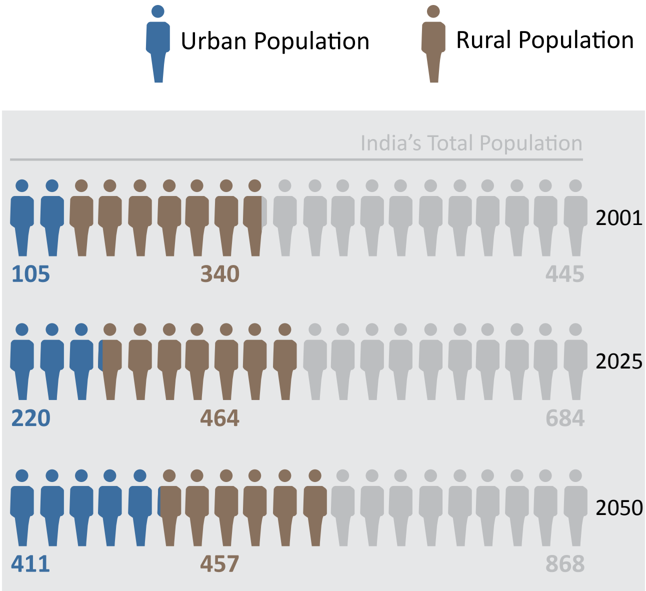
Urban-Rural Divide Projections Country-wise



Source: United Nations Population Division

As is the case with India and China, the smaller countries of the Himalayan sub-region, Nepal and Bangladesh, will have significant urban populations by 2050, with 46% and 56% of their people living in urban centres respectively. This is likely to reflect on their water demands, with the domestic sector requirements expected to increase.

Ganges Basin Urban-Rural divide Projections



Source: International Water Management Institute

Pollution and Inefficiency 05

Water, the life-line of the Himalayan sub-region, faces a definite threat from human- induced factors. Over the years, its quality has been rapidly deteriorating as populations, industrialization and urbanization continue to grow unabated. The water sector in all the four countries is notorious for uncontrolled pollution and inefficient management. However, given the precariousness of the situation confronting the Himalayan sub-region, people are often faced with no option but to avail of whatever is available, resulting in health hazards and other problems.

Pollution

China, Nepal, India and Bangladesh face a daunting challenge to provide access to safe water, with river and groundwater resources excessively polluted. Poor water quality in the Himalayan sub-region can be largely attributed to the rapid and haphazard pace of development in the river basins. Unchecked pollution has virtually ruled out any possibility of restoring water quality to permissible levels. As a result, people living in the basins confront growing health problems, while ecological balance, particularly for the water-dependent species, is being increasingly threatened in three of the four countries. Only Nepal's major rivers such as the Karnali, Gandaki and Saptakoshi, have survived some instances of pollution due to a small industrial sector and slow growth.

Water quality in China is fast approaching dangerous proportions, with more than 70% of water in five of the seven major river systems polluted to an extent where it is no longer fit for human consumption. Development along the Yellow and Yangtze River basins, while economically beneficial, has come at a price. The rich fertile grounds of the middle and lower reaches, which support agricultural food production, are increasingly threatened by the large number of industries and rapid population growth within the basins. Almost half of China's 21,000 chemical plants are located along the banks of these two rivers, and are responsible for discharging excessive amounts of harmful toxins and industrial waste into the water bodies.

Lack of proper enforcement of anti-pollution laws in China has resulted in industrial and household units discharging an estimated 4 to 5 billion tons of waste and sewage into the Yellow River every year. In addition, blatant disregard for environmental protection measures has resulted in several instances of industrial accidents, such as the PetroChina 80km toxic slick in the Songhua River in 2005. Over the years, the Yellow River has experienced a combination of chemical spills, industrial wastage, heavy metal poisoning and domestic sewage dumped into its waters, making the river poisonous in several locations and biologically dead, i.e. unable to support any life forms, along 50% of its expanse. The Yellow River Conservancy Committee has declared 33.8% of the river water unfit for drinking, aquaculture, industrial use and agriculture, highlighting the severity of the problem.

China's other Himalayan glacier-fed river, the Yangtze, fairs no better, with approximately 10% of the river considered to be so severely polluted that it is said to be in a critical condition. In addition, reports state that 30% of its major tributaries, such as the Minjiang, Tuojiang, Xiangjiang and Huangpu are severely polluted. About 25 billion tons of industrial and urban waste is discharged into the Yangtze on an annual basis. People dependent on the river for their daily requirements are the most at risk, as industrial and other chemicals mixed in the water are likely to have major health implications. A study conducted in 2004, showed that 73% of the Yangtze's main stream was severely polluted. With more than 500 cities along the river, access to safe drinking water for the millions of people residing in the area is increasingly threatened. In addition, high levels of pollution have rendered the Yangtze River an economic catastrophe, with soil degradation and limited access to clean water, two of the major fallouts of the uncontrolled pollution

China's association with fishing dates back centuries. The area in question, which has traditionally been a major producer of seafood products and home to numerous fish farms, has had to contend with rising levels of water pollution. As a result, fish stocks have been threatened by chemical poisoning, with a further implication being the loss of livelihood for the fishermen who have been forced to migrate inland. The Yangtze and the Yellow Rivers are a vital aspect of China's identity, with millions of people dependent on its waters for their social and economic needs. However, rampant pollution and deterioration of water quality could have catastrophic implications for the future, with the rivers less likely to be able to support the growing water demands of people in their basins.

In India, the Ganges and the Yamuna face a situation similar to that of the Chinese rivers. It is estimated that approximately 50% of the Yamuna is severely polluted and does not meet national water quality standards. As with the Yellow River in China, the Yamuna flows through major industrial cities of Faridabad, Agra and Wazirabad – all of which are responsible for dumping large amounts of industrial waste directly into the river's water. The stretch of the Yamuna River between Wazirabad and Okhla barrage in Delhi constitutes about 2% of the catchment area, but contributes to approximately 80% of the river's total pollution. It is important to note that the Yamuna River accounts for approximately 70% of the water supplies to New Delhi, India's national capital. However, in an ironic twist, the city which relies on the Yamuna for its water supplies dumps almost 750 billion litres of sewage into its waters on an annual basis – adding to the health risk for those dependent on the river. Coliform levels, which indicate bacterial content in the water, are twice the permissible amount as the river enters the city and, 25 times the permissible levels as the water flows out of the city. Moreover, surface and groundwater resources are also threatened by the enormous amounts of fertilizers and pesticides flushed out from the agricultural fields into the river system. The negligence on the part of civic authorities to check pollution levels has damaged the rivers' water to a large extent – a problem which is likely to worsen as old cities expand and new townships develop along the stretch of the river.

Pollution in the Ganges River is primarily attributed to the disposal of human waste and sewage directly into the river. A study by the Uttarakhand Environment Conservation and Pollution Control Board declared that pollution levels in the river have reached alarming proportions. The present state of the river water makes it unfit not only for drinking and bathing purposes, but also for agriculture. Of a larger concern is the fact that the river meets all three standard pollution parameters – Bio-Oxygen Demand (BOD), Dissolved Oxygen and total coliform – only at Rishikesh, indicating that the rest of the river is in a poor condition, with Varanasi, Kanpur and Allahabad identified as the hotspots under the Ganga Action Plan. The primary contributor for the poor state of the river is the high level of untreated sewage released into the river on a daily basis, with a report by India's Planning Commission indicating that nearly 8,250 million litres is disposed into the Ganges from the 12 municipal towns that fall along its route till Haridwar. In addition, studies by Montana State University and the Government of India have revealed that the Ganges contains enterohaemorrhagic E.coli (EHEC) bacteria. The bacteria can cause dysentery and kidney failure and continues to kill people across the world. As the Ganga passes through several major cities, like Varanasi, Kanpur, Haridwar and Patna, it is estimated that municipal sewage contributes to approximately 80% of pollution, while the remaining 20% is attributed to industrial effluents dumped into it regularly. A significant proportion of industrial pollution is caused by the vast number of tanneries along the banks of the river. In addition, the Yamuna River, which is a major tributary of the Ganges, is also severely polluted, resulting in excess wastage flowing

River Pollution in Dhaka

Dhaka is one of the most densely populated cities in the world, with a population of approximately 12 million in 2008. According to the World Bank, its population is expected to increase to 30 million by 2025 and 50 million by 2050. There are around 700 industrial units in and around Dhaka city. These industrial units discharge approximately 1.5 MCM of waste water into the peripheral rivers such as the Buri Ganges, Turag, Tongi Khal, Balu and Lakhya on a daily basis. In addition, domestic and municipal waste is also discharged into these rivers due to the lack of adequate sewage infrastructure which has resulted in extreme pollution of the rivers.
Due to the severely polluted state of its rivers, 85% of Dhaka's demand for water is met from groundwater sources. However, the groundwater system is highly-contaminated at certain locations where the aquifers are recharged by river water. Dhaka's rapid pace of urbanization and industrialization has placed 450 city slums in a precarious position, with limited access to basic civic amenities such as drinking water and sanitation. Continued pollution of these rivers and the mismanagement of the already limited water resources will only exacerbate water shortages, leading to health and food insecurity in the future.

into the Ganges from other sources. The river, though considered very holy, is not considered safe for drinking or for agricultural needs in many places. For instance, the Haridwar city alone accounts for coliform level of 5500 colonies/100 ml which is 500 more than the maximum acceptable level for agriculture and 5450 above permissible level for drinking water.

The plight of the Ganges continues downstream, as the river flows into Bangladesh. Inadequate draining facilities, dumping of solid wastes, discharge from sugar mills and sewage disposal, further compound the pollution problems confronting the river's ecosystem. In addition, the presence of approximately 300 mills and factories in and around Khulna city, adds to the levels of pollution. Severe degradation of fresh water and marine ecosystems has led to further decline of fishing in the region, the impact of which is felt by those dependent on the waters for their livelihood and in terms of dwindling food supplies.

The importance of the Ganges and the Yamuna Rivers to the Himalayan sub-region is quite apparent. However, very high levels of pollution continue to jeopardize the health of millions who depend on these water resources within India. Furthermore, the river flows downstream eventually into Bangladesh, where water pollution is often already at extremely high levels, further complicating Bangladesh's ability to fully utilize the invaluable resource.

The state of the Brahmaputra River is considerably better than that of the Ganges and Yamuna Rivers. However, issues of pollution arising from the petroleum refineries and urbanization are an emerging concern, although the extent to which these factors impact the river will be considerably lesser than the Ganges and Yamuna – owing primarily to the lower number of people living in the area. In addition, the river is constantly polluted because of the dumping of domestic and municipal waste into it. Scientists have warned that the Brahmaputra could be degraded to the extent of the Ganges within the next 20 to 25 years if the river and its tributaries continue to be used as a channel for waste products. Furthermore, scientists warn that biological or bacteriological contamination of the river is reaching dangerous proportions and could pose a health risk to people dependent on the Brahmaputra's waters. However, while this issue is of concern, the river has remained comparatively pollution-free, underlying the fact that there is still some hope for reviving its resources.

On entering Bangladesh, the Brahmaputra River is confronted by issues of domestic and industrial waste being flushed directly into the river. However, as the river is defined by its high volume of water, the pollution and waste is inevitably washed into the sea, particularly during the monsoons. Meanwhile, the distributaries of the Yamuna River flowing from the left bank are affected by severe pollution due to rapid industrialisation and urbanisation in the north central region – an area home to 49% of Bangladesh's industry. In addition, the Buriganga River – the main river bordering Dhaka city – faces enormous pollution-related challenges, particularly due to several tanneries responsible for discharging approximately 4950 m^3 of organic waste daily. These tanneries are situated at Hazaribagh along the river. It is estimated that approximately 90% of domestic and industrial sewage generated in Dhaka is dumped into the wetlands and rivers in and around the city. The disregard for the environment has resulted in surface water pollution as also in the penetration of underground aquifers - two important sources of water for people in the country. Given that groundwater is an important resource for domestic water supply in the north-central region, the possibility of increased water pollution assumes greater significance.

The Surma and Kushiara Rivers merge to form the Meghna River in Bangladesh, which covers the north-eastern parts of the country. The region, which supports an estimated 44 million people, is dependent on the river for its supply of domestic and industrial water. However, excessive human activities within the river basin have resulted in the deterioration of water quality. In addition, the presence of small and medium sized industries has led to large amounts of industrial effluents being discharged into the river on a regular basis. The problem is further complicated by the flushing of pollution from the Surma River's catchment in India, which results in polluted waters entering Bangladesh's north-eastern region at the time of floods – resulting in a trans-boundary water quality problem.

While surface water resources are visibly affected by agricultural, industrial and domestic pollutants, it is the penetration of such waste products into the groundwater systems of China, Nepal, India and Bangladesh that is of considerable concern. Over-exploitation of groundwater resources does not allow water tables to be adequately recharged, thus stopping the pollutants from being flushed out of the system and, therefore resulting in the steady deterioration of groundwater quality. Groundwater in Bangladesh, the Terai region of Nepal and parts of West Bengal in India, face extensive arsenic contamination, leading to health complications for people, such as dark or white pigmentation of skin and hardening of palms of hands and soles of feet. In addition, drinking water supply in Nepal is highly contaminated by bacteria, as a result of inadequate protection at source regions and poor maintenance of infrastructure.

China and India have undertaken several projects to regulate the flow of the Yangtze, Yellow and the Ganges River through the construction of dams, in an effort to produce hydro-electricity. In addition, barrages and canals have also been constructed to divert water for irrigation. While these projects may serve an economic purpose, they also come at a considerable cost. Alteration to the natural flow of the rivers has intensified the impact of pollution, as rivers lose their natural ability to flush out waste products. Furthermore, future projects designed to divert water and alleviate water demands from the industrial and domestic sectors, are likely to compound issues of water scarcity and quality.

Inefficiency

The problem of the growing water insecurity in the Himalayan sub-region is further compounded by inefficient usage. From the agricultural, to the domestic and industrial sectors, water inefficiency results in added pressure on the resource and reduces its utilization potential in China, Nepal, India and Bangladesh. The industrial and agricultural sectors of India and China for instance, utilize a disproportionate amount of water resources when compared to the yield the two sectors generate. As water resources become increasingly scarce in the sub-region there will be an urgent need to reassess current practices to ensure the future survival of the resource. In addition, aging infrastructure and poor maintenance of water pipes has resulted in considerable water wastage during the distribution process. As a result of systemic mismanagement and wasteful practices, there has been a growth of private vendors in the water market.

China's per capita water usage is estimated to be 7-15 times greater than the per capita in developed countries. A ton of water in the United States of America for instance, produces USD $28-30 worth of GDP, in comparison to the USD $2-3 of the GDP in China. In addition, China's water consumption per unit of GDP is 4 times the world average and approximately 8 times that of developed countries. Inefficient utilization in China contributes greatly to the loss of the resource, thus fuelling the already acute water shortage confronting the country.

The lack of new and clean/green technology in manufacturing units across China, Nepal, India and Bangladesh has resulted in considerable inefficiency with regard to water usage and industrial output. China, the world's leading steel producer, utilizes almost double the amount of water than developed nations do to produce 1 ton of steel. The Indian steel sector, which ranks amongst the top ten producers in the world in terms of output, is much worse. In 2001, India's steel industry consumed 40 BCM of water and discharged 30.31 BCM of waste. On an average, the integrated iron and steel plants in India, consume 20-25 m^3 of water per ton of finished product as opposed to the global standard of 5 m^3.

On the domestic front, water usage is extremely inefficient across the Himalayan sub-region. India's capital city water authority, the New Delhi Jal Board, is supposed to supply 200 litres of water per capita per day but in reality, several areas across the city receive less than 30-40 litres per capita per day, while others receive between 400-500 litres per capita per day. This large discrepancy and unequal distribution of water is often because of poor infrastructure, water theft and preferential service to wealthy neighbourhoods. As with India, China's large cities too consume approximately 200 litres of water per capita per day, while rural areas receive approximately one-fourth the amount at 50-60 litres per capita per day. In addition, about 20% of water from water treatment plants is lost through leaks in distribution pipes across China. In 2005, water lost through leaky pipes across China constituted approximately 1.7% of water usage, or the equivalent of 10 BCM. In India, about 25-40% of the water supplied in the urban areas is lost due to pipe leakages. It is understandable why this figure of 'unaccounted for water' would be so high considering the water sector in India is highly disorganized. Nepal's urban areas lose around 40% of the total water supply due to leakages. Bangladesh's estimates for unaccounted for water are around 40-50%.

A major challenge leading to inefficient water usage in China, Nepal, India and Bangladesh is subsidized distribution of the resource. The practice does not reflect scarcity in the countries and serves to worsen the problem. Water prices in China are almost 70-80% lower than prices in countries with sufficient per capita water availability. Subsidized pricing has brought about tremendous careless attitude with regard to the water usage in the agricultural, industrial and domestic sectors in China. There is a severe lack of implementation of efficient water saving practices. In India however, the challenge is slightly different, with the country's poor unable to reap the benefits of the cheaper resource. Despite the Government of India spending approximately USD 1.1 billion a year on subsidizing water, majority of poor people in the country do not have access to potable water. Meanwhile, Indian companies pay Rs. 0.10-0.30 for a kilolitre (1000 litres) of water, whereas industries in the UK pay the equivalent of Rs.90 per kilolitre. The substantially cheaper rates in India result in several industries completely neglecting water saving norms

Arsenic Contamination

Arsenic contamination in groundwater was recognized as a problem in Bangladesh in 1993. Studies conducted have shown extensive contamination of between 50% and 90% in the shallow tube-wells across the southern and central regions of Bangladesh. The Government of Bangladesh employs a drinking water standard of 50 parts per billion (ppb) to measure arsenic levels in groundwater. However, the provisional guideline value, set by the World Health Organization (WHO), is far more stringent at 10 ppb for safe drinking water.

An estimated 25-30 million people in Bangladesh have been exposed to arsenic contamination. Sustained exposure to high doses of arsenic contaminated water is a serious health hazard. The use of this contaminated water over a long period of time leads to dark and white pigmentation, gradual hardening of palms and soles, along with the appearance of hard nodular lesions in the human body. In addition, it increases the risk of skin, lung and bladder cancer. Estimates suggest that around 85 million people in Bangladesh are at risk of exposure to arsenic contamination. This number could further rise as groundwater withdrawals for consumptive purposes increase owing to depleting fresh surface water resources and higher water demand growth rates.

Groundwater arsenic contamination is a public health issue in Nepal as well, with the initial tests being conducted on tube-well water in the Terai belt in 1999. Arsenic contamination is more prevalent in the Terai region as compared to the rest of the country, which uses open water sources from streams and rivers. Groundwater abstraction is highest in the Terai belt, thus exposing a larger number of people to the risk of arsenic water contamination. Studies conducted from 2001-2004 in six highly arsenic- affected Terai districts, found 400 people with arsenicosis, out of a population of 18,288. The highest prevalence of arsenicosis was in the Nawalparasi district, with skin abnormalities such as melanosis and keratosis common among those affected. Given that the Terai belt is the most agriculturally productive region in Nepal, arsenic contamination of groundwater could have serious implications on the agricultural sector.

and practices. Pricing that does not truly reflect the value of the water encourages inefficient water use in China, Nepal, India and Bangladesh. Readjustment of water pricing should be viewed as an essential step towards limiting inefficient water utilization, and must be implemented to discourage wastage of water.

National water policies in China, Nepal, India and Bangladesh must incorporate further emphasis on conservation tools. Rainwater harvesting and water recycling should be encouraged and even supported at the domestic, industrial and agricultural level. Although steps have been initiated to educate people, there still remains considerable room for improvement. In addition, it is imperative for government policies and recommendations to be implemented and effectively enforced by the concerned authorities.

China's Eleventh Five-year Program (2006-2010) stipulates waste water treatment for almost 80% of waste water but for most Chinese cities this is far from reality, with the actual figures being below 50%. Similarly, it not until 2002 when India's National Water Policy took the issue a little seriously by emphasizing the practice of non-conventional methods for water utilization, including artificial recharge of groundwater, desalination of sea water and rainwater harvesting. Nepal's government is yet to implement rainwater harvesting, despite the policy having been prepared in May 2009.

Nevertheless, water-efficient practices have been used on individual cases across the Himalayan sub-region. Chennai city in India has made it mandatory for all commercial and residential buildings to follow rainwater harvesting. Similarly, the New Delhi government has made it compulsory for every new construction of a house or hotel in the capital to have the necessary infrastructure and technology for rainwater harvesting. It is a fact that such progressive initiatives are successful and have a major impact only when they are implemented at the national level. The Gansu province in China, one of the most arid regions of the country, has been utilizing rainwater runoff for irrigation since the 1980s. In addition, the local population, in collaboration with scientists has successfully developed technology for further progress in rainwater harvesting with emphasis on its storage, purification and irrigation of rainwater. Over 3 million rainwater storage cellars have been built across Gansu which provide drinking water to 2.63 million people and irrigate 367,000 hectares of farmland. Seventeen provinces in China have adopted the rainwater utilization technique to provide safe drinking water for 15 million people and irrigation for 1.2 million hectares of land.

Given the state of water resources in Bangladesh, rainwater harvesting is now being viewed as a viable alternative to the arsenic groundwater. Initiatives by NGOs, such as Forum for Drinking Water Supply and Sanitation, are working towards making Bangladesh's rural community more self-reliant by developing rainwater harvesting technology. The growth and encouragement of such programs is necessary if the country wants to tackle the current water shortage as well as diffuse an impending water crisis.

The rewards for implementing efficient water practices are apparent. Water productivity for crops such as banana, cotton and sugarcane in India has improved by 45-225%, after the government's encouragement of drip irrigation systems as opposed to surface irrigation. Similarly, China's government is undertaking steps to expand areas under drip irrigation across the country. Purposeful initiatives that bring significant rewards must be widely implemented, particularly as agriculture forms the basis of the economies of China, Nepal, India and Bangladesh and, will account for the largest sector-wide water consumption up to 2050.

The deteriorating quality of freshwater in the Himalayan sub-region river basins is a result of the complex relationship between human actions and the environment. That declining quality as well as quantity of water will hamper future social and economic development is a fact. Moreover, the survival of ecosystems is increasingly threatened due to unrestrained and inefficient use of water. Lack of awareness among the population of the Himalayan sub-region with regard to essential issues like water conservation and the lack of political intent to enforce water standards will aggravate the situation. Furthermore, rivers flowing at lower levels will worsen the impact of drought on the land, thereby increasing the risk of desertification and land degradation.

Desertification 06

Desertification is another major problem confronting the Himalayan river basins of China, Nepal, India and Bangladesh. The threat posed by this environmental process could be detrimental to social and economic development. In 1994, the United Nations adopted the UN Convention to Combat Desertification (UNCCD) – an agreement to which all four countries are signatories. The UNCCD defines desertification as, 'land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities.' Climatic variations such as changing rainfall patterns and temperature fluctuations are the major causes of desertification in the Himalayan sub-region. In addition, human activities and unabated development are accelerating the process, while decreasing water levels, poorer water quality and over- utilization of the land intensify desertification in several parts of the river basins.

Climatic and Natural Causes

The Yellow and Yangtze River basins face severe land degradation and desertification at the source region due to the rapid melting of permafrost. In the case of Bangladesh, large areas of the north-west and south-west of the country, which form a part of the Ganges River basin, are prone to desertification. Lower precipitation levels and higher levels of evapo-transpiration (the sum of evaporation and plant transpiration from the land's surface to the atmosphere), rampant use of biomass and overuse of groundwater have led to increased land degradation in the river basins. Desertification within the Himalayan River basins of Nepal and India is an emerging issue. Erosion of the land by water will eventually lead to land degradation in Nepal, while India will be challenged by over-utilization of groundwater resources and the use of polluted water for irrigational purposes, particularly in the Ganges and Yamuna River basins.

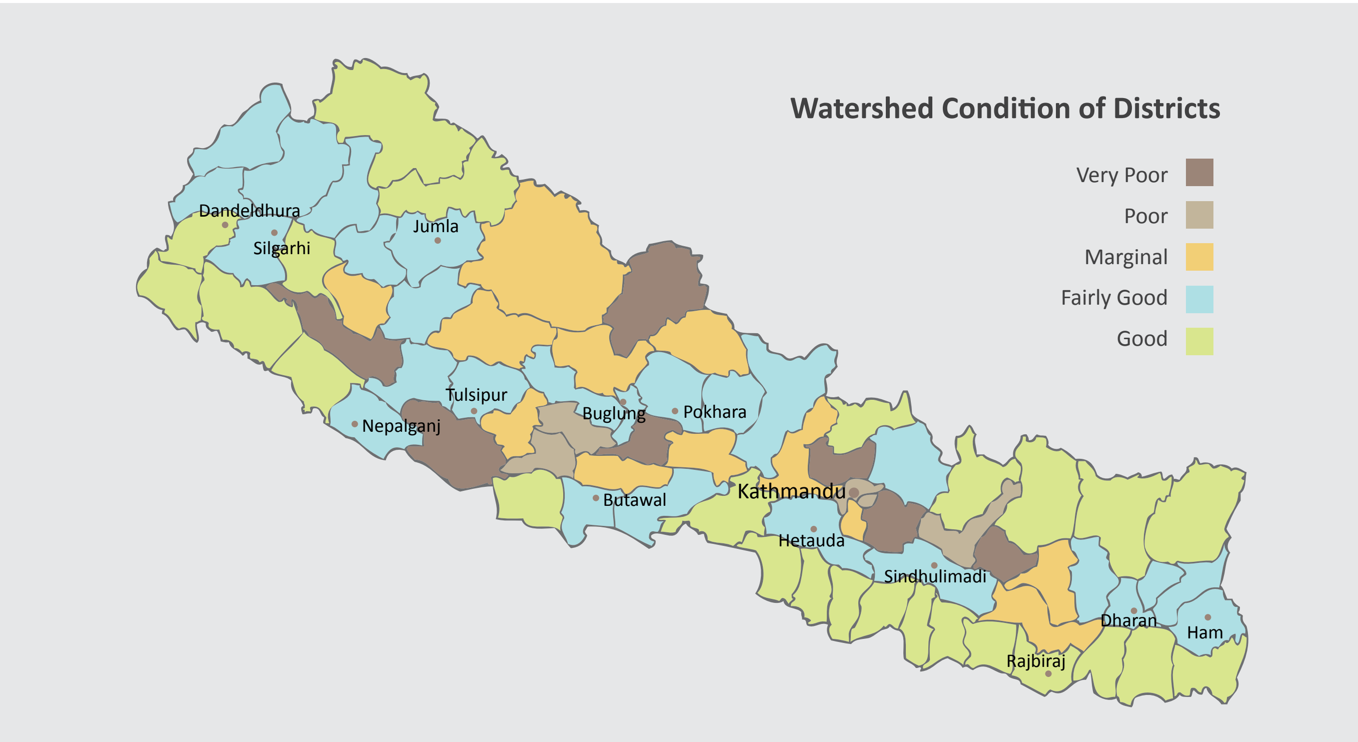
Desertification in China too has been occurring at the source region of the Yellow and Yangtze Rivers. Rising temperatures combined with a drop in precipitation levels has increased the pace at which permafrost melts. In addition, land already exposed to desertification at the source region of the Yellow River has been expanding at the rate of 1.83% per year - a significant amount considering that such land is rendered virtually un-utilizable thereafter. Studies conducted by Greenpeace have shown that the Yellow River is losing water at an average annual rate of 13% at the source region. As a result, the middle and lower reaches of the river are drying. Such occurrences pose a direct threat to the economic and social development of those dependent on the river for their survival – with supplies of safe drinking water inadequate to offset demand. As a result of the falling river levels, the lower reaches of the basin experience rampant land degradation, brought on by drought-like conditions.

The flow and quality of water at the middle and lower reaches of the Yangtze River is increasingly threatened by desertification. In addition, the survival of China's largest freshwater lake, Lake Poyang, in Jiangxi province, is also challenged by the prospect of droughts. In the winter of 2007, the surface area of the lake was approximately 1.6% of its 3500 square kilometres in the summer flood season. Instances of drought in Lake Poyang can be used as an indicator to measure water availability in the Yangtze River, particularly since the size of the lake is directly proportional to the rise and fall of the river. The impact of the lake shrinking is significant, as over 100,000 people are dependent on its water for their domestic and drinking requirements. China's Hubei province has seen the number of lakes reduce from 1066 to 326 since 1950, highlighting the potential impact of scarce water availability.

Nepal is confronted by the challenge of 'too much water, too little water', a phenomenon which is giving rise to instances of desertification across the Himalayan nation. Erosion, rising temperatures, high levels of evapotranspiration and unsustainable land use practices are resulting in greater tracts of land being classified as semi-arid to arid. The process is likely to intensify over the next few decades, as the impacts of climate change become increasingly intense and visible. Nepal's National Action Programme on Land Degradation and Desertification stated that erosion due to water was responsible for 50% of desertification across the country in 2004. The erosion of land by water has significant consequences on the environment, resulting in terrain deformation and the loss of the rich topsoil. Droughts across Nepal, stemming from the long winter dry spells confronting the country, are likely to exacerbate desertification, with districts such as Surkhet and Mustang most vulnerable. Estimates suggest that approximately 74,000 hectares of cultivated land in 16 districts of East Nepal was affected by drought in 2001. The result has been a failure of food crops, which understandably has major repercussions on the local population.

As harmful climatic processes occur more often in the future, Nepal is likely to face considerable challenges. Meanwhile, land degradation in the flat lands of the country is becoming worse due to sand deposition as rivers in the country change their course. The Koshi River, to the east of the country, has destroyed approximately 1300 square kilometres of land through sand deposition. In addition, many watersheds in the country are threatened by desertification as a result of physical and biological factors, with reports suggesting that 0.4%, 1.5% and 11.7% are in very poor, poor and fair condition respectively.

State of Desertification in Nepal



Source: "National Action Programme on Land Degradation and Desertification" http://www.unccd.int/actionprogrammes/asia/national/2004/nepal-eng.pdf

Woes of Ruo'ergai Wetland

The wetlands in the upper reaches of the Yellow River, cover 16,671 hectares of land in the Sichuan province. They are known as the 'Reservoir of the Yellow River' and supply almost 30% of the river's water. This is one of world's most important areas in terms of biodiversity and is also the world's largest alpine wetland. However, over the past 15 years, these wetlands have been reduced by almost 40% as a result of global warming, reduced rainfall and human activities. A large number of rivers and lakes in these wetlands have either shrunk or dried. The Xingcuo Lake has shrunk from 469 hectares to less than 10 hectares. It has become a source of desertification and is now a threat to the surrounding meadows. Experts say that the desertification of the Ruo'ergai is now going on at an annual rate of almost 12%.

Anthropogenic Factors

Climate-induced change is not the sole reason for land degradation in the Himalayan sub-region. The Yellow River basin, with a high average population density, covers a land expanse which is pre-dominantly classified as arid, semi-arid and dry sub-humid. Agriculture and animal husbandry constitute the primary occupation of the region, resulting in intense pressure on the land, as people depend on it for their livelihood and daily sustenance. Low vegetation cover as a result of overgrazing, excessive groundwater extraction and deforestation, are together responsible for having outstripped the carrying capacity of the land, prompting its degradation. Provinces such as Ningxia and Shanxi have experienced degradation of the land at a rate of 90-97%, in comparison to provinces with lower population densities such as Xinjiang, Inner Mongolia and Qinghai, which recorded land degradation at the rate of 80-87% since 1949. A report published by Greenpeace on the Yellow River states that around 3000 small lakes in this region have disappeared over a period of 15 to 20 years. Furthermore, grasslands in the Maqu County of Gansu province and the wetlands of Ruoergai in the upper Yellow River are slowly turning into deserts.

As in the case of the Yellow River, intensification of economic activity has been a major cause of land degradation in the Yangtze River basin too. Deforestation in the basin has resulted in the loss of over 85% of its forest cover during 1990s. Furthermore, the Yangtze basin is threatened by desertification despite the apparent abundance of water. Reports indicate that a quarter of China's land is desert, with the rate of desertification of the land over 3000 km^2 per year since 2000.

Land degradation in Nepal has been exacerbated by the expansion of rain-fed cultivation onto marginal lands, inappropriate crop intensification, mining, overgrazing, groundwater extraction and uncontrolled harvesting of biomass. The country is extremely vulnerable to erosion and degradation, given that its three main rivers flood quite often. In addition, deforestation in the Terai region resulting from efforts to bring more land under cultivation has increased the rate of erosion. Between 1990 and 2000, Nepal has lost an average of 917 sq. km of forest per year to these factors. In 1990 the total forest cover in Nepal 48,170 sq. km, which declined to 39,000 sq. km by 2000 and 36,360 sq. km by 2005. The average annual rate of deforestation was 1.90% during the same period. Between 2000 and 2005, this rate has decreased to 1.35% per annum. If that trend continues between 2005 and 2010, the total forest cover in 2010 should be 33,885 sq. km.

Rapid depletion of water in the Ganges and Yamuna basins in India, coupled with depleting groundwater resources in the surrounding areas, is likely to result in desertification in some parts of the river basins by 2020. The groundwater table in areas around New Delhi, which are fed by the Yamuna River, has decreased 20-30 meters since the 1940s, and is currently decreasing at an average rate of 3 metres per year. As a result, areas along the banks of the Yamuna will be unable to sustain themselves unless adequately replenished. In addition, semi-arid conditions along most of the river and destructive human activity are responsible for intensifying the desertification of the land along the rivers.

Bangladesh experiences extreme seasonal variability, with floods during the monsoons and droughts in the dry periods. November to April is typically marked by aridity, with districts to the north-west of the country such as Rajshahi and Kushtia; Jessore and Pabna, Bogra to the west and Dinajpur to the south especially prone to desertification. The groundwater table in the region drops below 8.95m to 18.56m during the dry season due to over-extraction. The low flow of the rivers, lower precipitation, over-exploitation of groundwater and higher evapo-transpiration levels have severely affected the soil fertility thereby triggering desertification.

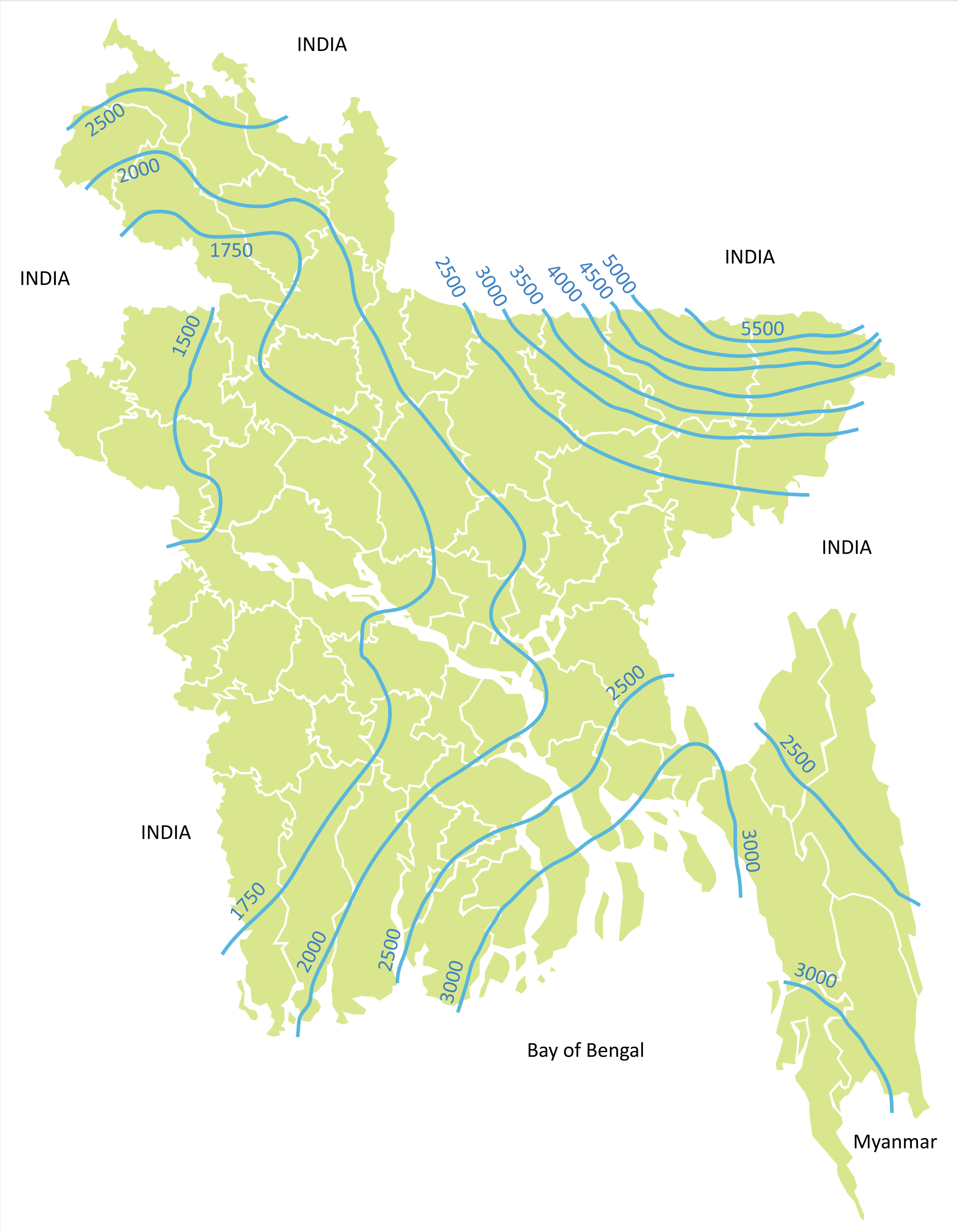
The Brahmaputra River basin in Bangladesh faces 'excessive evapotranspiration'- when the daily actual evapotranspiration rate exceeds the daily rainfall rate, i.e. the daily evapotranspiration being between 200mm to 400mm, with regions in excess of 400mm considered 'dry'. As a result, a large part of the basin faces drought for most of the dry season. Meanwhile, the north-central region near Dhaka faces moderate drought during the dry season, with annual rainfall less than

Misfortune of Maqu

Situated at the convergence of the Gansu, Sichuan and Qinghai provinces, the Maqu County was a large grassland area about 50 meters from the Yellow River. The county was known to have one of the largest wetland areas in the world, earning it the distinction 'Cistern of the Yellow River', as it supplied 45% of the river's water. However, the story is vastly different today, as the grasslands and 200km along the riverbank are increasingly threatened by desertification. Water bodies in the region, such as lakes, swamps, and wetlands have shrunk from 66,700 hectares to 20,000 hectares i.e. almost one-third. More than 90% of the total 856,000 hectares of grasslands have degenerated, with 6% of the grassland area now a desert. In addition, desert-encroached areas have been increasing by 6.14% annually since 1990. The Government of China has stated that overgrazing by cattle, deforestation and global warming are the reasons behind the pasture lands turning to sand. The banks of the Yellow River are being seriously affected by the desert's encroachment. As a result, water-levels have significantly reduced, leading to approximately 1000 springs drying up. Meanwhile, severe desertification along the Yellow River in the Qinghai Province has increased the sand content of the water, directly influencing the quality and quantity of water in the lower reaches of the river.

1600mm and evapo-transpiration in excess of 400mm. Degradation of the land in the region is exacerbated by human activity on land and water resources. The Meghna River basin in Bangladesh receives sufficient rainfall and has relatively fertile land, thus not making desertification an issue for the river basin.

Bangladesh : Mean Annual Rainfall (mm)



Source: http://www.banglapedia.org/httpdocs/Maps/MR_0052.GIF

Loss of Biodiversity 07

Climate change and the influence of anthropogenic factors are affecting the sustainability of the Himalayan River basins. The river basins in China, Nepal, India and Bangladesh are increasingly facing threat which will result in the loss of ecosystems. This will further affect the quantity and quality of water and will result in a complete loss of biodiversity. Rivers such as the Ganges and Yamuna in India and the Yellow and Yangtze Rivers in China face excessive organic pollution from domestic sewage, industrial effluents, and hazardous chemicals that are regularly dumped into them. Progressive exploitation of all forms of water resources, rising temperatures and lower precipitation levels are altering the ecosystems. In addition, the changing flow of the rivers, as a result of dams and barrages, has also threatened the fish biodiversity and wildlife in these countries, leading to their sharp decline.

The Yellow and the Yangtze Rivers in China are rich in biodiversity due to their unique geographical and ecological conditions, especially at the source region. In recent years, due to climate change and the degradation of biodiversity as well as uncontrolled human activities, the number of plant and animal species in the region has declined sharply. Many animal species such as the wild yak, Tibetan antelope, snow leopard, lynx, Tibetan gazelle and argali, which are commonly found in the source region, are hunted for their meat. As a result, their numbers too have declined and many of them are on the verge of extinction. In addition, valuable herbal remedies native to Qinghai Province which are used for medicinal purposes, and serve as a cure for hypertension, gastro-intestinal diseases and blood pressure are on the verge of extinction due to increased human activities and subsequent pressure on the land.

The functioning of the upstream ecosystem has had a direct impact on the productivity of the middle and lower reaches of these river basins. Flushing out sediments is an important function of the Yellow River as it protects the biodiversity and helps in sustaining the wetlands and fisheries at the mouth of the river. According to the Working Paper on the Yellow River published by IWMI in 2003, the minimum river flow required to flush out sediments is 14 BCM. An additional 5 BCM is necessary for other environmental requirements such as sustaining grasslands, wetlands and fisheries. This constitutes approximately one third of the annual flow of the Yellow River. However, this minimum flow has not been maintained, with the surface water being used almost to its full capacity for industrial, urban and agricultural needs. This has created a host of ecological problems downstream such as deterioration of wetlands and sea-water intrusion into the groundwater tables, which has, in turn affected the biodiversity of the region.

The middle and lower reaches of the Yangtze River basin have around 300 species of birds, 360 species of fish and 80 species of mammals. The basin is home to a wide range of animals such as leopards, giant pandas, Siberian cranes and Chinese sturgeon. In addition, the Yangtze River dolphin, which is one of four exclusive freshwater species in the world, is also found in this region. These dolphins, which were earlier found in smaller connecting rivers and lakes such as the Qiantang and Fuchun Rivers and Dongting and Poyang Lakes, are now seen only in the main river stream of the Yangtze. Recent studies have shown that these dolphins are presently 'functionally extinct', indicating that their numbers have declined significantly as a result of excessive pollution and insufficient freshwater. In addition, the number of animal species has fallen from 126 in 1980s to 52 in 2002 due to the widespread pollution. It is important to note that the loss of animal species is not quantifiable in monetary terms, with its biggest impact likely to be felt on future generations.

As with the Himalayan Rivers flowing through China, the Ganges River in India and Bangladesh traverses diverse ecosystems and sustains varied biodiversity. Along with the endangered Ganges River dolphin, which is mainly found within the river's length in Nepal, India and Bangladesh, the basin is home to around nine species of aquatic mammals and reptiles and, eleven species of freshwater turtles. In addition, the basin supports many plant species that help in water conservation, control soil erosion, provide nutrients and possess medicinal properties. The functioning of the Ganges River, which supports the rich flora and fauna, has reached a critical level as a result of tremendous pollution, excessive use of water and altering land use practices, resulting in the loss and degradation of the ecosystem and biodiversity. The Ganges River dolphins have reduced by 50% in the last five decades. It is estimated that there are approximately 2000 surviving today. Given the present rate of decline, it is estimated that the Ganges dolphin will be extinct by 2050.

Similar to the situation with the Ganges River, increased human activity such as deforestation and water pollution in the Brahmaputra basin has increased the pressure on the region's fragile ecosystem. The Brahmaputra basin provides a unique habitat for many

Sunderbans: Bereft of Beauty

The Sunderbans National Park is a UNESCO World Heritage Site formed at the Delta of the Ganges, the Brahmaputra and the Meghna rivers at the point where they flow into the Bay of Bengal. Sundarban means 'beautiful forest' and is one of the largest mangrove forests in the world. Approximately 62% of the mangroves are found in Bangladesh, while the remaining 38% lie in the southern tip of West Bengal, in India. Numerous creeks and inter-connected rivers supply freshwater to the delta from these Himalayan rivers.

At present, the Sunderbans delta is experiencing a sea-level rise of 3.14 mm per year, almost 63% more than the global average sea-level rise of 2 mm. The islands in the Sunderbans delta in India such as Lohachara and Suparibhanga have submerged as a result of the rapidly rising seas. Estimates suggest that 15% of the Sunderbans will be completely submerged by 2020. Rising sea-levels will also result in an increased level of salinity in the soil and water resources, which will negatively impact the growth of mangroves.

In addition to supporting a diverse and vibrant collection of flora and fauna, a large number of people are dependent on the Sunderbans for their livelihood. Deforestation, conversion of land for agriculture, shrimp farming and unplanned development projects have not just disturbed the overall environmental balance there but have also resulted in the loss of a significant portion of the mangrove forests. The increased economic activity along with sea-level rise is expected to further destroy this already fragile ecosystem.

rare and endangered species such as the great Indian one-horned rhinoceros, pygmy hog, hispid hare, Asiatic elephant, clouded leopard, marble cat, golden cat, binturong, hoolock gibbon, the white-winged Wood Duck and the Bengal Florican, which are presently endangered.

The numerous wetlands, or 'beels', found in the Brahmaputra basin are ecologically significant as they support a diverse range of flora and fauna. There are over 3,500 wetlands in Assam, 177 of which are of more than 100 hectares in size. These wetlands retain floodwaters that act as nurseries for harvesting traditional fisheries. As a result of the excessive siltation and unrestrained agricultural practices these wetlands are gradually degrading. In addition, there has been considerable decline in forest cover due to deforestation and conversion of land for cultivation. Shifting or 'jhum' cultivation, which is widely practiced in the north-eastern region, is a major cause of deforestation and has had a disastrous impact on the region's ecology through soil erosion and loss of soil fertility.

The Sunderbans, situated near the Ganges River and spread across areas of West Bengal in India and Bangladesh, form a fringe of the delta. The seasonally-flooded Sunderbans are home to approximately 330 plant species, 400 species of fish, 270 species of birds, 35 species of reptiles and 42 species of mammals. Covering about 10,000 sq km of forest area, it provides employment opportunities to the local economy and protects the coastal areas from storms and cyclones. Over the years, the unrestrained and inefficient use of ecological habitats has resulted in the loss of biodiversity in the region. Shrimp farming, mainly located in the Ganges River basin districts of Satkhira, Khulna and Bagerhat, is one of the fastest growing export industries in Bangladesh. However, intensification and expansion of shrimp farming has reduced the size of the Sunderbans in Bangladesh by 45%. The costs associated with economic growth on the natural environment are enormous, highlighting the need to focus on sustainable growth, which balances ecological longevity with development aspirations.

While the Himalayan River basins of China, Nepal, India and Bangladesh are environmentally varied, Nepal is considered a biodiversity 'hotspot', reiterating its importance to the overall balance of the region's ecology. The elevation of the land, climatic variations and diverse vegetation, make the country home to approximately nine eco-regions of the 60 found in the Himalayan region. The National Action Programme on Land Degradation and Desertification, states that Nepal has over 2% of flowering plants (about 7,000 species) and 8% non-flowering plants of the world. In addition, approximately 4.5% of the worlds' mammals, and over 9% of bird species are found in Nepal. Studies have shown that around 11 species of birds and 3 species of mammals are already extinct due to the destruction and alteration of the habitat, over-exploitation of species and climate variations.

Wetlands comprise approximately 2.6% of Nepal's area and support the country's rich biodiversity. In addition, given Nepal's abundant water resources, water availability is not a major issue for the country. However, the wetland ecosystem is under constant pressure from unsustainable agricultural practices, deforestation, encroachment and overgrazing. The tourism industry, a source of revenue, is heavily dependent on the Himalayan Rivers and the biodiversity of the country. As the pressures from population growth and anthropogenic factors increase, the economic growth of the country will be affected in the future.

Impact on Livelihood

As temperatures rise, the incidence of droughts will also increase. Lakes are expected to gradually disappear in the Yellow and Yangtze River basins, further affecting aquatic and animal life there. A report on climate change by the United Nations Environment Programme (UNEP), states that colder winters, frequent droughts, and flooding will result in the reduction of the rate of fish reproduction by 10% by 2030. It is also estimated that 80% of the water flowing in China's rivers is unable to sustain fish life. This has not just affected the food supply but has also hampered the livelihoods of people engaged in the fishing industry.

Similar to the Yellow and Yangtze River basins, lack of freshwater has also affected the livelihoods of people dependent on the Ganges River in India for their sustenance. Fishing activities are primarily carried out by the poorest sections of society. The estimated decline in river water by 2030 will surely affect the livelihoods of millions of people dependent on this industry within the region.

In Bangladesh, the Himalayan Rivers play a crucial role in maintaining the water flow in smaller river channels, thus controlling salinity intrusion as also helping sustain human and economic activity. The water flow facilitates connectivity with the smaller rivers for navigational purposes and helps maintain wetlands for open water fishing. Approximately 60% of land area in Bangladesh can be classified as wetlands over a seasonal period. However, wetland areas are shrinking due to expansion of boro rice cultivation especially in north-eastern regions, which includes districts such as Sylhet and Mymensingh. This has resulted in the decline of aquatic life. Estimates suggest that 70 million people in rural Bangladesh rely on the wetlands for their livelihood, with four out of every five people in rural areas dependent on aquatic resources to some extent.

The fishing industry in Bangladesh is an invaluable source of food security and nutrition to a large percentage of the population. The poor people in Bangladesh are even more dependent on fish for their survival. The degradation of fresh water due to human activity has led to a decline of fresh water fishing. It is reported that freshwater fish consumption fell by 38% amongst poor wetland inhabitants between 1995 and 2000. (The statistics for the last decade are not available) In future, rising surface temperature is expected to have a negative impact on fisheries, particularly shrimp farming. Furthermore, in the eventuality that temperatures cross a threshold of 32° Celsius, small shrimps will show a higher rate of mortality, which will eventually result in their decline.

Fishing is not a major industry in Nepal though it is an important source of additional income for rural people. Climate change is considered a serious threat to the aquatic biodiversity in this region. An IPCC Special Report on 'The Regional Impacts of Climate Change' states that fisheries at higher elevations, such as the hill or mountain fisheries in Nepal will be affected due to lesser availability of oxygen in the atmosphere as a result of increased temperatures. The timing of the monsoons in the plains and the expected deviations in the precipitation patterns due to climate change will also adversely affect migration of fish species from the river to the floodplains for spawning, dispersal, and growth. Any extreme weather events, such as floods will also be active factors in the depletion of fisheries in the plains.

The Eastern Himalayas are a source region for the major rivers in China, Nepal, India and Bangladesh. These ranges have been identified as one as one of the most threatened biodiversity spots of the world. The linkages between climate change factors and the effects of human activity on freshwater ecosystems that lead to the loss of biodiversity are apparent. In the next 20 to 30 years, fluctuations in water availability at the source region will have a detrimental impact on the river basins downstream, especially during the dry season. Changing climate patterns such as rising temperatures and unreliable precipitation will further alter the availability of water in these basins. This will directly impact the future of ecosystems and biodiversity.

In addition, as the basin population and economic sectors grow simultaneously, the loss of ecosystems and biodiversity will occur at an accelerated pace. Given the present trend in water use, it is estimated that the demand for water will outstrip the supply, especially in China and India. Changes in land use patterns and expansion of arable land will become inevitable, further straining the ecosystem of the river basins. The availability of freshwater biodiversity in these countries acts as a crucial parameter to measure the social and economic well-being of the population. Provision of food security will be a major issue as these countries try to maintain a balance between water required for human activity and, ecological services over the next 20 to 30 years.

Food Security 08

The Himalayan glacier-fed rivers face numerous environmental challenges such as increasing pollution, over-extraction, sea-level intrusion and flooding amongst others. Besides, as the rainfall patterns change, temperatures fluctuate and groundwater resources deplete, the water situation in the Himalayan sub-region could become increasingly precarious. Agriculture, as the primary source of employment in China, Nepal, India and Bangladesh, is likely to take a severe blow not just in terms of economic gaps in demand and supply of food production, but also with regard to loss of livelihood and nutrient consumption. The agricultural sector is almost entirely dependent on the annual monsoon season and the subsequent replenishment of surface and groundwater resources. However, irrigating the land is becoming more and more difficult as groundwater tables recede and annual river flows fluctuate. As a result, the lives of people dependent on agriculture become vulnerable to issues of water scarcity. Moreover, as competition to gain access to food intensifies and livelihoods are threatened, human security is also being increasingly threatened.

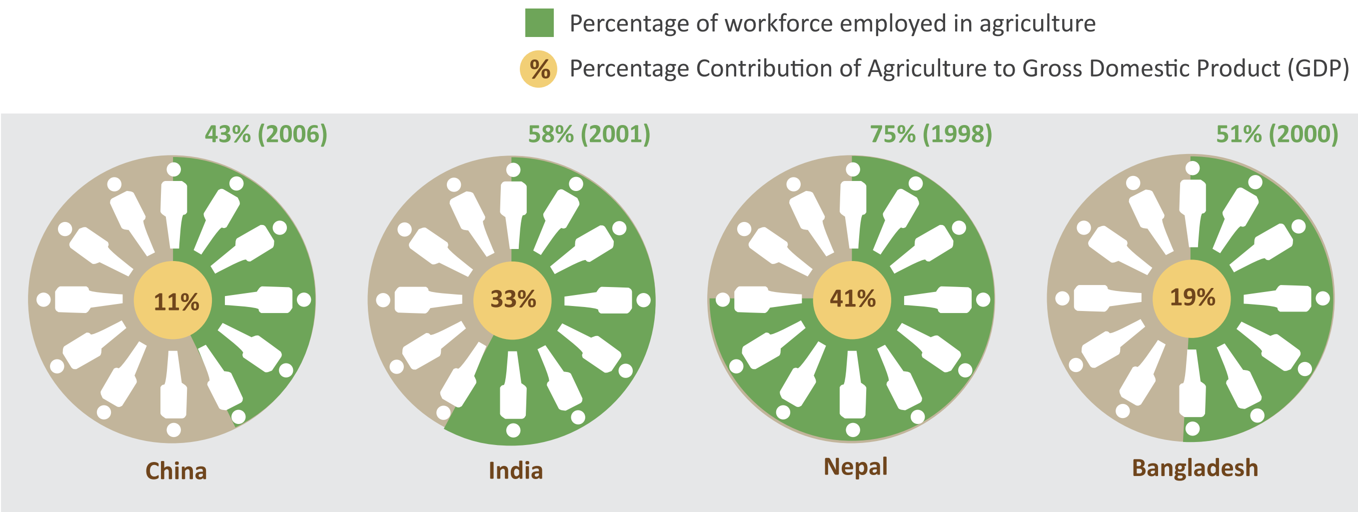
As with several other issues confronting the Himalayan sub-regional countries, the issue of food security does not occur in isolation. The repercussions of scarce water resources are likely to be felt at various levels and over an extended period of time. As arable land is lost, people will be forced to look for other means of sustenance. Meanwhile, a reduction in food supplies could result in price inflation or, the importing of food from elsewhere. 'Food insecurity' is not new to the sub-region, with Nepal and Bangladesh already facing the issue. Furthermore, there is a real possibility that the Himalayan basins of China and India could fall prey to the problem, putting the lives of close to 1.3 billion people at risk.

Agrarian Economies

China, Nepal, India and Bangladesh are primarily agrarian economies. Approximately three-quarters of Nepal's total workforce are engaged in agriculture. Similarly, over half of India and Bangladesh's workforce belongs to the sector while over 40% of China's labour is in the farm sector.

Agriculture is an important though declining component of the national economies of all four countries, as a share of Gross Domestic Product (GDP). About one-third of India's GDP and 40% of Nepal's GDP is contributed by the farming sector. Agriculture contributed about to about 11% of China's GDP in 2006 and 19% of Bangladesh's GDP in 2007. While agriculture is important to the region, the examples of China and Bangladesh highlight the extent of 'underemployment' present in both countries. Given that agriculture accounts for approximately 40% of China's workforce and 50% of Bangladesh's, the corresponding GDP figures are indicative of the small contribution (%) made by the sector to the overall national economy. In addition, agriculture is the largest consumer of water in the region – accounting for over 80% of the demand for the resource in India and Nepal, over 90% in Bangladesh and, approximately 65% in China.

Agriculture : Employment, Contribution to National Economy



The primary crops of the Himalayan sub-region are rice, wheat and maize. While other crops such as rubber, banana, tea and cotton are grown in the region, rice is the dominant crop in the Yangtze, Ganges, Brahmaputra, Karnali, Gandaki and Saptakoshi basins. Rice is also a very important crop among the three river systems in Bangladesh. Wheat farming constitutes the predominant crop in the Yellow River basin, while tea and rubber are important to the Brahmaputra basin in India. Once the Brahmaputra enters Bangladesh, jute takes precedence over the rest of the crops.

Dependency on Monsoon

Production of crops over the past few decades has been determined largely by the changing rainfall patterns in the Himalayan sub-region. The monsoon season, which is vital to the agricultural sector, now experiences fewer days of annual rainfall, typically defined by intense showers that are harmful to crops. This trend is likely to deteriorate in the future, with the agricultural sector taking a big hit. Despite improvements in irrigation infrastructure in China, India, Nepal and Bangladesh, farming still continues to be monsoon-dependent. While the countries of the sub-region are equipped to deal with occasional variations in the yearly rainfall, in terms of sufficient food stocks – recurring instances of deficit rainfall could still affect food supplies and thus shoot up prices.

In many aspects, a significant proportion of the GDP of China, Nepal, India and Bangladesh is linked to the monsoon season. Given that agricultural sector accounts for a large percentage of the national economy in these four countries, weak monsoons could affect farming output and subsequently the GDP.

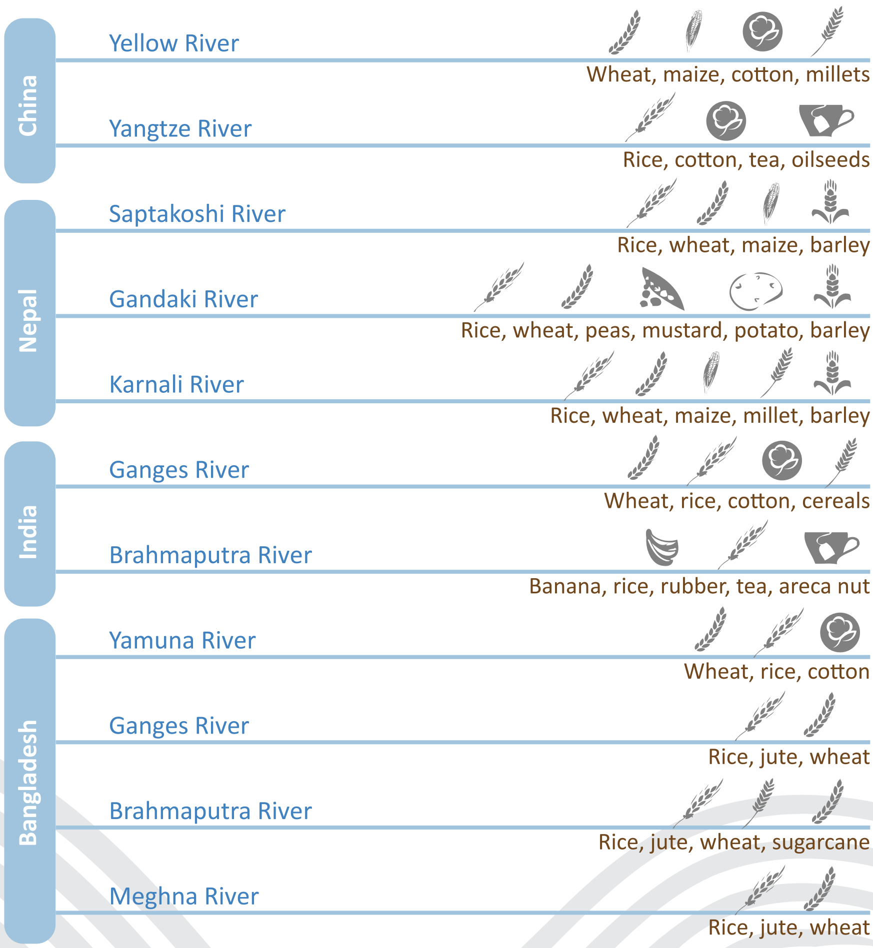
The relationship between irrigation and agricultural output is closely inter-linked. Farming units that are equipped with irrigation infrastructure are less likely to be dependent on the monsoon season and hence, on deficit rains. Although irrigation is dependent on rainfall and groundwater resources, it works as a buffer of sorts, allowing crops to be watered during periods of less rainfall.

The Yellow River in China is largely dependent on irrigation, owing to its location in an arid to semi-arid region. With approximately 7.5 million hectares of land under irrigation, the basin is one of the largest groundwater irrigated areas in the country. This dependence sets a dangerous precedent for future agricultural output in the region, as water scarcity is likely to have an impact on groundwater resources, which in turn will impact irrigation. Although irrigation reduces the impact of deficit rain on agricultural production, it ceases to be of much help during prolonged periods of no rainfall. The droughts in early 2009 affected about 63% of Henan province's 5.26 million hectares of wheat. The province contributes towards 25% of China's overall annual wheat production, highlighting its importance to the national narrative.

Nepal, which has only 35% of its 2.3 million hectares of arable land irrigated, faces numerous hindrances to its agricultural output in the event of delayed monsoons. It is imperative that the country's infrastructure is expanded to cover larger tracts of land, particularly in the mountain and hill areas, as they do not receive as much water as the Terai belt. As an example, Nepal suffered poor monsoons in 2006-2007 which resulted in a drop in rice production by 600,000 tons from the previous year, while a normal season in 2007-2008 resulted in a surplus of cereal production for the year – highlighting the vulnerability and dependence of output on rainfall. A good monsoon season in Nepal usually boosts the country's export of food produce, further driving the country's GDP higher. However, Nepal's over-dependence on an erratic monsoon affects the agricultural output and threatens to impact on the country's ability to feed its growing population. This also indicates the urgency with which Nepal must develop its irrigation infrastructure.

In India, 84% of the total wheat sown area and 47% of the total rice sown area is irrigated. Within the Himalayan river-fed basins and in particular, the Ganges, over 50% of the grain area is irrigated. Water from the river is used extensively for irrigational purposes, with the cultivable land in the states of Uttar Pradesh and Bihar, benefiting from the irrigation canals, which begin in Haridwar in the upper reaches and Naraura in the lower reaches. Large areas of land in Uttar Pradesh and Bihar are also irrigated by channels running from hand-dug wells. The high levels of dependency on irrigation within the Ganges basin make the quality and amount of water available in surface and groundwater reserves extremely vital to the future of agriculture in India. Given that water scarcity is likely to become an issue within the basin and that pollution is rampant in the Ganges River, agricultural production in the region could be affected drastically in the future. However, it is the repercussions of falling agriculture that are more likely to result in a larger systemic problem, as

Main Crops of Each Basin



employment opportunities decrease, food prices soar and human security is threatened.

Irrigated land in Bangladesh constitutes approximately 4.3 million hectares, or 50% of a total cultivable area of 8.4 million hectares. While the percentage amount with regards to total area is relatively large, Bangladesh's irrigation is 70% comprising of tube-well technology. This has strained groundwater resources during the dry season. In addition, the high levels of arsenic contamination in groundwater resources in Bangladesh are an increasing cause for concern, especially as the polluted water is used for agriculture. Furthermore, growing salinity brought on by sea level rise is also affecting the quality of the soil quality with estimates suggesting that over 443,000 tons annual rice production could be lost by 2050.

Rising Temperatures

Global warming has not only resulted in rising in temperatures but has also had an impact on crop production in the Himalayan sub-region, leading to changing patterns of land use as well as the crop variety. As China, Nepal, India and Bangladesh are located close to the equator they are likely to be adversely affected by a rise in temperatures – a fact reinforced by the IPCC in 2007. Over the next few decades, changing climatic conditions, particularly higher temperatures, will have an impact on agricultural production especially since crops require cooler temperatures. Moreover, crops such as rice, wheat and maize, that require warmer, humid climes, will have to be cultivated at higher altitudes, as their current cropping locations is becoming inhospitable. In addition, a rise in temperatures will prompt the use of hybrid crops, which are capable of sustaining higher temperatures and require less water.

Because of the impact of rising temperatures on agricultural practices in China, rice cultivation is moving northwards. The southern Chinese province of Guangdong, historically known to be a rice region, lost half of its crop area, or the equivalent of 85,000 hectares per year, between 1979 and 2005. By comparison, the north-eastern province of Heilongjiang, gained 64,000 hectares per year, highlighting the fact that temperatures in the region are warming up and are becoming more conducive for rice cultivation. Similarly, winter wheat cultivation in the north-east is moving further north and extending westward, to more suitable climates.

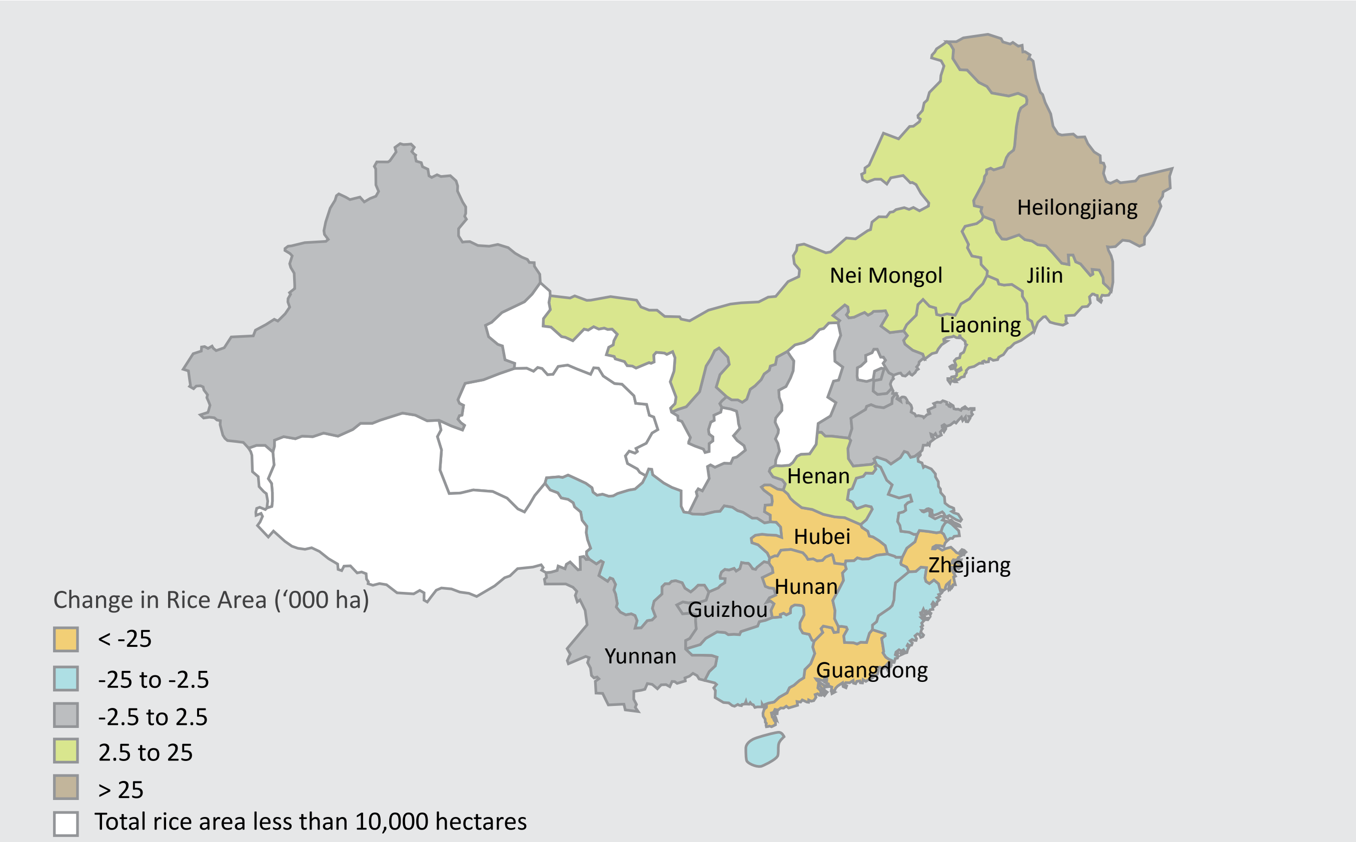
The situation is similar in India, with studies revealing that summer time temperatures in the north-east of the country have increased by an average of 5°C over the last two decades. The 2009 monsoon season saw Guwahati in Assam record maximum and minimum temperatures higher than the average by 5°C and 1°C respectively. Meanwhile, Shillong recorded a maximum temperature 3°C above normal. Given that these areas are traditionally engaged in the growing of tea, any increase is bound to have an impact on long-term productivity. In 2007, tea production fell by as much as 30% as a result of higher than average temperatures and a deficit rainfall. The Tocklai Experimental Station in Jorhat (the world's oldest institute for tea research), stated that irregularity in rainfall and rising temperatures will affect tea output and crop production adversely in the future.

The transition period, or the process over time by which agricultural production shifts base in a country, is likely to result in an overall increase in short-term output. However, this will be a temporary process, with rice cultivation in the Terai region for example, increasing Nepal's overall yield in the immediate future. Areas growing rice and wheat are likely to expand in Nepal in the immediate future, a trend that will be accompanied by a short-term increase in productivity. However, in order to be self sustainable, Nepal will have to increase its production of major crops with the intention to export surplus food grain.

In the long term, rising temperatures will impact the crop production, with every 1°C rise in temperature causing decline in the crop yield. Lower altitude regions in China, India and Bangladesh, will experience a 12% drop in rice yield for every 2°C rise in temperature. Assuming all other things remain constant, as per 1990 rice production levels of 192 million tons (M t), a 2°C rise by 2020 will result in a drop in rice production to 168.96 M t.

As per the General Circulation Model (GCM), a 2°C rise in temperature in Bangladesh at 330 ppm CO_2

China : Annual Change in Rice Area Between 1979 and 2005 by Province



decreased the yield of HYV (High Yielding Variety) Aus rice by 19%. Given that the production was 0.77 M t in 1991-92, and assuming all things remain constant, a 2°C temperature rise by 2020 will result in a fall in HYV Aus rice production to 0.62 M t.

If Bangladesh experiences a 2°C rise in temperature and 30% moisture stress by 2030, then the winter (boro) rice yield will decrease by 1-4% of the base year yield of 1990. By 2050, a 4°C rise in temperature and a moisture stress level of 60% will cause the winter rice yield to fall by 10-33% of the base year of 1990.

The IPCC's 4th Assessment Report suggests that the warming in India is likely to be above the South Asia average. A selection of regional modelling reports state that temperatures in India could rise between 2.5°C and 5°C by 2100, with a more pronounced impact over northern India. To put it into perspective and to get estimations of by how much temperatures will rise by 2050, we halve the numbers and find that there will be a rise of 1.25°C to 2.5°C by 2050. If global average temperatures increase by 1.5°C to 2.5°C, there is an increased risk of extinction of 20%-30% of the plant species in India. Rising temperatures will have a more serious impact on agriculture and the health of people in India than changing rainfall patterns, a fact reinforced by the Indian Institute of Tropical Meteorology (IITM). Conversely, Nepal is likely to be affected to a greater extent by erratic rainfall, as opposed to rising temperatures.

Degradation of Arable Land

Other processes like desertification, soil erosion, flooding and sea level rise are also going to affect the Himalayan sub-region, all of which threaten to degrade the land and result in a loss of livelihood for people in the region. Loss of arable land will result in a reduction in crop yield as well as perennial plant cover, which could eventually impact animal husbandry.

Tracts of land along the Brahmaputra River in India and sloping areas in the Yellow River basin in

China are prone to soil erosion, which threatens to reduce agricultural productivity. Erosion along the Brahmaputra is aggravated by the frequent foods which hit the basin. The tea-growing areas of upper Assam's Tinsukia and Dibrugarh districts are likely to become victims of soil erosion in the future. The Thannai tea estate in Dibrugarh district was lost forever after the river swallowed approximately 350 hectares of plantation land. Meanwhile, between 1992 and 1999, approximately 1500 hectares of tea-growing land, estimated to be worth Rs.5.4 billion, has been lost to soil erosion.

If the trend continues, the existence of Assam's tea estates could be also be threatened, subsequently impacting the state and the national economy, as well as those employed within the sector. Assam's agricultural sector bears the brunt of annual floods, with estimates suggesting that 12.21% of the geographic area is directly impacted. Overall, approximately 130 million hectares of land or 45% of the total geographic area of India, is affected by soil erosion. Land lost to erosion cannot be recovered, making it a permanent impact on agricultural production as well as a permanent loss of the country's natural resources.

Bangladesh too has to contend with land loss resulting from coastal and river erosion. In the 23 years between 1973 and 1996, approximately 70,000 hectares of land along the banks of the Brahmaputra-Jamuna were lost to erosion. On an average, 3000 hectares of land are lost to erosion every year. As the glaciers melt and rainfall becomes more intense in the short term, the rate of soil erosion will increase in the immediate future. However, the main cause of loss of arable land in Bangladesh remains the rise in sea level, with estimates suggesting that Bangladesh could lose 20.7% of its arable land as a result of a 1m rise in sea level between 1990 and 2100. This could equate to a 6% loss in the country's rice production. According to some speculations, sea intrusion may affect more than 50 kilometres by 2030 and may even reach 200 kilometres in an extreme situation.

In addition to coastal as well as river erosion, Bangladesh is also greatly impacted by arsenic contamination. Given the dependence of agriculture on groundwater, arsenic contamination of the resource could have drastic implications on the health of the population. Ideally, contaminated land should not be used for cultivating crops. Consumption of arsenic-contaminated food through rice, cereals and vegetables, is likely to result in major health implications for people. Despite knowledge of arsenic contamination in soil content and groundwater resources, the land continues to be utilized, more because of the lack of research on the extent to which arsenic contamination has infiltrated the land than anything else. In the long run, arsenic contamination of the land will not only impact on health security, but will also displace farmers from the land as it becomes no longer cultivable.

The Yellow River in China is greatly affected by desertification – a problem compounded by the arid to semi-arid climate in the region. The agricultural output is also heavily dependent on groundwater irrigation. In the case of the Yamuna River, areas surrounding the river will face desertification over the next ten years due to the rapid depletion of water in the river and falling groundwater levels. Agricultural production in the basin area could also decrease in the future, as tracts of land are regularly being rendered uncultivable due to desertification.

The rapid pace of industrialization and urbanization has taken a toll of the land in the Himalayan sub-region by resulting in the loss of arable land. With increasing development, traditional sources of income such as agriculture, will occupy less space in the national economy and people will seek employment opportunities in the industrial and/or services-based sectors. The agricultural sector will nevertheless continue to dominate and will only decrease in comparison to its earlier position/percentage in the macro (national) perspective. It should also be noted that as arable land is lost due to natural processes, agricultural practices will adapt and modernize to ensure minimum impact on overall productivity. The case of China is one such example, where between 1952 and 1997 arable land in the country declined by 12%, as a result of industrialization and urbanization, but grain production increased due to multiple cropping practices and by using advanced methods of cultivation.

Future Prospects

As precipitation patterns change and temperatures increase, the need to alter and adapt modern agricultural practices to ensure crop productivity, will arise in China, Nepal, India and Bangladesh. Alterations to crops will also reflect on changing land use patterns. In Bangladesh, cropping patterns are dependent on land elevation. In lands with normal shallow flooding, farmers are able to grow 2-3 varieties of crops on an annual basis, whereas in the lowland areas, the options decrease. In addition, flooding, sea level rises, changes in rainfall patterns and soil erosion will affect the availability of arable land, thus reacting adversely on cropping patterns.

As water becomes more and more scarce, there will be a greater need for innovative methods to produce water-intensive crops such as rice. Aerobic rice, which is grown on land that is less dependent on water, like wheat and maize, could be increased. This variety of rice, which is being grown in the northern areas of China, uses 50-70% less irrigation than lowland rice. However, given that aerobic rice constitutes only 0.6% or 190000 hectares of China's total rice-cultivated area, this option needs to be pushed for implementation both, across the country and in the other Himalayan sub-regional countries of India and Bangladesh.

Rice production in the Jharkhand state of India is considered to be drought-tolerant. The 'Sabhagi dhan' variety of rice is currently being tested, with indications that it can survive even for 12 days without rain. India's rain-deficient land of nearly 6 million hectares stands to benefit through the development of such a variety of rice. Drought-resistant maize is also expected to be commercialized in India by 2010, which like the Sabhagi Dhan rice could help minimise the agricultural sectors' dependence on monsoons.

Adaptation measures have their limits. Mitigation strategies will be also important in the future. Given that the Himalayan sub-region relies heavily on the monsoons, there is a high possibility that agricultural production in these countries will be affected with rains becoming more and more unreliable. As the Himalayan river basins face increasing water scarcity, the foodgrain production of major cereals like rice, wheat and maize will be greatly affected. As climate patterns change in South Asia, the need for reassessing food production will increase. The issue of food security and its impact on national economies is important, and highlights the need to develop mitigation strategies to protect against any future social or economic disasters.

Nepal's question of food security assumes greater significance as it already receives significant food aid from Japan, France and the United Nations World Food Programme. The river basins of the Yangtze and the Ganges play an important part in the total grain production of China and India respectively. What this means is that the impact of water scarcity on agricultural output in these regions could prove to be catastrophic in terms of the sheer number of people they support. By 2025, the Ganges River basin will contribute almost 50% of the country's total produce. However, population projections at 684 million in 2025 and 868 million in 2050 – will translate into the fact that the agricultural production will be insufficient to meet the growing demand.

Changes in weather patterns and erratic monsoons will most likely increase water scarcity in the dry months. Scientists from India have predicted that changing weather patterns and global warming will reduce crop yields by 30%-50% by 2050. In addition, studies by the Indian Institute of Tropical Meteorology (IITM) state that over the next 50 years, India's monsoon pattern will also change, reducing the number of rainy days in a year by 8%-10% and increasing the intensity of rainfall. This will, in turn culminate into visible changes in the national economy and environment after 2050. It is important to note that the heavier, more intense rainfall predicted for India, the more harm it can cause to crop production. Furthermore, scientists predict that 2009's El Nino effect could become a regular occurrence in the future. If this were to happen, it would pose several more challenges and hurdles as it would make a large part of the arable land in this region susceptible to drought. As a result, future food stocks will be jeopardized and food prices will increase. Failing monsoons will also raise the demand for irrigation, leading to a greater consumption of and demand for electricity. Soil erosion and flooding that damage both, crop and land will eventually force the people dependent on the fertile soils of the Brahmaputra basin to migrate.

Agricultural production in China could decrease by 5%-10% by 2030 – with crops such as wheat, rice and maize being the worst hit. After 2050, climate change is likely to result in a drop in the production of rice, maize and wheat by approximately 37%. China's agricultural output will be affected over the next 20-50 years, though the extent to which food security is threatened will largely depend on how well the country adapts to the changing climatic scenario.

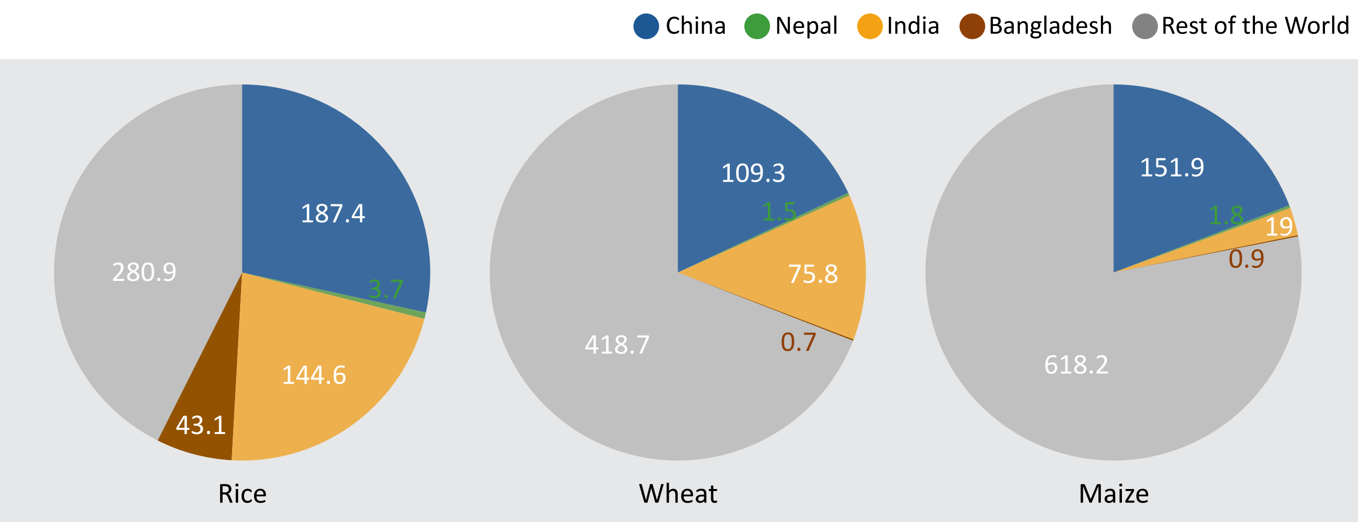
Nepal agricultural output is complicated by the 'too much, too little water' scenario. The country is heavily dependent on food aid, with the World Food Programme estimating that 3.4 of the country's 28 million people are food insecure – a problem worsened due to the rise in food prices in 2007-2008 and by the persistent droughts. The challenge confronting Nepal will eventually lead to more people migrating away from the rural areas. This could result in a possible drop in agricultural production over a period of time.

Considering the impact of various natural and human factors on food production, it is clear from the earlier discussion that crop yield will drop by 30-50% in the case of all the four countries by the middle of the century, particularly China and India which happen to be the two most populous countries in the world. It is expected that during the same period, demand for food grains will increase by at least 20% in the four countries. Thus, they will face a paradox of rising demand and falling supply. The net result will be massive deficit of food grains, anywhere in the range of 200-300 million tonnes per year of rice and wheat.

If Bangladesh, China, India and Nepal enter the world market as net buyers of rice and wheat, they will push the prices of these commodities to the sky. As a result, the poor in not only these four countries but also elsewhere in the world will be affected. This is assuming that crop yield remains the same as today. If there are technological breakthroughs, which enhance the crop yield but significant development of varieties of rice and wheat which require much less water than what can be imagined today, there will be some relief. The real impact of these crises will be felt in the second half of the century. However, we will see some indications already from 2020 onwards. India will also need to increase its own food production to 300 million tons by 2020 in order to feed its increasing population. Soil erosion, changes in monsoon patterns and climate change will make these efforts very difficult.

There is a strong need for mitigation and adaptation strategies vis-à-vis food security in order to safeguard agricultural production in the Himalayan river-fed basins. The looming water scarcity issues threaten to derail not only agricultural productivity, but will have an impact on a range of other environmental and human factors. Also, given the sheer population of the sub-region, a drop in food output will affect global

Contribution of China, Nepal, India and Bangladesh to Food Grain Production (2007) (in million tons)



Source: FAOSTAT. FAO

food prices too.

Over the next 30-40 years, food security in India and China will be greatly undermined as the issues of water scarcity, erratic monsoons, rise in temperatures and loss of arable land become more apparent and urgent. Nepal, which has no water scarcity issues, but is dependent to a large extent on monsoons for its agriculture, will have to survive unreliable annual agricultural production, unless the country rethinks developmental strategies for its irrigation infrastructure. Rising sea levels and extreme weather events will affect agricultural production in Bangladesh, apart from groundwater becoming increasingly contaminated by arsenic poisoning. The extent to which the repercussions are felt by the nearly 1.3 billion people living in the basins, will depend on how well the governments of China, Nepal, India and Bangladesh deal with the impending crisis.

Health Security 09

Conditions that affect the quality of water in the Himalayan sub-region such as pollution, flooding, droughts, and extreme weather events pose a threat to human health. As China, Nepal, India and Bangladesh are located in the sub-tropical region they already face high risk from vector-borne diseases like malaria, dengue and encephalitis. The changing weather patterns and rise in temperatures along with frequent flooding and extreme weather events will only increase this threat. Water-borne and infectious diseases like cholera, dysentery, trachoma and typhoid will spread like epidemics as the region heats up and falls prey to increased water-logging after floods and cyclones. As most of these countries lack a proper public health infrastructure, the suffering will worsen as it becomes increasingly difficult to control the spread of diseases. Inefficient public health systems will only magnify this spread. Since public health depends on safe drinking water and sufficient food, a scarcity of water in the future indicates a bleak future for this region.

Despite differing per capita water availability between China, Nepal, India and Bangladesh, none of the countries have been able to provide access to clean drinking water to their entire populace. At present, the quality of water available to a large segment of the population in this region is not safe for the purposes of drinking or even bathing. The region is already rife with water-borne, communicable diseases. Thousands of people die every year as a result of these diseases. As the Himalayan sub-region battles issues related to its water resources, infectious water-borne as well as vector-borne diseases will become more widely prevalent in the coming years.

Present Dangers

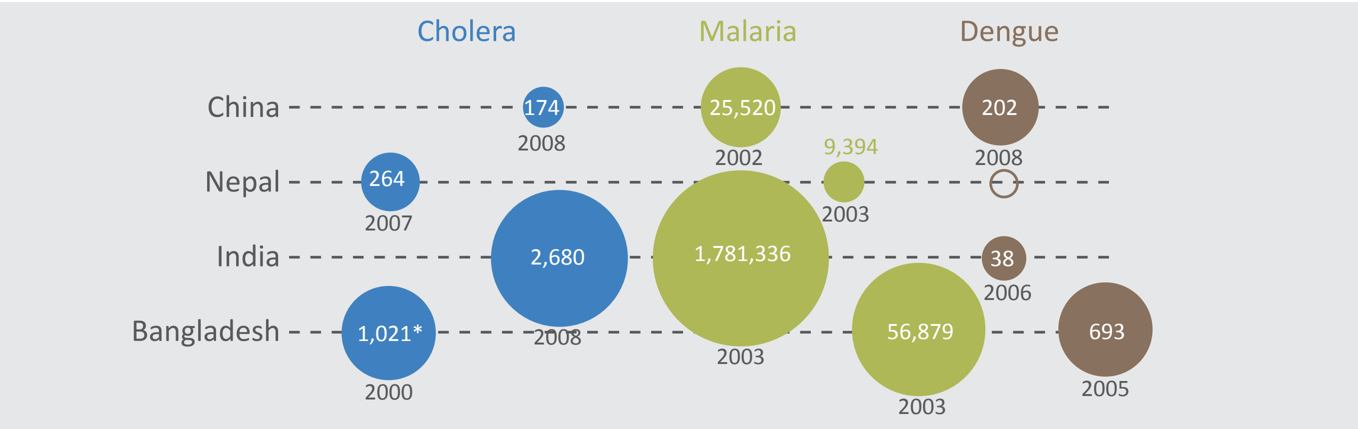
Water-borne and vector-borne diseases are rampant in the poorest sections of the society, amongst those who do not have the ability to pay for clean water. Those who use contaminated water do so out of desperation and lack of any other alternative. These are the people who are also the most affected in case of extreme weather events since many live in temporary homes. China, Nepal, India and Bangladesh are home to some of the poorest people in the world who are at highest risk from vector and water-borne diseases.

Water-borne diseases in China, India, Nepal and Bangladesh are caused largely due to lack of access to clean water and sanitation. With significant sections of the Himalayan river basins lying in the tropical or subtropical region, this region is an easy prey to water-borne diseases due to the warm climate and annual monsoons. Hundreds of cases of water-borne diseases like cholera are reported here every year, especially in Bangladesh and India.

According to the Epidemiology and Disease Control Division (EDCD), Ministry of Health and Population in Nepal, approximately 3000 people died in 2004 due to food and water-borne diseases including cholera, viral gastroenteritis, typhoid, Hepatitis A and polio.

Bangladesh experiences an onslaught of epidemic with every flood that hits the country ever year. In fact, there are

Number of Reported Cases related to Cholera, Malaria and Dengue



Source: Global Health Atlas, World Health Organization
* The last available information for Bangladesh on the Global Health Atlas is for 2000. By 2007-08, the number of cases would be higher.
Source: DengueNet, World Health Organization
Source: Global Health Atlas, World Health Organization

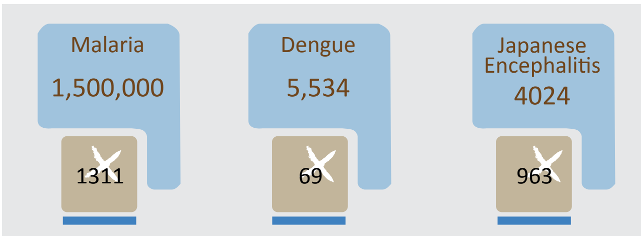
cholera outbreaks twice every year in Bangladesh.

Vector-borne diseases are transmitted to humans by insects, and require a warm and humid climate for the disease pathogens to survive and multiply. It is not therefore unusual for vector-borne diseases such as malaria, dengue, and Japanese encephalitis to thrive in these countries. Malaria is the most common vector-borne disease in China, India, Nepal and Bangladesh. As temperatures increase and rainfall becomes more erratic and intense over fewer days, more parts of these countries are fast becoming breeding grounds for the disease-causing vector, the mosquito. The mosquito is also a vector in the case of dengue, one of the fastest spreading vector-borne diseases.

Despite a highly successful national malaria control program launched in China in the 1950s, the country still faces a threat from malaria. 19 out of its 31 provinces and municipalities are considered malaria endemic. In 2007, the malaria incidence rate in China was 2.0 per 100,000 people.

India is afflicted mainly by 6 vector-borne diseases including malaria, chikunguniya, filariasis, Japanese encephalitis, and leishmaniasis. Filariasis is endemic in 19 States and Union Territories in India and there are approximately 29 million cases in the country. In 2009, the two Indian states of Gujarat and Goa had 104 cases of dengue with 2 deaths.

Number of Cases and Deaths due to Vector-Borne Diseases in India, 2007



Source: National Vector Borne Disease Control Programme, Ministry of Health and Family Welfare, Government of India

In Nepal, malaria was found to be endemic in 65 districts in 2004; approximately 74% of the total population is at risk.

Bangladesh has been severely plagued by diarrhoea, in part due to the after-effects of the cyclones that hit it frequently. Malaria and dengue are also wide-spread in Bangladesh.

Due to the state of the health infrastructure in these nations, the number of reported cases and deaths in relation to water-borne and vector-borne diseases might be understated. With climate change, ecosystems will gradually change and hence, the distribution of vector species will also change. But most vectors cannot survive above 40°C, so areas that will see a rise in their temperatures above this level, will actually see a decline in the rate of vector-borne diseases.

Number of Cases of Diarrhoea, Malaria and Dengue in Bangladesh

Diarrhoea	Malaria	Dengue
48,302,636	1,018,671	19,830
1988-2005	1974-2004	1999-2005

Source: Patwary, OH. "Climate Change and Security". BIPSS. Issue 7, September 2009.

Future Risks

According to IPCC's Third Assessment Report, there may be a 3.8°C rise in global temperature and 7% change in global precipitation (both increase and decrease) by the year 2080. The report has also predicted that climate change is likely to expand the geographical distribution of some vector-borne diseases such as malaria and dengue to higher altitudes and higher latitudes. Areas that will witness increase in precipitation levels along with rise in temperatures will also see an increase in water-borne diseases. Also, increasing frequency of extreme weather events such as cyclones will further spread these diseases. China, Nepal, India and Bangladesh are witnessing a rapid increase in their populations. Hence, the number of people at risk will increase significantly as the population rises and public health infrastructures will find it increasingly difficult to cope with the situation. Climate change is also likely to extend transmission seasons in some areas while some others might see a decrease in the transmission of vector-borne diseases due to reduced rainfall.

As global warming continues to affect the Himalayan sub-region, the distribution of some disease vectors is changing. Warmer climates facilitate breeding of vectors such as mosquitoes. The World Health Organization (WHO) has predicted that countries like India (especially in the north of the country) will witness an increase in vector and water-borne diseases because of global warming. The window of transmission for diseases like malaria would increase by nearly 3 months. Dengue has been labeled as the 'fastest growing' vector-borne disease worldwide. Though earlier restricted largely to Southeast Asia, dengue has now started spreading to South Asia, Africa, South America and parts of Australia. Bangladesh saw its first outbreak of dengue in 2000 while Nepal saw its first dengue case in 2004; since then, Nepal has been a witness to a steady rise in the number of dengue cases, a majority of these were initially found in the Terai district, the most densely populated and prosperous region of the country, bordering India.

Besides climate change, high level of pollution in a river system is bound to have a direct impact on the health of the people dependent on it. Increased industrialization, urbanization and human demands have rendered these rivers increasingly unfit for use. However, because of the limited water supply in some of these regions, people continue to use the polluted rivers for drinking and bathing purposes. This poses a huge threat to human health as these waters are carriers of disease and infections. The Yangtze River in China with its excessive pollution has become poisonous, putting the lives of a large number of people that live in its basin at risk. Intestinal infectious diseases like Hepatitis A and dysentery rates in certain areas of the Yangtze basin are 50% higher than elsewhere in China. E. Coli bacteria which causes gastroenteritis, urinary tract infections and neo-natal meningitis, is rampant in such water sources, and at some places in the Yangtze, is as high as 15,000 E. Coli/L.

Many of the Himalayan Rivers have turned poisonous due to chemical spills, toxic wastes and heavy metal poisoning by many industries. In certain cases, pollution levels are so high that they have caused birth defects and various kinds of cancers. The Yellow River serves as an example where there has been a sharp rise in cases of cancer, birth defects and water-borne diseases due to the rampant pollution in the waters – so much so, that the Yellow River Delta is known to have 'cancer villages'.

As discussed earlier, water pollution is one of the biggest issues facing the Ganges and the Yamuna rivers. The WHO has described the River Ganges as an 'environmental hazard' due to its extremely polluted water. The faecal coliforms being dumped to the river's waters due to the daily discharge of large amounts of untreated sewage make it hazardous for drinking and other purposes, especially due to the huge population that the river supports. The waters of the Yamuna River, once it leaves New Delhi, can only be described as toxic. The state of these two rivers, that are the life-line to the millions that depend on them, is expected to only worsen with time and the increasing water scarcity over the next 30-40 years.

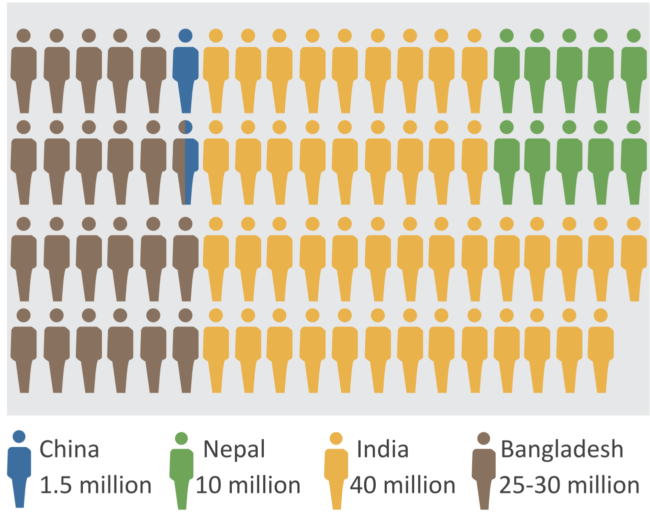
As the water becomes scarce, there is also an increasing likelihood of the water supply being contaminated by pollutants. Depleting groundwater levels allow pollutants to intrude and contaminate the existing water levels. In Bangladesh, apart from the industrial and human pollution, the Ganges river basin too faces the problem of arsenic contamination.

Arsenic contamination of water is also a major health hazard in China, India, and Nepal. Prolonged exposure to arsenic leads to dark or white pigmentation, gradual hardening of palms and soles and also increases the risk of skin, lung and bladder cancer. As mentioned earlier, arsenic has entered the food chain due to irrigation with contaminated water. Due to arsenic contamination of water sources in Bangladesh, Nepal and some parts in India, and due to arsenic entering the food chain in Bangladesh, the health of a large section of the population in this region is and will be severely threatened, though the actual impact may not be evident for years.

The figures for people exposed to arsenic contamination in each country are only estimates. These may not be exact figures due to lack of readily available reliable data. Approximately 76 to 81 million people have been exposed to arsenic contamination in China, Nepal, India and Bangladesh.

As the population increases, the risk of serious effects of arsenic poisoning is bound to increase unless proper remedial measures are taken. The majority of the population living in these regions lacks the resources necessary to buy clean drinking water, so the people are forced to use whatever water is available to them. As water becomes scarce, more and more people will be forced to rely on the groundwater in these regions that is contaminated with arsenic thereby, increasing the spread of arsenic poisoning.

People Exposed to Arsenic Contamination



*Source: Van Halem, D; Bakker, SA; Amy, GL; & Van Dijk, JC. "Arsenic in drinking water: not just a problem for Bangladesh". Drinking Water Engineering and Science Discussions. 2009. <http://www.drink-water-eng-sci-discuss.net/2/51/2009/dwesd-2-51-2009-print.pdf>

#Arsenic contamination has been found in the groundwater of the 20 districts in the Terai region in Nepal. The population of this region is 11 million. 90% of them depend on groundwater for their needs. This means about 9.9 million have been exposed to arsenic contamination.

As polluted water supplies affect the health of more and more people today, changing rainfall patterns are also expected to affect human health in the near future. Given that changing rainfall patterns affect the water supply, there is an increased risk of water-borne diseases like diarrhoea, cholera, skin and eye infections. Fewer days of intense rainfall will result in frequent water-logging. With temperatures rising, this water-logging will aid in the spread of water-borne as well as vector-borne diseases. In the future, as these trends become more entrenched, the population in the Himalayan sub-region will gradually get exposed to higher risk from such water-borne diseases. Governments in this region are aware of this impending disaster. According to the Bangladesh Ministry of Environment and Forests, a combination of higher temperatures and potential increase in summer precipitation may cause the spread of many infectious diseases in the country.

As changing patterns of precipitation, in tandem with the rising temperatures have an impact on agricultural production and food security, the nutritional levels of the population get affected. The resulting malnutrition in turn, will make people more prone to water-borne and infectious diseases.

With frequency and intensity of extreme weather events like floods, cyclones and tidal surges increasing in the region, more and more lives, property, crops are being threatened. Bangladesh is the most vulnerable in this region to extreme weather events. In 2009, the tropical cyclone Aila that hit the Bay of Bengal killed around 300 people in Bangladesh in the month of May alone. After such extreme natural disasters, there is an increase in the spread of water-borne as well as vector-borne diseases. After Aila, the flooding in Bangladesh contaminated both, potable water supplies as well as freshwater ponds that supplied people with fish. Water sources were highly polluted with sewage and dead animals. As a result, the threat of waterborne epidemics was high in parts of Bangladesh that were hit by Aila, especially cholera which is endemic to the region. An outbreak of diarrhoea which spread across Bangladesh's south-west left more than 5000 sick and another 3000 suffering from waterborne diseases like dysentery. Within three months of the cyclone Aila, India had reported 100,000 diarrhoea cases resulting in 31 deaths.

Large-scale water-logging after intense floods carry the imminent possibility of an epidemic. Relief camps are extremely vulnerable due to unclean conditions and dearth of safe drinking water. Flooding and water logging may also give rise to vector-borne diseases like malaria, as was witnessed after the Kosi River floods in 2008 that affected millions in Nepal and India. With its teeming population, this region too could fall prey to epidemics that threaten the lives of millions.

Inadequate Water Supply

Water shortages have an enormously devastating impact on human health, including malnutrition, pathogen or chemical loading, infectious diseases from water contamination, and uncontrolled water reuse. With the water supply slowly becoming inadequate to meet the growing demand for water, the availability of safe drinking water will decrease. Lack of safe drinking water could result in people using whatever water is available to them, including water tainted with sewage and agricultural runoff or even, contaminated water. People living in rural areas and urban slums will be more vulnerable to disease and infections since they do not have access to piped water and cannot afford to buy clean water. According to World Bank estimates, 21% of communicable diseases in India are related to unsafe drinking water. In Bangladesh, diarrhoeal diseases kill over 100,000 children each year. Growing water scarcity also means that more and more people are unable to wash themselves or their clothes, leading to spread of diseases like trachoma. The countries in the Himalayan sub-region are already struggling to make safe drinking water available to all of their population; with growing water scarcity, this will become an uphill task. As water stress grows, food will become more expensive and increasingly unattainable to a larger percentage of people, resulting in malnutrition or starvation.

By 2040-2050, when India and China will be water-stressed and the region as a whole will be facing more frequent extreme weather events like flooding and cyclones, infectious diseases will become more widespread and rampant than today. With the precipitation patterns changing and temperatures rising, vector-borne diseases will spread northwards affecting higher altitudes in the Himalayan sub-region. Water shortages will lead to more cases of malnutrition, as well as diseases like cancer. Failure to establish efficient public health infrastructure and limited access to clean drinking water could complicate the situation in all of the Himalayan river-fed countries.

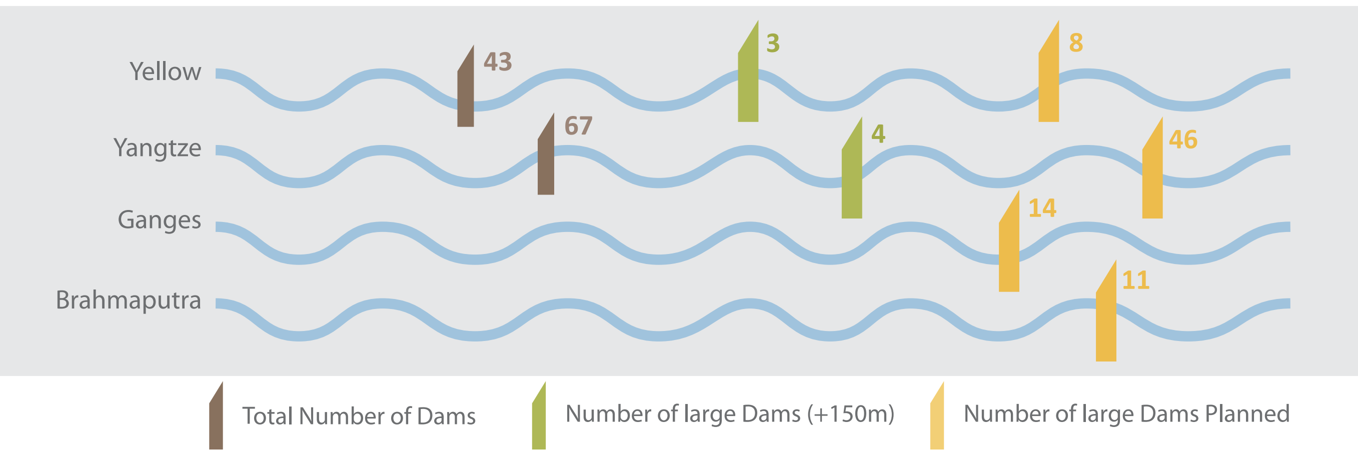
Dams and Diversions 10

As the threat of water scarcity looms large over the Himalayan sub-region, China, Nepal, India and Bangladesh are being pushed towards safeguarding their interests. The impending water scarcity will surely have repercussions on food, health, social and economic security of each of the four countries. Policymakers in these countries are developing infrastructure schemes to alleviate the present as well as impending water shortage. Water shortage will be accompanied by many related problems like having to use contaminated water, spread of disease and infections and death due to water shortage. Therefore, the temptation to build infrastructure projects guaranteeing water supply to the population is extremely high. Potential ramifications of such projects, whether environmental, political or social, are very often missed out. As a result, numerous infrastructure projects in this region have been constructed or are in the planning stages that have not taken into account their impact on future of water, agriculture, and population. If and when completed, some of these projects may have more negative consequences than imagined presently.

Building dams is often regarded as the quickest way to secure and harness available water resources. Power generated from these hydropower projects is a clean and renewable energy source that does not contribute towards emissions. That makes it a highly lucrative form of energy as well. However, there is no comprehensive and up-to-date database on both dams planned or under construction.

Out of the four countries, China has been the most prolific dam builder. China has historically built several large dams in a bid to harness hydropower – with the country having a total of 26,000 dams (large and small) at present and hundreds more in the proposal stages.

Dams on Himalayan Rivers



Sources: Water Resources eAtlas, World Resources Institute, 2003.
Source: “Rivers at Risk Dams and the future of freshwater ecosystems”. World Wildlife Fund. 2003.
* This report defines ‘large dams’ as being higher than 60 meters and generating more than 100 MW of power.

Dams on the Yellow River:

1. Sanmen Gorge hydroelectric power station (1960)
2. Sanshenggong hydroelectric power station (1966)
3. Qingtong Gorge hydroelectric power station (1968)
4. Liujiaxia (Liujia Gorge) hydroelectric power station (1974)
5. Yanguoxia (Yanguo Gorge) hydroelectric power station (1975)
6. Tianqiao hydroelectric power station (1977)
7. Bapanxia (Bapan Gorge) hydroelectric power station (1980)
8. Longyang Gorge hydroelectric power station (1992)
9. Da Gorge hydroelectric power station (1998)
10. Li Gorge hydroelectric power station (1999)
11. Wanjiazhai hydroelectric power station (1999)
12. Xiaolangdi hydroelectric power station (2001)

Dams on the Yangtze River:
1. Three Gorges Dam (2003)* - 22,500 MW
2. Gezhouba Dam (1988) - 3115 MW

* 2003 is the year the dam first produced electricity. The Three Gorges Dam is yet to be fully operational.

In India, there are two major dams on the Ganges River. One of them is at Haridwar; built in 1854, this dam diverts waters into the Upper Ganges Canal. The other at Farakka was built in 1974 to divert waters from the Ganges into the Bhagirathi River. The Tehri Dam, built on the Bhagirathi River is a tributary of the Ganges. This dam started functioning in 2006-07. This is a primary dam of the Tehri Hydroelectric Project and is the fifth tallest dam in the world at a height of 260 meters. The dam has been inundated with controversy right since its planning and construction stages in the 1970s. Its reservoir completely submerged more than 40 villages and the Tehri Town and led to the displacement of thousands of people. This dam has power generation capacity of 1000 MW.

The Rihand Hydroelectric Project, on the Rihand River, was constructed in 1962. About 91 meters in height, this project generates 300 MW of power. The Rihand River is a tributary of the Son River which is a tributary of the Ganges.

Nepal has enormous hydropower potential, but is unable to exploit it to the maximum. This is largely due to lack of financial resources and access to technical expertise. This is also one reason why Nepal has not yet constructed any major dams. Absence of dams in Nepal has also worsened the flooding situation. Intense monsoons cause floods in Saptakosi River, and these travel down to the Gangetic plains in India, wreaking havoc on their way.

In Bangladesh, the topography is not suited to construction of large-scale hydropower projects.

Future Dams

With the region facing a threat of water scarcity and with increasing emphasis on reduction of emissions to combat climate change, hydropower schemes are fast developing to meet the growing demand for energy. The countries in the Himalayan sub- region, especially China and India are planning numerous hydropower projects on their rivers in the future.

Nearly 200 dams have been proposed for the Yangtze River and its tributaries. 19 of the proposed dams will be constructed on the upper reaches of the Yangtze, upstream from the massive Three Gorges Dam. The dams under construction on the Jinsha River, a tributary of the Yangtze will have a combined capacity of 40,000 MW. The construction of this series of dams was stalled briefly in 2005 as the project was located in a national rare fish reserve. The problem has since been resolved.

1. Xiluodu Dam: Its construction started in 2005 and completed in 2007. Its height is 278 meters and its capacity is 12,600 MW.
2. Wudongde Dam: This dam is scheduled to be completed in 2020. When finished, its height would be 235 meters and its generating capacity will be 7400 MW.
3. Baihetan Dam: This dam is scheduled to be completed in 2020. When finished, its height would be 277 meters and generating capacity will be 14000 MW.
4. Xiangjiaba Dam: When finished in 2015, its height would be 161 meters and its capacity will be 6000 MW.

Other dams on the Jinsha River include Guanyinyan and Ludila. Dams proposed on the main stream of the upper Yangtze include Xiaonanhai, Zhuyangxi and Shipeng.

Five dams have also been planned for the middle reaches of the Yarlung Tsangpo River, including a hydel power generation project at Zangmu, 140 kilometers southeast of Lhasa. In addition, there are other dams planned on the Salween and the Mekong rivers.

According to reports, the government of India too is planning a series of four hydroelectric dams on the Ganges-Bhagirathi River between a 125 kilometres stretch between Gangotri and Uttarkashi.

Some projects under planning or construction in the Ganges River basin:

1. Tapovan Vishnugarh hydroelectric project on the Dhauliganges River, a tributary of the Ganges, with a generating capacity of 520 MW.
2. Lohari Nagpala Barrage Project on the Bhagirathi River, a tributary of the Ganges, with a generating capacity of 600 MW.
3. A run-off river dam at Koteshwar, under construction, is situated about 22 kilometres downstream on the Bhagirathi River from the Tehri Dam. This is also a part of the Tehri Hydroelectric Project and will produce approximately 400 MW of electricity when finished.

India has recently set up a panel to study alternatives to tap the Brahmaputra to strengthen its claim over the river's tributaries, since there have been reports that China plans to divert these tributaries. The options before the panel include construction of dams. As per the Second International Workshop on Water Security in Dhaka (Annexure 2), India has plans of building 140 hydroelectric plants in Arunachal Pradesh. 104 MoUs have already been signed to this effect.

Since Nepal's own public and private sector resources have so far been unable to meet the financial investment required to exploit its immense hydropower potential, the country has created an investment-friendly environment. Hence, many projects are being planned to tap into Nepal's hydropower potential with help of technical expertise and financial assistance from countries like India and China.

1. The Pancheswar Hydel Power project on the Mahakali River: The 5600 MW project, planned through Indo-Nepal cooperation, will be situated on the border between Nepal and Uttarakhand state of India. India and Nepal have decided to set up a Pancheswar Development Authority (PDA) for the execution of this project.
2. Sapta Kosi High Multipurpose Project on the Sapta Kosi River: The governments of India and Nepal have set up a Joint Project Office in 2004 for investigations into this project. When finished, this dam would be 269 meters high with an installed capacity of 3300 MW.
3. Four hydroelectric schemes, Pokhra (1 MW), Trisuli (21 MW), Western Gandak (15 MW) and Devighat (14.1 MW) have been implemented in Nepal with India's cooperation.
4. Upper Karnali Project on the Karnali River: When completed, it will generate 4180 MW of power.
5. Karnali Chisapani Multipurpose Hydropower Project on the Karnali River: When finished, this 270 meter dam will generate 10,800 MW of power.
6. 456 MW Upper Tamakoshi Hydroelectric Project: Work on this project is expected to start from June 2010.

Environmental Impact

Though dams promise a source of clean, stable energy, their impact on the environment is not entirely positive. Studies show that decomposing matter in the reservoirs of large dams produces greenhouse gases, especially when the dams are situated in warm, humid areas. Construction of large-scale infrastructure projects on fragile ecosystems of rivers causes harm to the environment.

Destruction of aquatic life

Construction of large dams leads to destruction of the marine life in rivers. The Yangtze River is home to about 322 species of fish and 169 species of amphibians. The river is already fragmented with a number of dams; China plans to build around 46 more large dams (over 60 meters in height) on the river. Hence, the aquatic life in the river, already at severe risk by the functioning dams, will be further endangered in such conditions. Excessive dam-building on the Yangtze has been the primary cause behind the extinction of the river dolphin or 'baiji' since dams constricted its habitat. Other species at risk in the Yangtze River include the Chinese alligator and the finless porpoise. The ecosystem of the Yangtze has been altered to a level where certain rare river species are facing extinction. Building large hydropower projects block migration routes for fish and endanger fragile spawning grounds. It also alters the water temperature and oxygen content as well as the speed of the current. For instance, the plans for the Xiaonanhai Dam have come under a great deal of criticism since this dam will impact the river's only fish reserve that is home to 180 species of fish including some endangered varieties.

The Ganges River dolphin in the Ganges basin is at risk due to a high level of river fragmentation caused by dams and canals. This species is also found in the Brahmaputra basin. With around 25 new dams being planned for the Ganges and the Brahmaputra rivers, the Ganges River dolphin and other species face a growing threat.

The Yangtze River has also been an important ground for fisheries. Excessive damming of the river is causing a decline in the population of important commercial variety of fish like the Chinese sturgeon, carp and paddlefish.

Release of Methane

There is evidence that large hydroelectric projects release methane into the atmosphere. The plant material that settles at the bottom of the reservoir during the flooding stage of construction decomposes due to lack of oxygen. This causes a build-up of methane which is eventually released into the atmosphere as the water passes through dam turbines. The quantity of methane released depends on several factors like temperature, vegetation, depth of turbine intake, altitude, construction procedures and the depth and shape of the reservoir. A large-sized dam is bound to emit a large quantity of green house gases. Since methane is 21 times as powerful as CO_2, its impact on the fragile ecology of regions like Tibet will have serious repercussions.

Loss of flora, fauna and livelihood

During the construction of dams when the course of a river is changed, the surrounding areas have to be flooded which results in a loss of flora and fauna. Since dams reduce the speed at which river water flows, they also affect the flood riparian habitats like waterfalls, rapids, riverbanks and wetlands that act as feeding and breeding grounds for many species of marine life. These species contribute greatly towards maintaining the ecosystems. Hence, construction of dams does have a negative impact on the ecosystem by affecting the plants and animals of the area. In addition, older dams release water stored at the bottom of their reservoirs, which is usually much colder than what the aquatic species downstream are adapted to. Naturally, the species cannot get acclimatized to this fluctuation in their habitat's temperature and perish.

Building of dams also floods arable land that is the source of sustenance for the local population of the area. It forces people to leave their homes and move to other areas for employment. China has seen violent large-scale civil unrest due to its dam-building plans. The Tehri Dam in India led to the eviction of approximately 100,000 people whose homes and lands were submerged for the built. In some cases, the filling of the reservoirs of large dams has cut down the water flow downstream, making water shortage even more acute. There has been criticism that the filling of the massive Three Gorges Dam has worsened the drought facing the Yangtze River delta downstream.

Poor water and land quality

A significant downstream impact of dams is that the water quality of the river declines. Since dams constrain the natural flow of the river, they impede the natural capacity of the river to break down organic pollutants in its water. For instance, the bottom layers of a dam reservoir are often low in oxygen content. These waters with depleted oxygen levels can produce toxic hydrogen sulphide gas. Also, such waters, when released from dams, have a reduced capacity to process waste for up to 100 kilometres downstream. Dams are also known to spread waterborne diseases. The Three Gorges Dam on the Yangtze River in China has been highlighted as an environmental disaster waiting to happen. Its reservoir is polluted with human and industrial waste, leaving its water tremendously toxic. Several tributaries of the Yangtze that flow into the main reservoir are extremely polluted. With the dam slowing the flow of the river, the ability of the river to flush out pollution in turn, gets impeded.

Since dams slow the movement of water downstream, the downstream movement of sediments to deltas and estuaries, forests and wetlands is affected. With seasonal floods no longer enriching the downstream farmlands and forests with natural fertilizers and sediments, the fertility of the land deteriorates. Hence, productivity of land downstream from the dam declines.

Dam-building projects cause displacement of people, leading to social instability. Hydropower projects have historically uprooted people from their homes and forced them to move. The resettlement initiatives and compensations given by the governments are hardly sufficient to cover the cost of losing one's home. Besides, in the sub region, such benefits often do not reach to the affected people due to the corrupt system and red tapeism. During the construction of the Three Gorges Dam in China, more than a million people were displaced. China saw large-scale protests against the construction of the dam and the forced displacement due to it. In 2004, there were huge protests against the building of the Pubugou Dam on the Dadu River, a tributary of the Yangtze, in the Hanyuan County of the Sichuan Province.

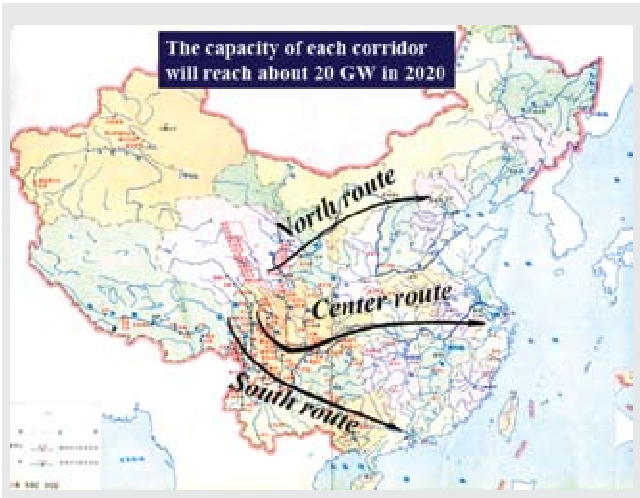
If dams are situated in a seismically active zone, the risk of a potential catastrophe in the event of an earthquake is extremely high. For instance, the Tehri Dam in India is situated in a highly active seismic zone. Although it has been designed to withstand earthquakes up to 7.2 on the Richter scale, an earthquake of a greater magnitude leading to a dam burst could potentially wipe out several major towns and a population of almost 500,000 downstream. Big dams in seismically active regions such as the Tibet Plateau fail to take into account the magnitude of losses in the event of an earthquake or dam burst.

Lack of Foresight

The Sanmenxia (Sanmen Gorge) Dam on the Yellow River in China is an example of a project which has lacked political foresight. Built in 1960 with Soviet assistance, the 350-foot Sanmenxia Dam was the largest hydel project in China at the time. However, within 4 years of its opening, the dam lost about 40% of its storage capacity due to massive silting. The Yellow River carries a large amount of silt. Over the years, Sanmenxia has caused several floods upstream due to mismanagement of silt. Hence, the building of the dam was short-sighted as it did not foresee the consequences of such a huge construction project, nor did it factor in a very basic characteristic of the river on which it was built.

At a height of 331 feet and a reservoir more than 600 kilometres long, the Three Gorges Dam was built in order to generate hydropower and control floods in the Yangtze. However, the risk of earthquakes and landslides has increased since its construction. This shows a clear lack of foresight on the part of politicians and decision-makers.

China : Diversion Routes



Source: Xi Chen, "Precipitation and temperature trend analyses in the last five decades for the Southwest China" presentation at Second International Workshop on Himalayan River Basins hosted by SFG - BIPSS at Dhaka on January 16, 2010

Large-scale dams under construction or in the planning stage often fail to take into account the effects of glaciers melting. Once the lean period flows of rivers start decreasing as a result of melting glaciers, large-scale dams will become worthless. The generation of hydroelectricity through these dams will decrease due to low flow of rivers. As a result, the costs, financial, social, political and environmental, of building mega dams will no longer be justifiable.

As the Himalayan glaciers melt, the future of certain glacier-fed rivers is increasingly threatened, with some eventually becoming seasonal. If they become seasonal in the coming decades, construction of massive infrastructure projects on these rivers, that cost billions of dollars and thousands of man-hours of labour; displace millions of people; and endanger fragile ecosystems, will all be of no use.

Several of the Himalayan sub-regional rivers are trans-boundary. The construction of infrastructure projects on trans-boundary rivers often threatens the water security of the lower riparian nations. However, altering water availability through dams and diversion projects is easier and thus more tempting in the absence of stringent international laws regarding the matter and, in the absence of water-sharing agreements between countries, such as India and China. This trend of infrastructure development on water resources will only grow in the next few years as governments come under greater pressure to make alternate arrangements for ensuring reliable water supply to their citizens. However, such short-sighted thinking could prove disastrous in the long run.

Speculation about Diversion

The South-to-North Water Diversion Project in China is a controversial large-scale engineering project, costing an estimated USD 62.5 billion that aims to transfer around 45 BCM water from the south to the parched north of China every year. One of the 3 'routes' of the project aims to divert waters from rivers like the Yarlong, the Tongtian and Dadu to the upper reaches of the Yellow River. Since this would involve building a series of canals and tunnels along one edge of the Qinghai-Tibet plateau, this section of the project promises to be the costliest, most complex and environmentally the riskiest portion of the entire project. This diversion of water from Yarlong Tsangpo will definitely impact the lower riparian nations India and Bangladesh as it will alter the dry season flow of the river significantly.

There are reports that China is planning a huge hydel dam on the Yarlong Tsangpo, at the 'Great Bend', also known as the 'Namcha Barwa', just before the river flows into India. Once completed, this massive dam will generate 40,000 MW of electricity. Though the Chinese government has denied these reports, there is speculation in the media to raise this issue as a cause of concern. The Government of India has also said that there is no evidence of work having been done on the 'Great Bend' as of now, although the construction a dam of this magnitude in an earthquake-prone region on a trans-boundary river would be alarming, especially since there are no water-sharing agreements between India and China. This could lead to a conflict between India and China, as will be discussed later elsewhere in this paper.

China is not alone in the region to consider diversion of rivers. There has been much discussion in India about a USD 600-800 billion project that had aimed at balancing water usage in India by linking the major Indian rivers. This project was designed to provide a solution to the drying of certain rivers in summer months. There are, in all, 30 inter-linking river projects, 14 of which are in the Himalayan region. Five links had been identified as priority including the Ken-Betwa link, the Parbati-Kalisindh-Chambal link, the Godavari-Krishna link, the Par-Tapi-Narmada link and the DamanGanges-Pinjal link. Vociferously opposed by environmentalists as well as some politicians, this project still remains on paper. In fact, recent reports and statements made by senior officials of the Indian government seem to indicate that this project may not go through.

Another Indian project that has attracted controversy is located in the Indian state of Manipur in the north-east. This is the Tipaimukh Dam on the Barak river that is expected to generate 1500 MW of electricity once ready. It will also serve the purpose of flood control for the states of Manipur and Mizoram. Work has recently resumed on the controversial dam after being stalled in March 2007. The Tipaimukh is scheduled to be completed in 2012 and Bangladesh claims that the dam will dry the Surma and the Kushiara Rivers, rendering the north-eastern regions of the country into a dry sandy wasteland. India has reiterated that the dam is being constructed only for the purpose of generating hydroelectricity and that the project has nothing to do with irrigation. Since the Barak-Surma-

Great Bend

The proposed Dam and Diversion project along the 'Great Bend' of the Yarlung Tsangpo River is an important issue in bilateral relations between India and China. While there is still much speculation as to whether the dam is to be constructed, the project, at least on paper, appears to be bigger than the Three Gorges Dam, and will generate approximately 40,000 MW of power. In addition, the dam itself will constitute a half of the project with the other half meant to divert approximately 200 BCM of water annually to the Yellow River.

The Chinese government has denied media reports of the proposal, with virtually every facet of the project shrouded in controversy. There has been discussion of China using a Peaceful Nuclear Device (PND) to facilitate the construction of a diversion canal through the plateau. Meanwhile, a dam of this magnitude is likely to threaten the water security of the lower riparian nations, India and Bangladesh. In addition, the large reservoir required to store water will slow the water flow downstream, especially during the dry season when it is most required. Conversely, the storage and diversion of water during the wet season could prompt flooding downstream, while also affecting India's hydroelectricity potential.

The dam's location in a highly-seismic region is a further point of contention, as any structural damage to the dam could potentially submerge vast tracts of land in both India and Bangladesh. In the absence of binding water treaties between China, India and Bangladesh, the question of equitable access to water resources from the Yarlung Tsangpo/Brahmaputra arises – with the lower riparian nations likely to protest diminished availability of the resource. Furthermore, the biodiversity of the basin area will be threatened, with two UNESCO World Heritage sites, the Sunderbans National Park and Kaziranga National Park, becoming very vulnerable to changes in the ecological equilibrium, brought forward by alterations to the natural flow of the river.

Kushiara is an international river, Bangladesh as a lower riparian country may feel the impact of a dam that has been built for the purpose of flood control in the wet months. In addition, as the dam is being built in the earthquake-prone hilly regions of North-East India, it would be catastrophic for Bangladesh in case the dam bursts in the event of an earthquake. Bangladesh has urged India to conduct a joint study on the impact of the dam on the region and the future flows of the river system. In a summit level meeting between Heads of Government of the two countries in January 2010, the Indian Prime Minister agreed to address Bangladeshi concerns.

Such projects aiming towards water security for these nations may, in the long run, create more crises. Impulsive building of huge dams and diversion projects on rivers, that are shrinking and may eventually dry up, is a wasted effort. Issues like sedimentation, silting, pollution and the destruction ecosystems need to be considered before investing in massive infrastructure projects. Since these rivers are mostly trans-boundary, such projects, are destined to draw the ire of lower riparian nations since their own water security would be threatened by lower flows, higher probability of flooding in the monsoons, droughts in the dry season, and catastrophic results in case of earthquakes. Hence, any kind of infrastructure development on the Himalayan Rivers will require foresight and a deep knowledge of the terrain, as well as a high level of cooperation between nations.

Migration and Social Instability 11

As the issue of water security and water availability becomes increasingly prominent, China, Nepal, India and Bangladesh will be challenged, albeit to varying degrees, by the internal migration of citizens fleeing adverse conditions. The receding glaciers that supply water to Nepal, China, India and Bangladesh are the source of life for more than 1.3 billion people, or a-fifth of the world's population. Any variation in water flow, whether an increase or a decrease, will definitely have an impact on those living in and around the river basins. In the decades to come, growing water scarcity and the changing climate scenario will have an impact on people's health, their livelihood and their social sensibilities. Moreover, the addition of cultural beliefs and ethics, as well as linguistic differences, could complicate issues, as people from Asia's ancient civilizations find themselves having to adjust to new ways of living. At a national level, governments could find themselves having to alter long-standing agricultural, economic and resources utilization practices in an effort to better prepare for expanding populations and greater demands on resources.

A changing environment will also necessitate a shift away from 'traditional' security threats in our mapping of human security, with the phenomenon of 'climate refugees' or 'environmental migrants' becoming more prominent. Amidst the changing scenario, governments could find themselves having to deal with more number of people displaced by climate change and water scarcity in the coming years. As water shortages, flooding, droughts, desertification, sea-level rise, and other extreme weather events reduce reserves of food, health and livelihood security while simultaneously motivating policymakers to build dams, environmental migrants and water-insecure populations from both within a country and beyond a nation's borders could pose challenges to the future stability of each country.

Migration, as a consequence of water and climate-induced factors has historically been temporary in nature, with people 'escaping' adverse conditions, only to return home after an improvement in the situation. However, with water availability fast becoming less of a guarantee, and climate change worsening with each day, thereby increasing the frequency of droughts, floods and sea-level rise amongst others, people will seek to migrate on a more permanent basis. Considering that the basins are home to almost 1.3 billion people at present and several more millions by 2030, there is plenty at stake in the event of depletion of water resources becoming a more prominent feature in the regional landscape.

Economic Migrants

The primary driver for migration in all four countries has traditionally been economic and social betterment, with people moving from rural to urban centres in China, Nepal, India and Bangladesh in search of monetary gain.

Limited industrialisation in Nepal has been responsible for voluntary migration in the country. The trend is expected to continue as more people migrate to urban centres where there is an increasing presence of industry in the country. However, there is also a possibility that the government could look towards industrialisation projects in the Terai belt as the country's economy continues to grow – eventually forcing people to migrate away from the region. While Nepal has witnessed economic migration, it has traditionally been from the mountain and hill areas towards the Terai – a trend which is understandable, given that most employment opportunities have been in the agricultural Terai region. However, as Nepal's economy grows the country is expected to witness greater urbanization, with the UN predicting that 46.3% of the population will be living in urban areas by 2050.

According to estimates by the United Nations, approximately 57% of Bangladesh's population or 125 million people will reside in urban areas by 2050 – an increase of approximately 79 million in a span of 40 years. In addition, as environmental degradation and ecological changes brought about more and more by climate change take hold, and the agricultural sector fails to develop, there is likely to be large-scale migration from rural to urban centres of the country. While migration as a result of climate or weather-induced disasters has been a regular feature in Bangladesh, it has been temporary in nature – a pattern which is expected to change as more than 35 million people or 21% of the population lives along the vulnerable coastal districts. Cities such as Dhaka receive more than 500,000 additional people every year, resulting in a direct economic impact on the urban development. The forced migration of people as a result of water scarcity will undermine growth in the urban centres, while disrupting economic development and prompting further instability.

China has witnessed large-scale rural to urban migration over the years, with labourers primarily shifting away from the more destitute provinces of Sichuan, Anhui, Henan and Gansu, towards the coastal areas and large urban centres of the country. As with Nepal and Bangladesh, the shift has historically been motivated by the desire to improve economic conditions, although the repercussions of the migratory wave are being felt in both the rural and urban centres – with dwindling food supplies due to a lack of farmers in the former and, increasing poverty, disease and crime in the latter. While the Chinese government is trying to curb migration, a report in the Heinz Journal estimates that between 30 and 40 million additional people will move to different parts of the country by 2025.

While migration in China has traditionally occurred under the backdrop of economic gain, environmental degradation and a lack of vital resources is fast becoming a catalyst in people moving out, as sustainable living becomes increasingly more difficult. The north of the country, home to 44% of the population and having 58% of the cultivable land, now has just 14% of the country's water resources at its disposal. Thus, arable land is rapidly decreasing as a result of desertification, while water resources are depleted due to drought and high industrial and urban demand. The lack of water resources in the region has led to crop failure as high as 33% in recent years – a figure which does not bode well considering that China relies on the north for 50% of its wheat and 33% of its corn supplies. Given the circumstances, it is understandable why people are migrating towards the coastal regions – a trend that is likely to continue into the foreseeable future.

China's path towards industrialization and urbanization has been aided by recent economic reforms, leading to more people migrating from rural China towards the urban centres. Rural to urban migration has increased significantly in China from the 1980s, with approximately 8.9 million people migrating in 1989. However, by 2000, the Census of China revealed that there were 100 million rural migrants. According to the National Bureau of Statistics of China, there were 118, 132 and 140 million rural migrants in urban areas in 2004, 2006 and 2008, respectively. The Census of China in 2000 predicted that there would be an additional 5 million rural migrants every year from 2000. This prediction has been more or less borne out by the National Bureau of Statistics of China figures. If the annual trend of 5 million extra migrants from 2000 continues, then in 2010, there should 150 million rural-urban migrants. However, the recent global recession has seen over 20 million urban dwellers rendered out of jobs leading to a reverse migration of people. It is unlikely that this trend will voluntarily continue and, as the Chinese economy revives, the focus is expected to return to the country's cities and coastal areas.

India will be especially vulnerable to a lack of water availability and climate change, owing primarily to the high levels of poverty and population density, which are further compounded by the country's geography. High population levels will mean greater demand and competition for resources, in a society which is already grappling to provide adequate provisions to its populace. As has been previously highlighted, unpredictable rainfall patterns, retreating glaciers and the El Nino effect are a handful of factors which are likely to impact the agricultural sector in India and push people towards urban centres.

Desertification and Migration

With the agricultural sector featuring prominently in the economic milieu of China, Nepal, India and Bangladesh, there is a high probability that as land is lost through adverse climatic conditions or becomes uncultivable people will be forced to seek alternate livelihoods and regions to live, for their survival.

While it is difficult to quantify the impact of desertification or deforestation along Nepal's three main rivers, it is apparent that the rapid deforestation to create more agricultural and industrial areas has led to erosion and increased desertification in the country. Degradation of the land, as in the Chitwan Valley, will reduce economic opportunities for people – a trend which could become increasingly prevalent in the future, rendering vast tracts of land unusable and forcing people to migrate. While Nepal faces flooding every year, the country also has to contend with droughts. This has led to more than 74,000 hectares of land in 16 districts, including Surkhet and Mustang, being impacted by desertification in 2001.

Over the years the impact of droughts in Nepal has resulted in crop failure, an outcome which could become more regular in the future. This is likely to result in large scale migration away from the Terai belt towards the mountain and hill areas, as opposed to economic migrants of previous years who would have moved to the Terai region. While these areas are considered Nepal's urban centres, the migrants are likely to be a part of the urban fringe of society – not possessing the required skill sets to assimilate into the working population. In addition, while the migration trend has historically been temporary in nature, increasing frequency of droughts has exacerbated desertification of the land, thus minimizing the likelihood of migrants returning to the Terai belt.

The arable land of China's Northern Plains is decreasing as a result of desertification, meaning that farmers in the region will have to contend with falling productivity and increasing dearth of resources in the near future. The Yellow River basin is faced with a similar problem by virtue of the fact that it lies in an arid to semi-arid area. As a result, desertification along the river is further compounded, forcing farmers to migrate to the southern regions of the country. Similarly, deforestation along the watershed of the Yangtze River has left the area prone to desertification, with the next 30 years considered a crucial period, as the river battles to survive.

While river bank erosion is expected to lead to land loss along the Brahmaputra and Ganges in India, people living along the Ganges are unlikely to migrate as a result of desertification. While land is lost through this process, the loss will be negligible as compared to the loss caused by droughts or industrialization. However, the largest tributary of the Ganges, the Yamuna, is likely to face the problem. With the groundwater table in certain areas along the river depleting, there is a possibility that agricultural land could be lost as there is inadequate water to replenish the ecosystem. In such an eventuality, people dependent on the river for their livelihood could migrate away from the Yamuna. Desertification will not be so much of an issue along the Brahmaputra and will not cause migration.

Erosion and Displacement

Increased short-term runoff in the Ganges and Brahmaputra, as a result of increased precipitation and glacial melt, is likely to intensify erosion, which could affect agricultural productivity as land is lost to the river. In addition, erosion along the river could pose a threat to homes and force people to migrate away from the rivers. The 'great' earthquake of 1950 highlighted the problem of river bank erosion along the Brahmaputra, with the river changing its course at various points. The enormity of the problem has been demonstrated through the continuous 'shrinking' of Majuli Island. The land mass which had an area of 1250 square kilometres has been reduced to a total area of 650 square kilometres since 1950 because of erosion, and has led to the displacement of over 30,000 people in the last 25 years. With a population of approximately 160000 the world's largest populated river island, with a rich biodiversity, could soon be extinct as the Brahmaputra River slowly claims the land.

The Indian state of West Bengal is threatened by erosion along the Ganges River, which could lead to it merging with smaller tributaries, subsequently affecting thousands of villagers. Experts believe that the Ganges may join course with the Pagla in West Bengal, inundating a large area of the district and forcing approximately 20,000 people to migrate. Meanwhile, as the Ganges River continues to erode agricultural land in Jharkhand's Sahibganj district, hundreds of families have become homeless.

Bangladesh's battle with climate change is frequently associated with sea-level rise, a thought-process justified when one considers that a rise of 0.5 metres over the last 100 years has led to the erosion of approximately 65% of the landmass of Bhola, Hatia, Kubdia and Sandwip. Research work carried out on river bank erosion in Bhola district between July to September 2004, revealed that 3332 families had lost their houses to river erosion, while 7 schools had been destroyed and 14 were under constant risk of being eroded. Since 1960, Bhola Island has lost 3000 km of land, with estimates suggesting that the island could totally disappear by 2050, if the current rate of river bank erosion continues. Given the vulnerability of the land to erosion, it is understandable that people faced with a constant threat will seriously consider migrating to safer territory.

In recent decades, erosion and flooding have led to the displacement of approximately 12-15 million people in Bangladesh, underlying the gravity of the situation confronting the low-lying country. In Bangladesh, it is estimated that close to a million people lose their homes and approximately 10,000 hectares of land is lost as a result of river bank erosion each year. In addition, people living along the Brahmaputra River are frequently displaced as a result of the phenomenon. Estimates suggest that between 1982 and 1992, 730,000 people have been displaced in Bangladesh as a result of riverbank erosion. While migration patterns show that displaced people initially seek to relocate within the same village or area, the long term scenario demonstrates an urban shift towards Dhaka and Chittagong, as people eventually seek better employment opportunities.

Forced Out by Floods

China, Nepal, India and Bangladesh are all susceptible to flooding due to the Himalayan rivers. Nepal is confronted by floods on an annual basis, with the local population frequently seeking temporary migration to other parts of the country as the land is submerged and their homes destroyed. In addition, flooding is often accompanied by large landslides and a loss of agricultural land, thus having a direct and negative impact on people's livelihoods. As the occurrence of flooding is expected to increase in frequency and magnitude, there is a possibility that migrants will seek a permanent relocation to safer grounds, where economic and social opportunities are more stable.

The situation in China is similar to that of Nepal, where flooding to the south of the country, particularly in the Yangtze River basin, is leading to short-term migration. However, centuries of deforestation have exacerbated the problem, with instances of flooding expected to become more prevalent. A report by the OECD states that approximately 10 million people are vulnerable to flooding along China's main coastal cities.

With approximately 40% of the land around the Brahmaputra susceptible to flooding, the region faces a constant threat to its natural resources. In addition, strong monsoons, the weak geological formations of the area, massive deforestation, high population growth and being a highly seismic area makes it more vulnerable. Furthermore, the high sediment load of the river and deforestation along the banks has resulted in excessive soil erosion and surface runoff, increasing the problem of flash floods. The magnitude of flooding in the northeast was reinforced by the 1998 monsoon season, which submerged approximately 38,200 square kilometres of land or 48.65% of Assam's geographic area and, affected close to 15 million people. Such occurrences are likely to push people away from areas susceptible to natural hazards.

Serious floods in Bangladesh Over the Last 26 years

Floods	Land Inundated	Estimated damage (USD)	Loss of life	People affected	Other Damage
1984	> 50,000sq.km	$ 378 million	-		
1987	> 50,000sq.km	$ 1 billion	2055		
1988	87,840sq.km	$ 1.2 billion	2000-6500	45 million	
1998	100,000sq.km	$ 2.8 billion	1100	30 million	500,000 homes damaged
2004	54,720sq.km	$ 6.6 billion	700	3.8 million	
2007	32,000sq.km	$ 51 billion	694		1.2 million acres of crop destroyed, 85,000 homes destroyed & 1 million damaged

Source: 'Climate change and Security'. BIPSS. Issue Brief. Issue no.7, September 2009. <http://www.bipss.org.bd>

Although the 2009 season was characterized by deficit rain, a trend which is likely to continue into the future, the pre and post monsoon period could be marked by increased incidence of rainfall. Given that this is the period when temperatures are relatively higher, there is likely to be a higher degree of glacial melt, resulting in more water flowing downstream.

The flood plains of the Ganges, Brahmaputra and Meghna Rivers in Bangladesh are susceptible to flooding, with approximately two-thirds of the country vulnerable, considering it is less than 5 metres above sea-level. The flat and low-lying topography, high population densities and high levels of poverty, aggravate the threat posed by floods on human security. Bangladesh is often confronted by serious and recurring floods, such as those which struck the country in 2002, 2003 and 2004. In an average year, approximately 25% of the country is submerged, while once in every four to five years, 60% of the land is under water, resulting in substantial damage to infrastructure, property, and life.

The submergence of land as a result of flooding could force people to seek permanent migration towards the northwest of the country, in an effort to secure their homes and livelihood. While migration waves have been temporary in nature, the trend could change given the yearly risk posed to the land as a result of flooding.

Driven by Drought

Monsoons, while becoming more erratic, are also likely to become truncated, with heavier volumes of rainfall in shorter periods of time becoming the norm. This is likely to intensify the phenomenon of droughts as lesser quantities of water are absorbed into groundwater aquifers. With lesser water during winters and the dry season, those already stressed by the lack of water resources will be even more pressurized, perhaps forcing them to migrate.

The case of 'too much water, too little water' in Nepal is likely to lead to an increase in temporary and permanent migrants, as the issue of alternating floods and droughts forces people to move to the hill region. China's northern plain faces a problem similar to that of the Terai belt in Nepal, where droughts and unreliable rainfall are driving long-term migration. With approximately 15.3 million hectares of farmland (equivalent of 13% of the total area) facing a drought-like situation every year, the cultivable land is reducing. The deteriorating situation is thus forcing farmers to migrate to other parts of the country in search of a secure livelihood.

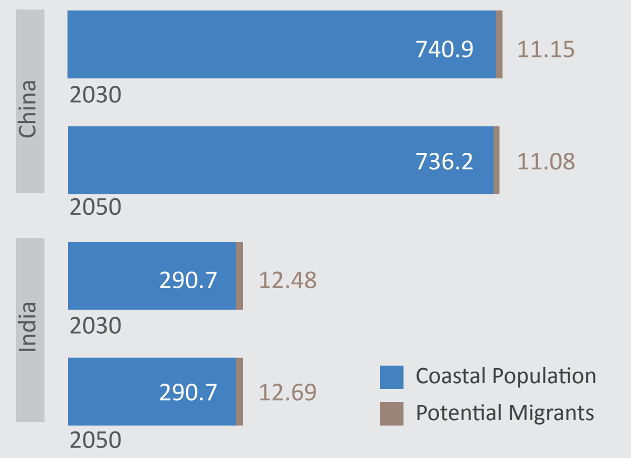
The northwest of Bangladesh has a propensity for droughts and, as rainfall becomes increasingly unpredictable and groundwater levels decline, people will be forced to migrate in search of a secure source of water. While the government has invested heavily on improving the situation through the development of irrigation facilities, the impact continues to be felt, as climate change increases the frequency of droughts, thus offsetting the government's intervention. Ironically, the frequency with which natural hazards hit Bangladesh has made the northwest of the country a refuge for people seeking to escape the flooding, sea-level rise and erosion of the coastal districts.

Given that more than 60% of India's cropped area is still reliant on the monsoon rains and that agriculture supports 70% of India's working population, the resultant impact of unreliable rains could see farmers from the northern agro-belt moving away from the Ganges and Yamuna basins. In 2009, the states of Bihar and Uttar Pradesh, both of which are fed by the Ganges and/or its tributaries recorded rainfall 43% below average, meaning that the production of paddy, sugarcane, pulses and oilseeds, the crops which make up India's staple diet, were substantially reduced. Regular occurrences of such scenarios are likely to lead to the rise of environmental migrants, as they seek greater economic and social security elsewhere.

Coastal Refugees

Rising sea-levels is a problem that will certainly impact China, India and Bangladesh in the future. Over the next 30 years, people living within the delta regions of the Yangtze and Yellow Rivers will have to migrate as rising waters threaten their homes and livelihood. The delta regions that have traditionally been economic hubs have attracted migrants from across the country – a trend which could soon be reversed. A report by the OECD states that approximately 11 million people living in China's coastal areas will be vulnerable to global sea-level rise, with vast tracts of the country's coastal land being gradually lost to the seas. In recent years, there has been an annual acceleration in the rising water by 2.6 mm, highlighting the urgency with which the problem must be addressed. Over the next 30 years, sea-levels will continue to rise by 1-16cm and it is estimated that by 2050, water levels will be 26cm higher. Undoubtedly, the rapid increase in water levels will result in massive economic losses. However, it is arguably the damage to the ecosystem with the destruction of submerged sandbanks and marshes and, sea-water intrusion into the groundwater table that is likely to have a larger impact. China's coast is host to 70% of the country's large cities, with more than half its population residing in the area and, approximately 60% of the economy dependent on the region. Rising water levels will have an adverse impact on the growth of the economy and will lead to large-scale migration away from the area as human security is threatened.

People vulnerable to Sea Level Rise (million)



*The total coastal population of India and China was calculated using total coastal population in the 2000s and extrapolated from there using UN Population Division statistics for population growth in each country. Here, it is assumed that the coastal population will grow at the same rate as the national population.

The potential number of migrants is calculated for China using an OECD estimate for the year 2008. Assuming that this number grows at the same rate as the national population, the figures have been calculated using UN Population Division Statistics.

The potential number of migrants is calculated for India using a Times of India report estimating those in the Bay of Bengal region that could migrate. Assuming that this number grows at the same rate as the national population, the figures have been calculated using UN Population Division Statistics.

Migration as a result of a sea level rise along coastal India is likely to be negligible in comparison to other 'push' factors. For the most part, populated areas surrounding the Brahmaputra basin within India will not be affected by the sea-level rise. While the Sunderbans will be affected by increasing salinity, the process will constitute a greater threat to the ecology of the region rather than to its people. This is not to say that rising sea-levels in the area will not lead to migration, as research already shows that approximately 7000 'environmental refugees' have fled the Sunderbans. However, when compared to other push factors, rising sea levels along India's coastal areas will constitute far less of a driver to migration. The issue is more pertinent when analysing the Ganges River basin. Experts at the National Coastal Zone Management Authority (NCZMA) have warned that rising sea levels are causing salt water to flow into the Ganges River – threatening eco-systems and turning vast tracts of cultivable land completely barren. The process could eventually salinate groundwater supplies in and around Kolkata, while posing a threat to the agricultural land. Increasing salinity and rising waters, which are up to 3.14mm/year in the Bay of Bengal, could threaten up to 12 million people living in and around Kolkata, while denying them of their livelihood - leading to the eventual internal-migration of people.

Bangladesh's battle with rising sea levels is well-documented, with 12 of the country's 64 districts lined along the coast. The coastal areas of the country are home to an estimated 35-40 million people. In addition, the population density in the area is more than 743 people per square km, meaning that the low-lying country will face serious consequences owing to rising sea levels. The Khulna region that lies to the southwest of the country is already experiencing a sea level rise of 5.188mm per year, which is expected to increase to 85 cm by 2050. A World Bank study states that a 100 cm rise in sea levels within the next 100 years will inundate 15 to 17% of the country's land area, which equates to 22,135 to 26,562 sq km. Given the country's population density, this is likely to make 20 million people environmental refugees – an outcome which will threaten Bangladesh's stability and have far-reaching implications for its neighbour India.

Between 3% to 6% of Bangladesh's land could be lost to the sea by 2030 and 2050 respectively, giving the country the unenviable distinction of being the third most vulnerable country to sea level rise in the world. Rising waters will endanger the lives of thousands of Bangladesh's people and will also be the reason for large-scale migration towards the northwest of the country. About 33 million people could be forced off their land by 2050, and up to 43 million by 2080, as a result of rising sea levels. It is important to note that this figure does not take into account extraneous factors such as salinity and erosion, which will become more pronounced as sea levels rise and, could eventually force between 51-97 million people to leave their homes by 2080.

In addition to the migration of people, the southwest of the country is considered an important industrial and commercial region, with areas such as Patuakhali, Khulna and Barisal all expected to be affected by the rising waters. Furthermore, agricultural land in the southern districts of Khulna, Satkhira, Bagerhat, Jessore and Magura will also be affected by salinity intrusion forcing people to permanently migrate further inland.

Sea level rise will have a negative impact on the Sunderbans - a major source of subsistence for almost 10 million people in Bangladesh. It is estimated that a 10cm, 25cm and 45cm rise in waters will inundate 15%, 40% and 75% of the Sunderbans respectively. In addition, a rise in sea-level by a meter will inundate the entire mangrove forest of the Sunderbans. Increased salinity will have an adverse impact on the ecological system of the area. The loss of ecological areas such as the Sunderbans will have a drastic impact on future generations, as the loss of unique systems cannot be quantified in monetary terms.

Apart from the threat of flooding, sea level rise, loss of land through erosion, industrialization and dam-building, climate change is likely to increase the frequency of extreme weather events or natural hazards, which could also lead to temporary and eventual long-term migration of people. The increased incidence of typhoons to the south and southeast of China is likely to lead to temporary migration of people, while the possibility of intensified storm surges in the deltas of the Yangtze and Yellow due to sea-level rise, is likely to result in people leaving the area. Strong typhoons in August 2009 prompted the government to evacuate thousands of people along the eastern coast – a practice which could become more frequent as extreme weather events occur more often.

Bangladesh receives approximately 1% of the worlds' cyclonic storms every year, the frequency and intensity of which is likely to increase in the future due to climate change. In addition, rising sea levels will make inland areas more vulnerable to extreme weather, with a sea level rise of 32cm coupled with a tropical cyclone of similar intensity as that which occurred in 1991, estimated to increase the area of land vulnerable to flooding from 42% to 51.2%. Such eventualities will lead to migration and will also compound the problems faced by Bangladesh. In addition, the country's propensity to be hit by extreme weather events is highlighted by the fact that Bangladesh faces a severe tropical cyclone at least once every three years. Given that natural disasters tend to accompany periods of drought or the monsoons, the impact on the population and economy is often more pronounced.

The migration of people as a consequence of weather events and ecological threats is bound to challenge the social fabric of society. As 'outsiders' perhaps of a different religion, caste, ethnicity or linguistic background resettle in other parts of the country, there is the possibility that animosity towards the new migrants could increase. However, while the internal migration of environmental refugees will undoubtedly be a challenge to countries, its impact on regional stability is arguably limited, as it remains within the confines of a country's borders. The litmus test for the region comes by way of cross-border migration, as water scarcity drives people to seek refuge in other countries. Unless properly managed international environmental refugees could heighten tensions in the Himalayan sub-region and increase the risk of geo-political conflict.

Displaced by Dams

China's history of displacement as a result of its 70,000 dam projects is well-documented, – the most famous of which is the Three Gorges Dam, that has seen the displacement of over 1.17 million people thus far, and could lead to the relocation of as many as 5.3 million by 2020. Beijing has considered the construction of dams as an integral aspect to its development ambitions. However, as with other large-scale infrastructure projects, the loss of land for developmental purposes has often resulted in the displacement of people – a trend which is expected to continue along the upper reaches of the Yangtze and Yellow Rivers.

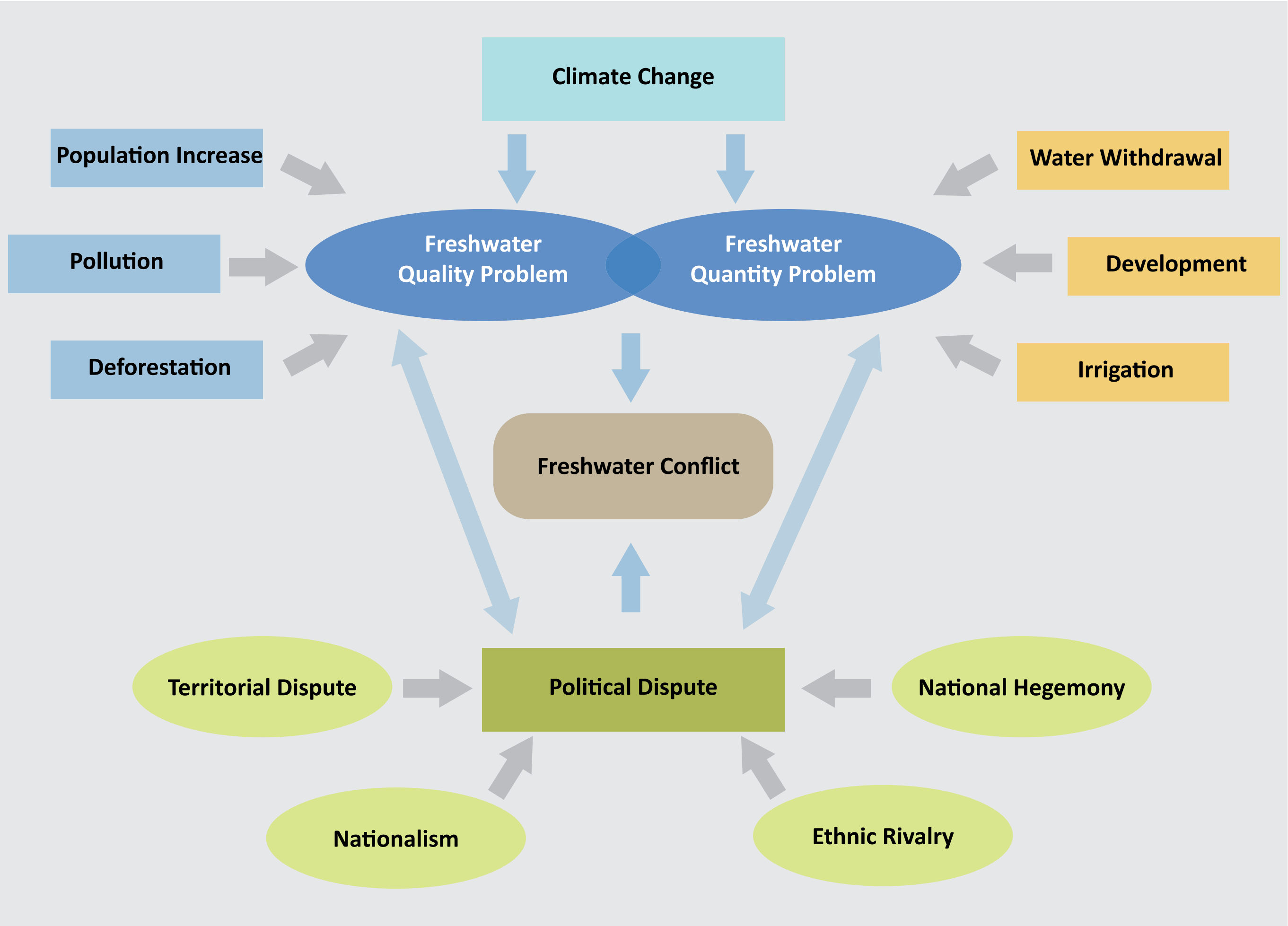
The northeast of India is considered to have enormous potential to generate power through hydro-plants. The Government of India has initiated plans to construct dams along the Brahmaputra and its tributaries in an effort to harness the potential of hydro- power. There is a possibility that people could be forced to migrate as a result of these developments, although given that the population density in the northeast is comparatively less than other parts of the country and, that most people live near urban centres, the number of people forced to migrate will be relatively few. However, it is important to note that while people might not be forced to migrate as a direct consequence of dam construction, there still is a possibility that such man-made structures could exacerbate the risk of flooding, which would, in turn, lead to people migrating.

Unlike its Himalayan river-fed neighbours, Bangladesh's flat topography limits the country's hydro-electricity potential, meaning that the displacement of people as a result of the construction of dams within the country will not occur.

Social Discord

As thousands of people are displaced as a result of deterioration of water and climate-related conditions, there is a risk of Himalayan sub-regional countries facing manifold threat to their social stability. While there is no widely-accepted understanding of what social instability is with regard to water security, we interpret it to mean that, as changing water flows and environment that could lead to the disruption of what is considered 'normal' life, through events such as migration, displacement and competition for resources. In addition, it includes the possibility of increasing tensions and animosity as a result of ethnic and cultural differences which become more pronounced as people relocate or migrate away from their 'habitats' to new surroundings, where

Drivers of Fresh Water Conflict



Source: Malik Fida A. Khan, "Ideas for Cooperation in Data Sharing & Scientific Exchange" presentation at Second International Workshop on Himalayan River Basins hosted by SFG - BIPSS at Dhaka on January 16, 2010

they are likely to be viewed as an 'outsider' or a minority. Furthermore, while social instability could be considered as a disruptive phenomenon, it does not necessarily lead to conflict.

The case of 'too much water, too little water' in Nepal is likely to lead to an increase in temporary and permanent migrants, as the issue of alternating floods and droughts forces people to move to the hill region. Initial resentment of the circumstances is likely to be directed towards the government, with people holding the authorities responsible for a lack of employment opportunities in their new surroundings. However, given the hill regions' situation of scarce groundwater, there is likely to be a growing sense of resentment towards the migrants, especially if the migrants are perceived to be infringing on the resources of the locals. The hill region is likely to feel the impact of poor monsoons and droughts and will have lesser water and fertile land than the Terai plains – leading to a struggle for meagre resources and increasing the likelihood of conflict.

The forced internal migration of people in Nepal as a consequence of water scarcity could fuel anti-government sentiment in the country – strengthening the resolve of the Maoists and posing a direct challenge to the democratic government. Though the Maoists are currently a part of the political mainstream, social instability fuelled by protests and resentment could provide them with a greater impetus to stake a majority control of the country.

The Chinese government has acknowledged that increased water scarcity and the subsequent migration or displacement of people could potentially ignite instability in the country. A report by the Ministry of Water Resources stated that between 1990 and 2002, more than 120,000 water-related conflicts were reported in the country, several of which resulted in violence. Despite China's impressive economic growth and social development, there still remains tremendous disparity between the predominantly urban eastern seaboard and the rural western interiors. The west of the country is home to an estimated 90% of China's poor, all of whom are in competition for the scarce water resources. In addition, the west has the highest proportion of ethnic minorities, including an estimated 20 million Muslims. The social fabric of the region, which has already witnessed several instances of ethnic tension, has been further tested by the government's policy of re-settling Han Chinese in an area where there is growing resentment towards outsiders, who locals believe to be taking their jobs. The influx of Han Chinese has also put a strain on water resources in the west, with a deteriorating situation likely to exacerbate minority discontent.

Crop failure in China in the past has led to social instability, with The Straits Times reporting 'countless skirmishes' in 2000 over water resources. In addition, Jilin province and Shenzhen have both witnessed clashes between migrants and locals or, migrants and government officials over depleting water and food resources – instances of which could become more prevalent in the future.

The potential for social instability in China is further complicated by the rural-urban divide, with the potential for class division and indifference likely to grow as the northeast, which is mainly comprised of Han Chinese, faces a critical water shortage. The northeast of the country is also the primary grain-producing

Salinity in Bangladesh

Salinity intrusion is a serious problem confronting China, Nepal, India and Bangladesh. And its seriousness increases with climate change and sea level rises in the deltaic countries. Currently, 31 districts of Bangladesh face severe salinity problems, with saline water flowing up to 240km inland during the dry season.

Rising sea level increases salinity in surface water resources, groundwater and the soil. As a result, the agricultural sector, which Bangladesh is heavily dependent on, is expected to face a significant drop in food-grain production.

Salinity also poses several other challenges:

- Reduction in cultivable land impacting food security
- Unsafe drinking water
- Decrease in agricultural output
- Rise of socio-economic problems, particularly for women
- Loss of biodiversity.

region and is heavily dependent on irrigation. However, the growth of urban centres has increased the demand for water, forcing the government to re-allocate resources away from the rural areas. With the livelihood of rural dwellers threatened as a result of the diversion of water as well as the government's inability to rectify the situation, there is a possibility of clashes between both sides of the economic divide.

Environmental degradation in China led to the displacement of between 20-30 million people in the 1990s, a figure which experts believe will jump to between 30-40 million by 2025. With migrants already constituting as much as 20% of the total population of several Chinese cities, an influx of more people could place a considerable stress on scarce resources. While China's coastal cities have managed to absorb the high numbers of migrants thus far, there are signs that the threshold is fast approaching. In conjunction, the threat posed to the coastal cities by rising sea levels will eventually lead to reverse migration towards the central and western parts of the country within the next 30-40 years, to areas where water security is already a major cause for concern. The reversal of trend is likely to create a new avenue for conflict as areas from where people once fled are now the recipients of migrants.

While most migration in Bangladesh is rural to urban, 10% of the population migrates from rural to rural areas on a short-term basis, usually after a natural disaster. In the past, such circumstances have led to incidents of social instability as returning migrants have been left landless either as a result of the natural calamity or due to having lost their land deeds in the disaster. As the number of people dependent on smaller tracts of land increases, there are likely to be further clashes in a bid to gain access to the required resources.

In Bangladesh, a major determinant of the potential for conflict lies in its ability to balance relations between its majority Muslim population and its minority groups over scarce resources. A report by the Bangladesh Institute of International and Strategic Studies stated that climate change could de-stabilize the country's economy – in much the same way that Nepal, China and India are threatened. With natural disasters expected to increase, the report states that 15% of GDP will be directed towards management of such catastrophes by 2015. The challenge for Bangladesh is apparent, with the government having to balance mitigation practices with growth prospects. In addition, there will be a need to ensure that as people are forced to migrate, the internal stability of the country is not compromised in any way. The floods in 1988 caused great dissatisfaction amongst the people and led to a point where they questioned the ability of the government to provide for their needs. The anti-government protests that followed resulted in political anarchy for two years, with the end result being the toppling of President Hussain Muhammad Ershad's government. With more and more people becoming vulnerable to water scarcity and climate change in the future, there is a possibility of further political turmoil in Bangladesh.

In India, at a local level, incidents of violence could be potentially disastrous in an already-fragmented society, which has often faced problems along religious, cultural and ethnic lines. Given the sheer number of people who are likely to be affected, coupled with the fact that poorest segments of the country will face the brunt of climate change, it could very well be India's litmus test in social and political governance. At a national level, social instability could potentially derail India's impressive growth, with the economy not only taking a beating from a possible reduction in agricultural productivity but, from a tarnished image as an attractive investment destination.

As the basin population grows, there will be an increase in the demand for food and electricity, both of which rely on water to sustain production. It is important to note that an over-dependence on one resource, in this case water, will naturally have a trickle effect on the availability of other products and services. As June 2009 demonstrated, deficit rainfall in the capital city Delhi impacted on the supply of water and power, leading to several areas of the city experiencing frequent power cuts, some lasting 10-12 hours. As life was thrown into disarray, citizens took to the streets, with riots breaking out in many places. The protests such as those witnessed across parts of New Delhi in 2009 could set a disruptive precedent people will look to vent their frustrations against the government's inability to ensure water, perhaps through violent means. It is important to note, that while power cuts in urban centres are arguably manageable, deficit rains or drought-like situations are likely to result in load shedding in the agricultural northern belt of the country – hampering production, reducing food stocks over a sustained period of time and, overall impacting the national economy to quite an extent.

In states such as Maharashtra, where the issue of migrants has traditionally revolved around jobs, a changing environmental scenario could lead to ethnic clashes over resources, as competition and/or demand surges in relation to a comparatively static, if not decreasing supply. Political groups, that have often attacked 'north-Indians' under the guise of protecting the Marathi Manoos, or the 'sons-of-the-soil', could target environmental migrants who are perceived as eating into the states resources. Similarly, environmental migrants from the affected states could move to other 'prosperous' parts of the country, such as Karnataka, Kerala or Goa, resulting in further divisions and ethnic or cultural rivalries.

Conflict aside, scientists and meteorologists are certain that changing weather cycles will have an impact on agricultural productivity in the country. The persistence of such situations could trigger 'farmer suicides', as has been occurring in the Western state of Maharashtra, Karnataka, Andhra Pradesh, Madhya Pradesh and Chattisgarh. Statistics show that more than 182,000 farmers have committed suicide between 1997 and 2007 across India. While the primary reason for farmer suicides is the inability, or burden of repayment of debts, we cannot deny the possibility that farmer suicides in the northern belt of the country could arise from water scarcity and its diminishing impact on crop production.

At the regional level, Nepal's potential to generate hydro-electricity is likely to become a source of contention, as the Himalayan nations' bigger neighbours, India and China, look to tap the country's large available resource. Development experts are of the opinion that dams on any of the three large rivers, as well as the hundreds of smaller rivers, can generate substantial revenue for Nepal. There is also a possibility that the country could look towards dam construction as a means to increase its own agricultural and industrial output, while exporting surplus power. However, any medium to large-scale projects in Nepal, while promising to be monetarily beneficial, will result in the permanent displacement of thousands of Nepalese people, which could potentially trigger social unrest.

In addition, water scarcity coupled with growing frustration of the people against the government, could trigger the rise of grass-root level social movements similar to that of the Naxalites in India. The belief that a segment of the population, particularly those living in rural areas, is not keeping up with the pace and progress of the nation, could result in mass uprisings and vigilante behaviour, as people resort to violence in a bid to gain access to water resources to sustain their livelihood and their daily requirements. Furthermore, given the large number of people living in the lower-income social segments of China, Nepal, India and Bangladesh, there is a real possibility of people uprising against the state.

As migration and other factors combine to exert increasing pressure on the population dynamics of the countries of the Himalayan River basins, it is likely that these internal pressures could become externalized. Apart from the issue of migration, the scarcity of water resources could become a principal trigger for a larger regional conflict. The threat for geo-political conflict over scarce water resources, cross-border migration and infrastructure projects is real and looms large over the Himalayan sub-region.

Geo-Political Risks 12

A geo-political conflict occurs when there is a clash of interests between nation states. This happens especially when countries differ on certain policies in politics, geography, demography and economics usually with respect to foreign policy. Geo-political conflicts invariably lead to stressful relations between stakeholders that are expressed through diplomatic protests, sanctions, dissolution of agreements, verbal condemnation and third-party intervention. In an extreme eventuality, when all efforts to resolve differences fail, a geo-politic conflict could also lead to an armed response or war.

As China, Nepal, India and Bangladesh look to secure their individual water resources for the future, the possibility of internal grievances and demand for water turning into a geo-political conflict will increase. With each of the four countries looking to sustain themselves, if not improve their current economic growth rates, there will be increasing pressure on governments to ensure that the competition for water resources does not derail future growth projections. In addition, as segments within the population shift along the social and development indices, both monetarily and by means of employment, the demand for water and distribution patterns for the resource are likely to change. Meanwhile, in an attempt to prevent an internal catastrophe and protect livelihoods, nation states and the citizens most at risk could look beyond their borders to secure water resources – which could aggravate the possibility of a geo-political conflict within the region by 2050.

Competition over Nepal

As the race for regional political supremacy between India and China heats up, there is some risk that relations between New Delhi and Beijing deteriorate as both countries look to secure their individual water resources which are extremely important requisites for development. The tremendous untapped hydropower potential of Nepal, which in 2007 had reached 612 MW or less than one percent of the total 83,000 MW potential, also has not gone unnoticed by either of the Himalayan kingdom's neighbours with both countries vying for their share of Nepal's 'water pie'. As for Nepal, its attempts to urbanize and industrialize its own economy will reflect on its need for power. Therefore, surplus of power for export to India and China will be more competitive than it is perceived at present. Such competition can produce diplomatic and commercial rivalries, although a conflict over Nepal between India and China is rather far-fetched. The main impact of the competition over Nepal's hydro-power will be in terms of deteriorating atmospherics between India and China, which could also exacerbate conflicts in other contexts or undermine the potential for cooperation.

In 2009, Beijing increased its annual aid package to Nepal by 50%, taking the total amount to more than US $21 million. In addition, China has made no pretences of its interest in Nepal's water sector, pledging an increase in hydropower and infrastructure development projects. Not wanting to lose out on Nepal's potential, India too has reiterated its intent to push forward traditionally strong relations with its Himalayan neighbour by undertaking most of the private hydropower development projects in the country, either through joint Indo-Nepal ventures or, individually. Given that water security is an integral aspect to India and China's development prospects and that both countries will be increasingly challenged by the impact of human and climate change factors, there is a sense of urgency in both New Delhi and Beijing to ensure that agricultural, industrial and domestic growth is not hampered by a lack of water resources.

While it is still too early to ascertain the extent to which political developments in Nepal will affect India, the inclusion of the Maoists into the political mainstream will surely not have gone well in New Delhi and will be viewed as a political victory in Beijing. Although Maoist leader Prachanda resigned as Prime Minister in 2009, the fact remains that Nepal's Maoists won the country's first democratic elections in 2008 and are very popular and influential in the country's rural areas. There is no denying that India's position vis-à-vis Nepal is strong. However, with a new contender in Nepal's political fold, the possibility of an eastward shift in Kathmandu's stance cannot be ruled out – a prospect which could diminish New Delhi's access to vital resources and, which could escalate tensions with China.

Great Bend

Aside from Nepal, a potential driver for conflict between India and China is the speculation about the highly contentious Chinese proposal to construct a 40,000 MW dam along the 'Great Bend' in Tibet. Despite Beijing's repeated denials of undertaking the project, recent and frequent media speculation in India has brought the issue to the forefront of Sino-Indo relations. The location of the dam in a highly seismic region and the fact that the project in its entirety (diversion and dam) could have an adverse impact on the lower riparian nation of India, has led to intense debate and political opposition to the proposal within India. The idea of Beijing being able to turn the 'taps' of the Brahmaputra River on and off as per its requirements has also triggered an alarm in India, where dependence on the perennial waters is vital to the existence of more than 33 million people in the basin alone and, has the potential to be India's power house. China claims that it has no intentions of constructing any such diversions and attributes such speculations to views expressed by retired military officials. If at all China does go ahead with such a project, India may engage in propaganda and diplomatic warfare. This will not lead to any confrontation between the two countries but may induce India to attract China's rivals such as the United States and Japan into a new alignment in Asia. Such developments could lead to new polarization and produce a geo-political contest.

A further point of contention with regard to Beijing's alleged plans to construct a dam at the 'Great Bend', pertain to the potential loss of hydropower in India. With the Indian Government looking to construct 140 hydroelectric power generating stations in north-east, there is tremendous risk of losing out on power generated from these projects. Given that the completion of dam construction in India might coincide with the operation of the proposed dam and diversion at the Great Bend in roughly 20 years' time, there is a likelihood of India's dams being rendered unusable due to a lack of water flowing downstream. This will undoubtedly have a major impact, especially in the dry season, the period during which there is the highest demand for power. Leaving aside the potential monetary loss to India in constructing dams of little operational value in the future, the bigger impact will be felt in the loss of potentially utilizable power. The importance of the resource to the agricultural, industrial and domestic sector and, its clear linkages to human security, any perceived obstacle to its availability could trigger diplomatic and government protests.

Cross Border Migration

India's vast geographical expanse means that the country shares several of its borders with other countries. One, in particular, has been a gateway of sorts for illegal migration into India, with several million Bangladeshis currently residing in the country (the exact number of Bangladeshi refugees varies from one source to another as this is a political issue). The Government of India has initiated steps to curtail the illegal movement of people by constructing a high-tech fencing system along the 3360 km border. While India's current focus is on stopping illegal immigration, New Delhi is aware that Bangladesh's vulnerability to sea-level rise and climate change could drive hundreds of thousands more across the border, as they search for a secure access to water.

Trans-border climate refugees from Bangladesh pose a serious challenge to social stability in India. The sheer number of illegal immigrants could multiply as refugees seek shelter following potentially catastrophic natural disasters in Bangladesh. A study by the Washington-based National Defence University concluded that a 'destructive' flood in Bangladesh could result in an influx of refugees into India, which could, in turn, trigger religious conflict, spread contagious diseases and, cause overall damage to the infrastructure. The report also states that hundreds of thousands of refugees crossing the border could spread terrorism within India and, potentially pose a challenge to the government. Cleo Paskal of the Royal Institute of International Affairs in London, states that migrants from Bangladesh could fall prey to radical Islamic movements determined to de-stabilize India, adding that a large influx of Bangladeshis would further increase the risk of terrorist attacks. Subversive activities and/or anti-government behaviour could irk the host country, in this case India, and have negative implications for regional security. Furthermore, it is imperative to note that climate-sensitive diseases could spread rapidly between Bangladesh and India as refugees move across the border.

Addressing the issue of trans-border climate refugees will require the Indian government to adopt a tactful and sensitive approach. Turning away refugees, who more often than not constitute the poorest of the poor, would be a diplomatic and international blunder. Yet, allowing an influx of people into the country, each of whom require food, water, shelter and perhaps eventual integration into society, would not just be a logistical nightmare for a developing nation such as India but, would entail massive resource allocation, further straining supplies. In such a situation, animosity towards the 'outsider' is likely to grow – challenging the government's authority and leading to potential clashes. Moreover, if the government feels that the climate refugees are trying to exert pressure on authorities or enter into the domestic political process, tensions could rise. In such a scenario, the host country could look to repatriate refugees, which could, in turn, potentially result in a conflict with the sender state. Furthermore, a surge in Bangladeshi refugees could lead to the 'ghettoisation' of various area pockets in the north-eastern states, where majority of the illegal immigrants currently reside. As has been witnessed across the globe, the formation of such clusters often leads to racial tensions, as the minority population is ostracized for being culturally, physically or linguistically different.

In such an eventuality, there is a high probability of countries engaging in some sort of a proxy or scaled-down cross-border skirmish. While a full-scale war is unlikely given the international condemnation it would invoke and India's keen desire to be recognized as a responsible power, a military confrontation on some level cannot be ruled out. Such an outcome will be even more likely if the climate refugees are involved in nefarious activities and seen to be draining India's resources. In addition, Dhaka's actions with regard to controlling the flow of migrants, while ensuring that its citizens do not wage attacks on India will be regarded as an influencing factor in determining the likelihood of a conflict breaking out between India and Bangladesh.

Besides India's concerns about Bangladeshi migrants, there is also a risk of tension between the two countries over India's plans to build dams that could potentially affect river flow to Bangladesh.

It is unlikely that Nepal will be faced with a conflict scenario over water resources with any of its Himalayan river-fed neighbours. Keeping aside the potential for conflict between India and China over Nepal's resources, there is a possibility, albeit fairly remote, that New Delhi and Kathmandu could clash over the construction of dams on either side of the international border, as a result of the internal displacement of people. Projects undertaken in Nepal could result in the loss of valuable agricultural land, as the confluence of the three major Nepalese Rivers flowing into India occurs within the Terai plains. While all this will increase the possibility of flooding downstream and lead to a loss of income for the forcibly relocated Nepalese due to the construction of dams, the numbers are likely to be too few to warrant a conflict. In addition, New Delhi and Kathmandu's historically 'friendly' relations further dilute the possibility of a conflict, not to mention that the sheer size of the Indian economy and its accompanying military budget will deter Nepal from taking an aggressive stance. Ultimately, any dam construction project on either side of the border, where the possibility of an adverse impact to the other side exists, cannot proceed unless approved by both countries.

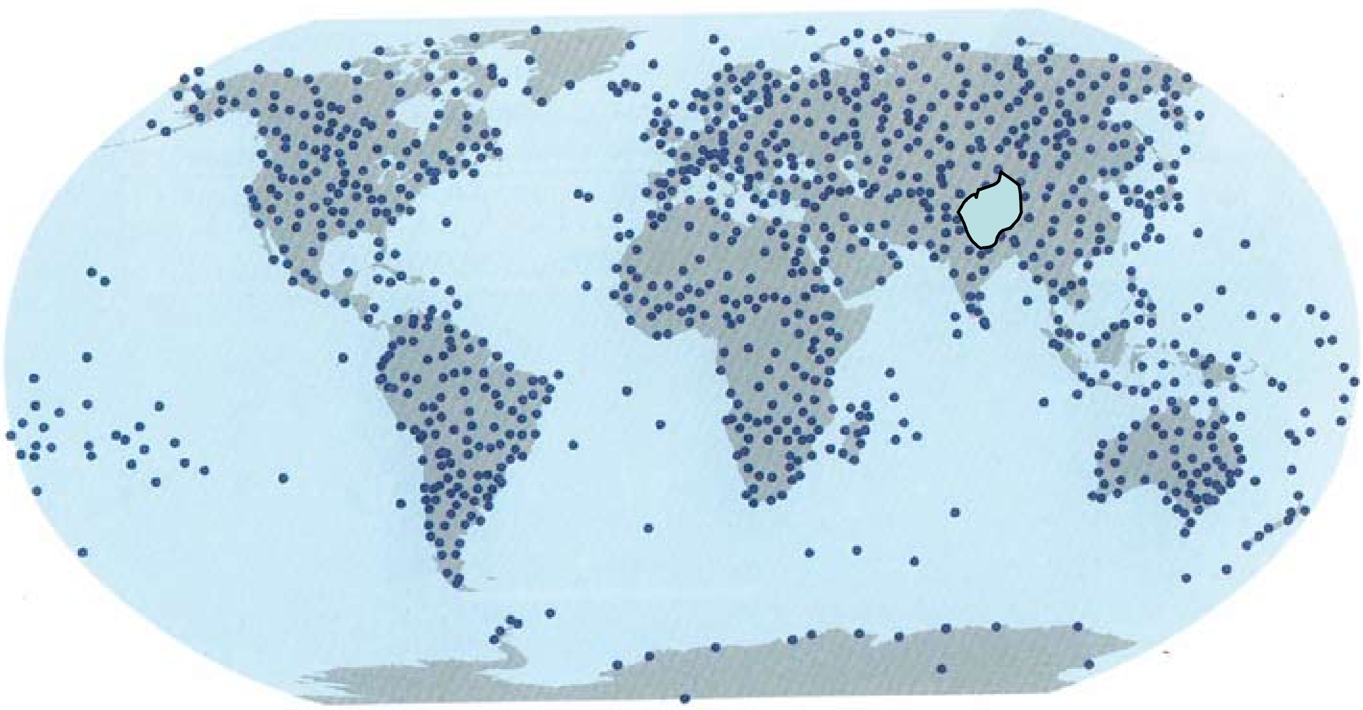
The possibility of a conflict arising amongst the Himalayan river-fed countries over water security-related issues and access to water resources does exist, though remote. There is a possibility that China, Nepal, India and Bangladesh will engage in diplomatic or legal discord instead of resorting to an armed conflict. While the analysis presented thus far does make the case for several scenarios which could conflagrate, there are other outstanding issues between the countries which are arguably a greater catalyst to a geo-political conflict – border disputes, competition for increasing spheres of influence and terrorism amongst others. Ultimately, while each country wants to sustain its growth and development in the future, any act of conflict or adventurism threatens to derail if not 'reverse' the process, while posing a threat to regional stability at the same time. The issue is not so much if a military conflict will take place. The issue is whether water security-related conflicts will deteriorate trust and confidence between countries in the region to the extent that they induce them to seek alliances outside the region and give birth to fresh alignments and rivalries in Asia or whether the countries find it in their interest to engage in mutual and sub-regional cooperation to address their problems. While water security essentially poses internal threats, trans-boundary cooperation is essential to ensure that all countries coordinate their policies and actions to prevent "beggar thy neighbour' politics and convert an adversity into an opportunity.

Part II : Sub-regional Cooperation

Data Sharing and Scientific Exchange 13

The trans-boundary nature of the major Himalayan Rivers, as well as the global impact of climate change makes international cooperation in this region both necessary and opportune. Increased collaboration between academics, scientists, policy-makers, and institutions, across China, Nepal, India and Bangladesh is required to deal with the many challenges facing the Himalayan Rivers that flow in these nations. Knowledge sharing is essential in order to identify common opportunities and risks of trans-boundary water management and to create fair benefit-sharing mechanisms. Another requirement is also consistent, information-based dialogue between nations to build a shared understanding in order to achieve solid, cooperative results. Any new efforts should be ideally build on existing institutions and initiatives.

GCOS Surface Station Network



Source: Ajaya Dixit, "Sharing and Scientific Cooperation: Reflections" presentation at Second International Workshop on Himalayan River Basins hosted by SFG - BIPSS at Dhaka on January 16, 2010

South Asian Association for Regional Cooperation (SAARC)

The South Asian Association for Regional Co-operation (SAARC) was established when its Charter was formally adopted on December 8, 1985 by the Heads of State or Government of Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. Afghanistan was accorded membership a little later and a dialogue partnership was created with a few countries including China and the United States.

SAARC provides a platform for data-sharing and policy cooperation by creating a programme focused on the Himalayan eco-system just as it has created similar integrated programmes of action in other areas. However, SAARC platforms do not have an impressive track record in the delivery of concrete results due to their excessively bureaucratic nature. SAARC has been criticized for not achieving its targets; the primary reason for this being that the national interests of member states have taken precedence over the regional priorities. There is no unifying South Asian ideology. Moreover, SAARC does not encompass all the countries in the Himalayan sub-region. China is only a dialogue partner and not a member of SAARC. At the same time members such as Sri Lanka and the Maldives are irrelevant with regard to discussions on Himalayan river –related issues.

India-China Cooperation

Currently, there is no water-sharing treaty between India and China over any of the trans-boundary rivers they share. Two MoUs (Memorandum of Understanding) exist between India and China over trans-boundary rivers. The first was signed in 2002 for provision of hydrological information on the Yarlong Tsangpo/Brahmaputra during the flood season by China to India. As per this MoU, China provides India with hydrological information regarding water-level, discharge and rainfall from the three stations - Nugesha, Yangcun and Nuxia located on the Yarlong Tsangpo from June 1st to October 15th every year. This data is supplied by e-mail twice a day and is used by the Indian Central Water Commission to forecast floods. China provided India with this hydrological data free of cost for the period 2002-2008. Post-2008, India agreed to pay for it until 2012.

The other MoU was signed in April 2005 for the provision of hydrological information on the Sutlej/ Langquin Zangbu in the flood season. The Chinese Government has been providing information from the Tsada station on the river since the monsoons in 2007. India has paid for this information through the years.

Provision of hydrological information between India and China is limited to the flood season i.e. the monsoon months; there is no data sharing between them for the rest of the year. During the Chinese President's visit to India in 2006, there was an agreement to set up an expert-level mechanism to discuss cooperation on provision of flood season hydrological data, emergency management and other issues linked with trans-boundary rivers. The Joint Expert Level Mechanism was set up for this purpose. The Indian Expert Group is led by the Commissioner, Ministry of Water Resources while the Chinese delegation is led by International Economic and Technical Cooperation and Exchange Centre, Ministry of Water Resources. It has also been decided that this mechanism will meet once every year, alternating between China and India. The first meeting of this mechanism took place in September 2007 in Beijing; the second meeting took place in April 2008.

Since 2006, India's Council of Scientific and Industrial Research (ICSIR) and China's National Natural Science Foundation have worked together on issues covering changing environments, ocean variability, land ecosystems, land-ocean interactions, land-atmosphere interactions, ocean-atmosphere interactions and coupled-modelling. A joint workshop held in 2006 between the two organizations had experts from India and China discussing monsoon-related ocean and land issues. Ten additional joint proposals were initiated at the conference.

In November 2009, India and China signed an agreement that includes conducting joint research on impact of global warming on the Himalayan and Tibetan glaciers. The agreement covers 'cooperation in observation and monitoring of climate change and undertaking mutually cooperative activities and programmes as appropriate.' In addition to joint research, the countries will also undertake developmental activities.

China-Bangladesh Cooperation

From 2006, China has been giving 'real-time' upstream flow data on the Brahmaputra River to Bangladesh to help the country forecast floods.

Any kind of collaborative effort with respect to the Himalayan Rivers will have to include all countries through which these rivers flow, i.e. China, Nepal, India and Bangladesh. For any collaborative mechanism to function well, trust between the members is of prime importance. Hence, regular meetings and discussions at different levels, aimed towards mutual understanding would be a necessary element. Cross-border research, monitoring and exchange of data are essential for the efficient management of a trans-boundary river. There is need for more data-sharing between countries on rivers like the Yarlong Tsangpo, the Ganges and the Kosi.

During the monsoon months, China shares flow data with India and Bangladesh over the Sutlej and Brahmaputra rivers twice daily. This data is primarily used for flood forecasting. Even this data is not enough since at times the countries have less than four hours to take action based on this flood data. The frequency of data-sharing exercises needs to be increased.

China has been contributing towards the development of water resources in Nepal on both governmental and non-governmental levels. Joint studies have been undertaken by Nepal and China on glaciers and rivers. A joint Nepal-China GLOF study expedition to the upper reaches of the Arun and the Sun-Kosi region of China took place in 1987. This expedition also included Canadian advisors. A report on the GLOF situation of water catchment areas of Pumko (Arun) and Poiko (Bhote – Sunkoshi) was prepared as a result of another joint study undertaken by Nepal and China.

India-Bangladesh Cooperation

The Indo-Bangladesh Treaty on Ganges' Waters was signed on December 12, 1996; it is valid for 30 years, with a provision for a review of the treaty after five years. Neither party has asked for a review yet. The treaty deals with the sharing of Ganges waters at Farakka during the lean season. This sharing of waters is monitored by a Joint Committee that comprises members of the Indo-Bangladesh Joint River Commission (JRC). This Joint Committee meets thrice every year. According to the Indo-Bangladesh Treaty on Ganges' Waters, India has been providing Bangladesh with flood data for the Ganges River from June 15^{th} to October 15^{th} every year; the flood data for the Brahmaputra River from the Pandu, Goalpara and Dhubri stations; and the flood data for the Barak River from the Silchar station, during the monsoons, for the purposes of flood forecasting. India also provides Bangladesh with data of the rivers Teesta, Manu, Gumti, Jaladhaka and Torsa.

However, Bangladesh is not happy with this treaty and has claimed that the country is not receiving the quantity of water through the Farakka Barrage that had been agreed to in the treaty of 1996. A JRC report has claimed that India has short-changed Bangladesh of 589 m3/second or 0.51 BCM of water between January 1^{st} and 10^{th}, 2010. In 2009, Bangladeshi members from the JRC protested that India was releasing less water from the Barrage than agreed upon. Bangladesh has also sought Indian cooperation for fair sharing of other trans-boundary rivers including the Teesta in January 2010.

Bangladesh, in addition, has complaints against India over the Tipaimukh project and over the now-stalled Indian River Linking project.

India-Nepal Cooperation

The governments of India and Nepal are involved in continuous dialogue at various levels for cooperation on issues related to development of water resources. The Joint Committee on Water Resources (JCWR) chaired by the Water Resources Secretaries of both countries is the body that discusses all water-related issues between Nepal and India.

The two countries signed a treaty on the Integrated

UN Convention on Non-Navigational Uses of International Water

The United Nations Convention of the Law of Non-Navigational Uses of International Water Courses was adopted in May 1997. The Convention was designed expressly for the purpose of providing countries with a fair mechanism to deal with waters that cross international boundaries, at both the surface and groundwater levels. Only 16 governments have ratified the Convention, it is due to this reason that it has yet to become enforceable.

Article 3 of the Convention recommends that States that share water courses enter into agreements that apply the provisions of the Convention and tailor them to the particular needs of the specific water body in question. It also states that pre-existing agreements will remain unaffected by the Convention. Besides this, the article also addresses a situation when less than all of the States that share an international water course enter into an agreement. In this case, the Convention necessitates that the agreement cannot adversely affect the water uses of another riparian nation without its consent.

Article 4 of the Convention states that for an agreement to apply to an entire international water course, all riparian nations have the right to participate in the negotiation of the agreement and become a party to it. Similarly, any riparian state whose utilization of the water course could be affected due to the implementation of a particular part of the agreement, that State has the right to be consulted in the negotiations relating to the agreement.

Article 5 of the Convention sets forth the idea that all riparian countries must use international watercourses in an equitable and sustainable manner. Similarly, all agreements that are entered into must look to share and develop watercourses with the view to achieving optimal results for all the States involved.

Article 7 of the Convention emphasizes that in utilizing international watercourses within their own territory, States should take all possible measures to ensure that no 'significant harm' ensues for other riparian states. It also states that if and when such harm is caused, the State that causes the harm should take all steps necessary to consult with the other riparian nation to minimize or mitigate the issue that has been caused or provide appropriate compensation for the damage.

According to Article 8, the signatories to the convention with shared watercourses are bound by a general obligation to cooperate on the basis of sovereign equality, territorial integrity and mutual benefit in order to achieve optimum utilization and protection of a shared watercourse. For this, the member states may set up joint mechanisms or commissions to facilitate cooperation and enhance sharing experiences.

Article 11 necessitates exchange of information, mutual consultation and negotiations on the possible impacts of planned measures on the shared watercourses.

According to Article 12, countries will have to notify other riparian nations of the planned development on shared watercourses and its possible adverse impact on them. They will also have to provide available technical data including results of environmental impact assessment, so that the riparian nations are able to evaluate these impacts thoroughly before the development process can proceed.

Article 33 of the Convention deals with the settlement of disputes between parties. In case the parties to the dispute cannot reach an agreement through negotiation, they may seek mediation either by a third party, settlement by way of arbitration or go to the International Court of Justice. If the parties concerned fail to reach an agreement through any of the above means, six months from the time of request, the dispute shall be submitted to a Fact Finding Commission, composed of one member nominated by each party and a Chairman of a completely different nationality, who is chosen by the nominated members. The expenses of this Commission are to be borne equally by the concerned parties.

Development of the Mahakali River/Sarda River in February 1996 (known as the Mahakali Treaty). The Pancheshwar Multipurpose Project on the Mahakali River is the centrepiece of this treaty. India-Nepal Joint Group of Experts (JGE) oversees the progress of this project. Unfortunately, this treaty has stalled; it will be discussed elsewhere in the paper. The other multipurpose project on agenda is the Sapta Kosi-Sun Kosi Multipurpose Project located in Nepal.

Dialogue between India and Nepal over the issue of river basin management resulted in the identification of benefits of collaboration beyond water allocation. These include hydropower and fishing. As a result, India has taken successful initiatives like afforestation drives in the upper reaches of its rivers to prevent sedimentation.

Lessons from Outside

Sharing of technical and scientific expertise among riparian nations may help in creating an environment conducive to further dialogue. Hence, a regional network of experts working on the issues related to the trans-boundary rivers would go a long way in facilitating more regional cooperation between China, Nepal, India and Bangladesh.

The South Asia Trans-boundary Water Quality Monitoring (SATWQM) Project, initiated in the US, has created a network of South Asian organizations that monitors water quality in the basins of trans-boundary Ganges and the Indus; and shares data over the internet. This network includes research institutes, universities and NGOs that collect water quality data in the border regions of Pakistan-India, Nepal-India and Bangladesh-India. Issues of concern include the impact of untreated sewage, industrial effluents and agricultural runoff; river siltation; increasing salinity in freshwater and environmental degradation of critical habitats. The main idea behind the project is to use cooperation over sustainable environment as a means to improving relations between countries. This initiative can be strengthened and extended to China since it already covers three other countries.

The UN Convention on the Protection and Use of Trans-boundary Watercourses and International Lakes came into being on March 17th, 1992 at Helsinki. It is, 'intended to strengthen national measures for the protection and ecologically sound management of trans-boundary surface waters and ground waters'. It obliges parties to the convention to prevent, control and reduce water pollution. The Convention also includes provisions for monitoring, research and development, consultations, warning and alarm systems, mutual assistance, institutional arrangements, and the exchange and protection of information, as well as public access to information.

SFG Workshop Proposals

Two workshops on water security in the Himalayan region hosted by the SFG in partnership with other institutions have emphasized an increased need for scientific cooperation and regional collaboration to reduce the information gap that currently exists. The primary reasons for the lack of data include the limited number of hydro-meteorological stations and the absence of any pooling together of data and research.

Even with the data available, one of the main issues with the current level of sharing is that China, Nepal, India and Bangladesh share hydrological data only in the monsoon months. This limits the use of data-sharing only to flood forecasting. Data needs to be shared more regularly and throughout the year. There is no collaborative data-sharing on low season (lean season) flows. It is important to have cooperation in data-sharing all through the year between China, Nepal, India and Bangladesh so that lean season flows of Himalayan Rivers can be predicted. Since these flows are essential for a host of activities such as navigation and hydropower projects downstream, it is imperative that the countries collaborate for more frequent data-sharing the year round. There is also need for a channel of emergency communication, a type of SOS, between the countries.

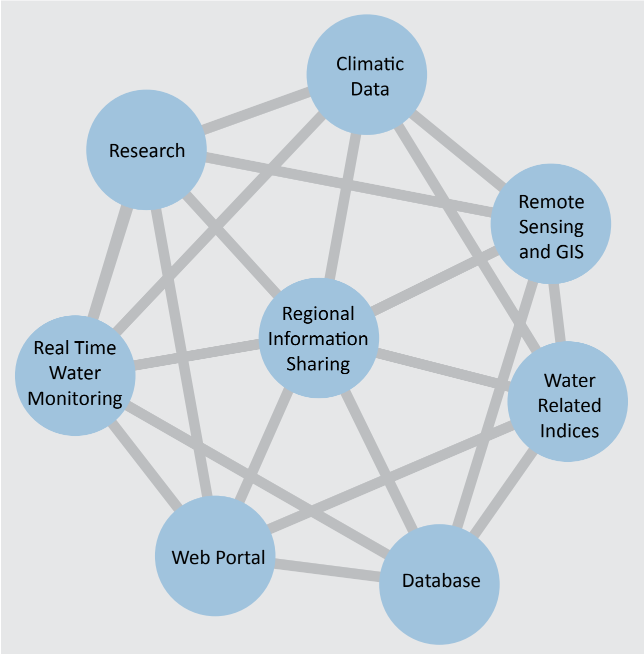
The ***Dhaka Declaration on Water Security*** has proposed an expert committee to prepare a roadmap for data-sharing and scientific exchange and to prepare guidelines to ensure transparency regarding relevant data. The Second International Workshop of SFG stressed the need to modernize the current data-sharing. One of the participants came up with some proposals for data-sharing in the region including a common data-sharing policy for the region; countries linked through high-speed, high-capacity broadband network; and creation of a web-based meta-database with each organization following a standard format for developing their own database. He also proposed collaborative studies for setting up a web-based drought monitoring information system for dissemination in co-riparian nations. The participant also suggested that the current flood information dissemination system ought to be improved and applied to a regional context. The risk of disasters can be minimized through better information on floods and erosion in the sub-regional context.

The Second International Workshop also suggested establishing joint research projects involving China, Nepal, India and Bangladesh to acquire, collect, generate and process appropriate and updated data, especially where data-sharing is restricted due to security issues. It is also essential that these countries cooperate on undertaking joint assessment studies in order to determine the future changes as a result of climate change and their impact on the main Himalayan rivers and their water flows. A starting point for any kind of cooperation could be Track II initiatives that function through unofficial channels and result in creating constituencies of support. Such initiatives may act as preparatory processes for wider, official cooperation. Since the countries share waters of the Himalayan rivers, it is essential that an effective mechanism be developed where countries can share data along with technical and scientific expertise on a common platform through knowledge-based partnerships.

The First International Workshop on 'Water Stress and Climate Change in the Himalayan River Basins,' organized by Strategic Foresight Group in August 2009 in Kathmandu brought together experts and policy-makers on water issues from China, Nepal, Bangladesh and India. One of these experts said that country-level models do not account for regional trends, hence, there is need for regional models to study trends specific to the region. All experts urged the countries to overcome the present tendency to resist sharing of scientific and technical data in a context where national solutions are not feasible. They recommended the use of local traditions to preserve livelihood, action research, ecosystem-as-a-whole approach involving all stakeholders and the use of instruments of international co-operation, like the UN Convention on Biological Diversity and the Ramsar Convention.

At both the workshops, a proposal for a Regional Information Sharing Network was mooted.

Regional Information Sharing Network



Source: Ajaya Dixit, "Sharing and Scientific Cooperation: Reflections" presentation at Second International Workshop on Himalayan River Basins hosted by SFG - BIPSS at Dhaka on January 16, 2010

Some of the proposals for joint research include:

- The impact of climate change on flood management of the Ganges, the Brahmaputra and the Meghna basins;
- The impact of climate change on snowmelt and water availability;
- Development of regional water quality network;
- Regional navigational connectivity towards developing a multi-modal transportation system for trade facilitation in South Asia.
- Institutional capacity-building in relation to climate change monitoring.

The Abu Dhabi Dialogue (ADD) provides a successful example of sustained, informal dialogue between nations that is working towards a shared vision for the region. A similar process could be designed for these four nations as well. The ADD Knowledge Forum is also a good example of cooperation for knowledge.

It is clear that on the issue of data sharing, scientific and technical exchange, a lot more needs to be done in the Himalayan sub-region. The steps taken so far are not enough to reduce the information gap that currently exists in the region vis-à-vis the impact of climate change on these countries. There is also a need for a joint assessment of future changes as a result of climate change and their subsequent impact on river flows. Trust-building is required for successful cooperative effort. In order to facilitate an atmosphere of trust, it is important that China, Nepal, India and Bangladesh cooperate in other fields too. Steps taken to boost bilateral and multilateral trade will eventually contribute towards building of trust between these nations.

Trade, Transit and Eco-Tourism 14

Over the years, specific measures have been taken to control floods, expand irrigation and harness hydropower in the Himalayan region in China, Nepal, India and Bangladesh. Large scale development of water transport on shared rivers did not feature as a major objective due to the development of roads and railways, especially in India - an important transit country. The focus shifted away from waterways as a viable option to other modes of transport since the water networks were confined to specific regions where the river flows. Moreover, with increasing competition over water resources for non-navigable uses such as for irrigation and hydropower, maintaining adequate levels of water for transit has become a hurdle. However, water-based transport is highly energy-efficient and an environment friendly mode of transport. It has high employment potential and is also expected to play a major role in meeting the emerging transport infrastructure requirements of the future.

Nepal, the south-west of China and the north-east of India are essentially land-locked sections. Nepal relies on the provision of access to ports in India for its exports to a third country. Nepal's major trading partner is India followed by the United States and Germany. Its trade with Bangladesh is negligible. Both these countries - Nepal and Bangladesh, can therefore benefit immensely by opening up river transit routes through India since it will not just improve the balance of trade but will also be economically viable.

At present, a major portion of the traffic between north-east of India and the rest of the country passes through the Siliguri Corridor or 'Chicken's Neck', a narrow strip of land connecting the states in the north-east of India to the state of West Bengal in India. The trans-boundary waterways in Bangladesh have been opened up to transfer goods to and from the north-east to other parts of India. Despite this, the present use of the waterways is limited due to lack of infrastructural facilities.

China, on the other hand, can benefit greatly from the opening up of water trade routes in the north-east of India to facilitate the transit of commercial goods from south-west of China to south-east Asia and other markets in the region. Hence, collaborative development of waterways in the context of regional development of the Himalayan River basins becomes not just important but also progressive.

In addition to trade, development of waterways provides a convenient function in related activities, such as passenger navigation, tourism, and water sports. The Himalayan region provides ample tourism potential with its unique wildlife and forests, religious places and ethnic cultures, which are diverse in nature along the rivers. Given this, the prospects of tourism, more specifically ecotourism, look promising in the region since this will not only help in conserving the environment but will also inject economic development in the local communities of the region.

Water Transport and Ecotourism

In general, the utility of water transport has not been tapped to its full potential in the Himalayan River basins. As

Trading Pass Near Indian Border Town Kibithoo

Source: <http://www.boloji.com/plainspeak/119.jpg>

noted earlier, development of road and rail transport, lack of infrastructure and investment, increased use of water for non-navigable purposes has made waterways a less attractive and more expensive option. China and Bangladesh have relatively well-developed systems of inland water transport compared to those in India and Nepal.

The inland waterways in China are confined to Jiangsu, Guangdong, Hunan and Sichuan provinces, where the Yangtze and Pearl Rivers flow. Though China has a well-developed system of waterways, the south-west of China, much like the north-east of India, is underdeveloped and landlocked. The opening of the Kibithoo Pass between Tibet and north-east India has facilitated the transport of commercial goods from south-west China reaching the Brahmaputra's furthest upstream port of Sadiya in India for transport downstream. In addition, the construction of a major bridge crossing the Lohit River has improved access into Tibet from India all through the year. The usage of the pass has, however, been limited over the years.

The inland water transportation in Nepal, at present, is limited to the use of small ferries at numerous crossings concentrated mainly in the lower reaches of Karnali, Narayani (Gandak in India) and Saptakoshi Rivers. The Karnali and Narayani Rivers are considered suitable for the development of navigation from the Indo-Nepal border right up to their confluence with the Ganges. In Nepal, the lower reaches of the rivers are navigable throughout the year. Hence, there is good potential for extending and developing navigation from Nepal to Kolkata port through Patna. In India, the Patna-Kolkata stretch of Ganges River is a part of the National Waterways-1 developed between Allahabad and Haldia port. The possibilities for further extension of navigation to the north in Nepal from India and inclusion of navigation in the Indo-Nepal Treaty have been explored in the past. However, no substantial progress has been made on this front due to doubts raised over the availability of adequate water levels for navigation during the dry season, especially in India.

In India, the stretch from Sadiya port on the Lohit River to Dhubri near the Bangladesh border on the Brahmaputra River forms National Waterway-2. The Brahmaputra River, along with major tributaries Lohit, Dhansiri, and Subansiri Rivers, have the potential to become major water transit routes for goods from south-west China to the Kolkata port or other ports in Bangladesh. The water transport could likewise boost movement of commercial goods from major transit points from cities further east in southern China, namely Chengdu, Kunming, and Dali. It is important to note that the Brahmaputra and its tributaries are not navigable across the India-China border. Hence, a multimodal transport system could be developed in the region connecting roads to the waterways. This will benefit the geographically-isolated regions in both India and China to connect with the mainland.

National Waterway-1 in India

Source: Inland Waterways Authority of India. <http://iwai.gov.in/mapnw1.htm>

Apart from water-based trade, navigation along the Brahmaputra can also be channelised to develop the tourism industry. Presently, there are some private river cruise ships that already operate on the river with several floating restaurants thriving on the banks of the river Brahmaputra. As noted earlier, the Brahmaputra and its tributaries are not navigable across the India-China border. Hence, water-borne travel can be expanded to include only the areas that are very close to the border. The tourism boards of India and China could boost the number of tourists the region draws through communication and mutual promotion of ecotourism.

Navigation has always been an integral part of the transport system in Bangladesh. Around 6,000 km of waterways are currently navigable by larger mechanized vessels during the monsoons. The inland water transport's mechanized fleet carries cargo to and from inland river ports to the maritime ports of Chittagong and Mongla. The other form of inland water transport includes movement of domestic cargo between the districts. There are 11 major river ports in Bangladesh. A large portion of the cargo originating from seaports is bound for inland river ports, mainly Dhaka, Narayanganj and Khulna.

The Sunderbans, situated in the lower end of the Ganges, Brahmaputra and Meghna River systems, provide ample scope for ecotourism development. The Sunderbans are very rich in biodiversity and comprise of two eco-regions namely, the 'Sunderbans freshwater swamp forests' and 'Sunderbans mangroves'. The Indian portion of the Sunderbans has cruise ships that operate on the Hoogly River system. Bangladesh is beginning to experience growth in its ecotourism. The Sunderbans increasingly attract both domestic and international tourists. However, the percentage of international tourists is still small. If ecotourism in the Sunderbans can be developed and promoted as a single destination, the overall economic and environmental benefits will increase manifold in the region.

National Waterway-2 in India

Source: Inland Waterways Authority of India. <http://iwai.gov.in/MAPNW2.HTM>

Water Treaties

A general analysis of the various engagements between the riparian countries show proposals drawn to expand the waterways based on geo-political relationships shared by the countries. In addition, the engagements have primarily been bilateral in nature, especially that of India, even though the Himalayan Rivers flow through more than two countries.

Treaty of Trade and Transit between India and Nepal

The Treaty of Trade and Transit between India and Nepal provides a bilateral framework on trade and transit. This treaty includes a provision whereby it is automatically extended for seven years unless one of the contracting parties gives written notification of its intention to terminate it. The two countries have further cooperated in developing a multi-modal transport system based on road and rail service for goods moving to and from Nepal through the territory of India. In August 2009, India allowed Nepal to trade through the Visakhapatnam port in addition to Haldia port.

This treaty is limited to provision of port facilities to Nepal; the transit routes are restricted to road and rail transport, and do not include water transport. Proposals have been made to develop the inter-country water transport between the two countries. The Kosi Navigation Canal, for example, linking Chatara in Nepal to the National Waterway-1 in India was proposed, though it is yet to be implemented.

Inland Water Transit Protocol between India and Bangladesh

This is a bilateral protocol on inland water transit and trade providing water transit between Kolkata and two points in Assam - Dhubri and Pandu without touching Meghalaya and Tripura. The protocol is renewed every two years under which, each side has provided four ports for loading and unloading commodities. India has assigned Kolkata, Haldia, Karimganj and Pandu ports for this purpose while Bangladesh has assigned Narayanganj, Khulna, Mongla and Shirajganj ports for the same. In addition, cargo sharing is permitted on equal basis for transit and inter-country trade by vessels in India and Bangladesh.

The benefits of this treaty can be fully realized only with further development of infrastructural facilities of ports in both the countries that will help in bringing down transport costs substantially. This treaty has a very good scope for expansion to include the proposed National Waterway on the Barak River between Lakhipur and Bhanga in India, which can be connected to Haldia and Kolkata through Bangladesh.

In January 2010, India and Bangladesh signed five agreements during the Bangladesh Prime Minister Sheikh Hasina's visit to India on trade, connectivity, water and power sharing. India has agreed to provide USD $1billion credit to improve Bangladesh's railway network and dredging the rivers shared between the two countries. This recent development will further enhance the trade and connectivity between India and Bangladesh. The trade between the two countries stood at over USD $2billion in April-December 2008-09. In addition, Bangladesh has requested a guaranteed dry season flow in the new treaty that will be signed on the Teesta River.

There are no existing treaties at present between India and China, Bangladesh and Nepal and China and Nepal or Bangladesh on water-based transit and trade.

Sub-regional Forums

Bangladesh-India, Myanmar-Sri Lanka and Thailand Economic Cooperation (BIMSTEC)

BIMSTEC is an international organization involving a group of countries in South Asia and South-East Asia. The member countries of this group include Bangladesh, India, Myanmar, Sri Lanka, Thailand, Bhutan and Nepal. The purpose of this regional grouping is to provide trade and technological cooperation among its members in six areas - trade and investment, tourism, transport, and communication, technology, energy and fisheries. The agreements between the BIMSTEC countries have been bilateral in nature and have focused sparsely on the development of waterways in the region.

South-Asia Sub-regional Economic Cooperation (SASEC)

The SASEC initiative includes four countries - Bangladesh, Bhutan, India and Nepal. These countries geographically cover the Eastern Himalayan and Bay of Bengal sub-region of South Asia. In India, it covers 13 states including the seven north-eastern states. SASEC focuses on boosting regional cooperation in six sectors, which are energy and power, transportation, tourism, environment, trade and investment and private sector participation.

The Tourism Working Group was formed in 2001 and comprises of the National Tourism Ministries/Boards of the 4 countries and ADB representatives. The SASEC Tourism Development Plan (TDP) released in 2004 is an important outcome of the discussions among the members of the working group with inputs from industry and private players. This TDP serves as the overall framework for the development of tourism in the entire SASEC sub-region and guide investment, infrastructure development and policy-making on tourism.

The TDP focuses on two themes of ecotourism and Buddhist circuit. Specific tourism projects have been designed to target the tourism sector and develop ecotourism in the rivers of Ganges, Brahmaputra and Teesta linking the national parks in the region. The primary focus will be on wildlife, cruise tourism and ethnic culture, trekking in the Himalayan belt from Nepal through Sikkim, Bhutan, Arunachal Pradesh and Assam, development of tourism in key cross-border areas like Pararpur in Bangladesh – Siliguri, Bagdogra, water-based adventure tourism in Arunachal Pradesh, Nagaland, Bangladesh, Tripura and East Bhutan. The TDP has been designed on the basis of the Greater Mekong Sub-region (GMS) Tourism Model.

The GMS Tourism Model, however, has been considered a failure among the communities due to lack of co-ordination between various tourism agencies and unsustainable development of ecotourism. In addition, lack of infrastructural facilities has resulted in decrease in the flow of tourists in some parts of the region.

The main objective of the model was to reduce poverty through an integrated development approach. However, the benefits of tourism in general and ecotourism in particular, have never reached the poorer sections of the communities in the region.

The Himalayan sub-region can draw inspiration from the European experience, though it cannot learn direct lessons since the European topography is fundamentally different from mountainous topography of the Eastern Himalayas. According to the Inland Navigation Europe, the EU waterway network of 35,000 km covers most major cities. Centres of commerce and industry and ports are also well-connected by rivers and canals. There are four main corridor networks – North-South corridor, Rhine corridor, East-West corridor and the South-East corridor, which are interlinked. The connected network provides easy access to carry goods from producer to customer. Apart from facilitating trade among the European countries, the waterway network has generated employment. In Germany, for example, around 400,000 jobs are directly or indirectly dependent on the inland waterway sector and related companies.

The European Union (EU) has in addition, launched a specific modal shift programme called “Marco Polo” in 2003. Under this, projects will be funded to shift part of the volume of international freight transport from road to rail, inland waterways and short sea shipping. The objective of the programme is to help decrease the number of trucks on the roads and thus, reduce traffic congestion as well as the negative impact of road traffic on people’s health and the environment. This programme boosts regional development in addition to promoting environmentally-safe means of transport by exploring inland waterways as a transport option.

An inland waterway network in the Himalayan sub-region cannot be developed on such a massive scale, considering the difficult terrain as well as the economic and physical constraints of the region. However, positive aspects such as easing and standardizing navigational rules at inter-country transit points and exchange of information on river navigability, especially during the dry season between countries can be adopted. Along with this, a feasible modal shift programme on the lines of the EU Marco Polo programme can be constructed for development of future regional cooperation on water-based trade and navigation.

A coordinated Himalayan river basin management by the riparian countries on water-based trade and transit will promote economic and environmental well-being throughout the region. It is clear that the effective use of water resources throughout the Himalayan River basins is essential to tackle poverty, increase food security and create a stable and cooperative geopolitical environment. The opening up of the river routes through these countries could bring about major changes in the trading pattern thereby having a positive impact on the economy of the river basins. This will, in addition, facilitate ecotourism and improve transport connectivity in the region. It will also provide scope for developing alternative development programs that can be structured, as per the needs of the region.

Some experts say that the transport costs could be reduced by half, if a multimodal transport network is used to transport goods from Kolkata to Agartala through Bangladesh. Accordingly to this system, goods could be carried from Kolkata or Haldia port by ship along the coast to Chittagong port in Bangladesh, then by railroad to Akhaura in Bangladesh. From here, the closest point is Agartala in India where the goods could be finally transported by road to various destinations in the north-east of India. An agreement to open the Ashuganj port by Bangladesh, which is 40 km from Agartala in September 2009, is a positive development with tremendous economic potential for both India and Bangladesh.

A sub-regional cooperation in the water-based transit and trade is the basic means for promoting economic linkages among India, China, Nepal and Bangladesh. The Himalayan sub-regional water transport can comprise of two corridors, with India and Bangladesh as transit nations. The first segment includes ***Nepal-India-Bangladesh*** Corridor-1 connecting Karnali, Narayani and Saptakoshi Rivers in Nepal to the National Waterways-1 in India. The second segment includes ***China-India-Bangladesh*** Corridor-2 connecting south-west of China to ports in Bangladesh through Indian waterways.

The two proposed trade corridors can be inter-linked through the sea-routes, connecting ports in India and Bangladesh, so that there is optimal utilization of ports, which will reduce traffic load and congestion. In addition, waterways in the Sunderbans can be developed further for promotion of the mangrove forests as a single destination for ecotourism as also for use by smaller vessels. This will maximize the potential economic benefits of the waterways in the region.

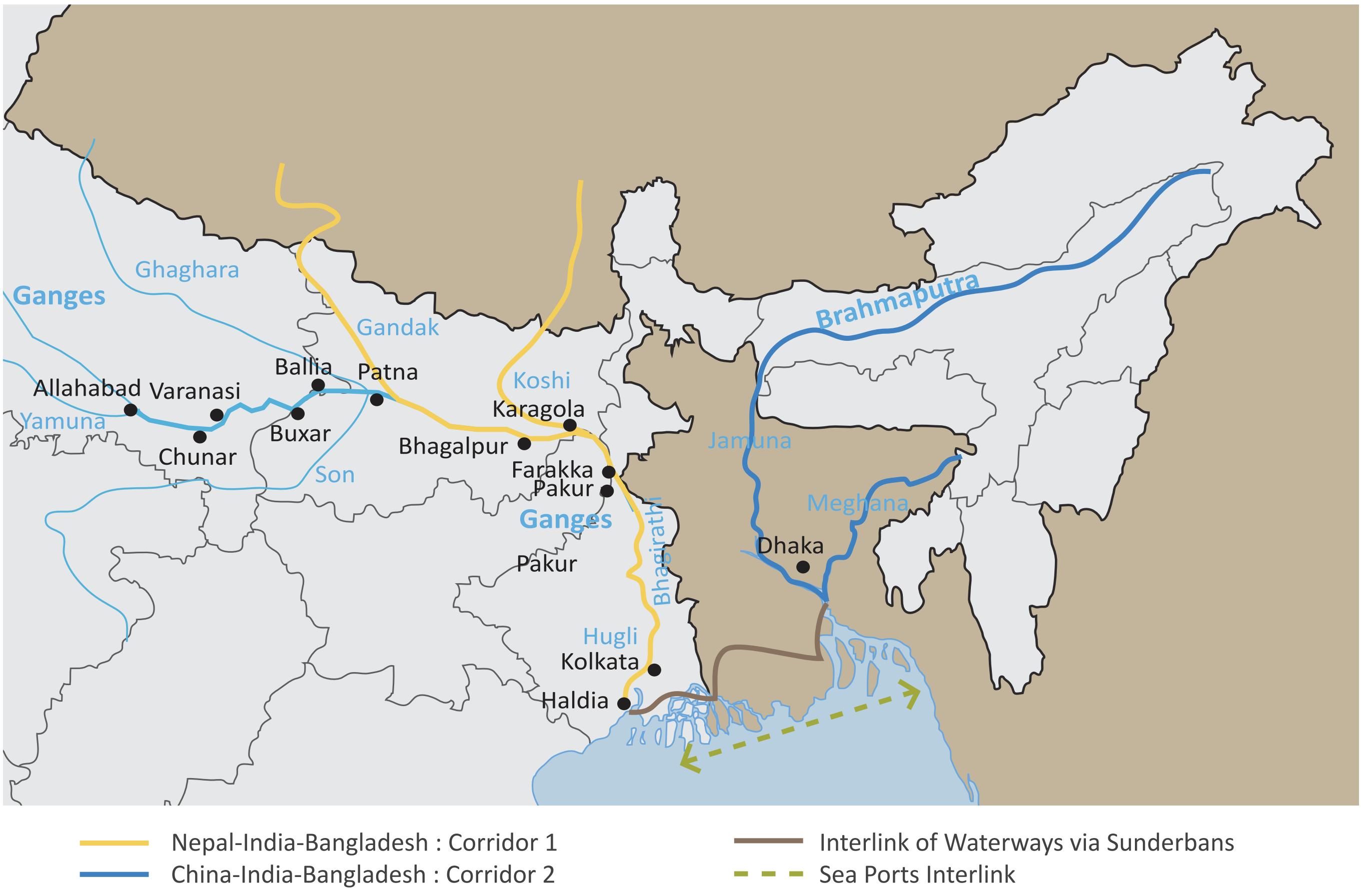
Corridor-1 will be economically the best mode of transport to the sea for Nepal, especially since the country is landlocked. The development of waterways in Nepal, in addition, will mutually benefit India by providing an opportunity for expansion of trade with Tibet. Nepal can access ports in Bangladesh if the Inland Water Transit protocol between India and Bangladesh is extended to include Nepal as well. Bangladesh will also gain substantially not just in terms of transit fees for providing Nepal access to its ports, but also to use Nepal as a transit country to expand trade with Tibet. Currently, Chinese trade routes access Kolkata ports on two longer routes.

Corridor-2 will benefit China for accessing ports in Bangladesh and India through more efficient water transport routes in the north-east of India. This will facilitate cross-border movement of goods and people and will also ensure labour and economic mobility of the local population. The Yunnan Province in China, has sought to increase passageways along the Kunming-Kolkata economic corridor to facilitate the export of abundant natural resources in south-west China. India, Bangladesh and China will benefit immensely as it will not only enhance trade and investment climate but will also provide access to wider trade markets for the economically underdeveloped and landlocked regions.

The water-based transport, in addition, will be fuel-efficient and operating costs will be much lower as compared to road or rail transport. The cost per ton per km by waterways is Re. 0.55 as compared to the Re. 1.00 by road and the energy consumption ratio of water transport to road transport is 1.5:4 which makes it very energy-efficient.

On the whole, the proposed water-based transit routes will enhance the transport connectivity in the region. However, the need of the hour is to develop multimodal transport connectivity especially in places where the rivers are not navigable due to the topography, especially across India-China border. At the Second International Workshop in Dhaka organized by

Proposed Water Transit Routes Connecting India, China, Nepal and Bangladesh



Strategic Foresight Group and Bangladesh Institute of Peace and Security Studies, the need to develop local–level infrastructure for community water transport on secondary rivers in the region was suggested. Developing local water transport will contain transport energy needs in the region. It will help in maintaining connectivity during the monsoon period when large parts of the region are inundated.

In order to gain a better understanding of navigation between the countries it is important to undertake a joint study which indicates economic and environmental gains for each country as a result of improved connectivity through water-based trade and transit and ecotourism. Based on this, India, China, Nepal and Bangladesh could formulate a comprehensive sub-regional water transport policy in tandem with other water policies since navigation requires water conservation, especially during the dry season. An integrated development will provide production and trade opportunities within the region that can be further extended to other regions. This will, in addition, create job opportunities, expand the demand for goods and decrease transport energy demands too. An integrated and collaborative effort among India, China, Nepal and Bangladesh, is therefore important for the successful economic development of the Himalayan River basins in these countries.

Hydropower and Agriculture 15

Hydropower is of immense importance in the Himalayan sub-region. As countries industrialize and urbanize at unprecedented rates, their power requirements too have reached new heights. China and India are at the very forefront of this demand, because of two important factors: their status as two of the most rapidly developing economies in the world and the size of their populations. Given this, the need to satisfy their demand for power has been a driving force of foreign policy for both governments. In the Himalayan sub-region, Nepal has the highest unrealized potential of hydropower. Due to its topography and the profusion of rivers in the country, Nepal has tremendous capacity in the hydro-electricity sector. However, a weak infrastructure and financial incapacity are the hindrances to Nepal's success in being able to exploit beyond one percent of this potential.

Most hydropower projects that have been conceived and executed so far have been large scale, especially in India and China. This trend continues unabated with both the countries having projects in the pipeline that are immense in size and capacity. China, in particular, has plans for large projects that could have an enormous impact downstream. And with their growing interest in Nepal, it is very likely that they bring their conventional wisdom to bear in the country as well, where they intend to invest their capital in large-scale projects that will have proportional pay-offs.

In 2007, the total installed power capacity in China was 713 GW. Over 70% of China's energy need is met by coal. Approximately 24% of its energy needs are met by hydropower. China's hydropower capacity is 172 GW, which is the largest in the region. The Chinese Government has repeatedly emphasized its interest in reducing its coal dependency, not just as a means to reduce its carbon footprint, but also as a way to make the future of its energy sector more secure. For this reason, China is more likely to pursue hydropower as the best option. The country has already shown a tendency towards expanding its own domestic hydropower sector. However, as this option becomes more unfeasible due to its dwindling water resources, China has started to target Nepal for its abundant water resources.

As of 2009, India's total installed hydropower capacity stood at nearly 37 GW. Hydropower occupies 24.7% of India's total power resources, with a majority of its total power capacity of over 156 GW, 64.6% to be exact, provided by thermal power. Like China, India is also looking to expand its alternative energy sector, and reduce its dependence on thermal power. In this regard, hydropower is an important source, as designated by the Indian government. India has attempted to gain a foothold in Nepal's hydropower sector for many years. However, most attempts to do so have resulted in failed or stalled deals, an example of which is the Mahakali Treaty. Despite this, India remains Nepal's largest exporting partner in hydropower.

Nepal has an installed hydropower capacity of 600 MW. This number is a mere fraction of Nepal's total hydropower potential of over 40 GW. Unlike India and China however, Nepal depends on hydropower for over 85% of its total energy requirements. Bangladesh, on the other hand, due its topography, is not well-suited for large scale hydropower projects. Bangladesh's installed capacity totals about 230 MW, and its total feasible hydropower potential is almost 1.9 GW, a significantly smaller number than the other three countries. In the future, even if Bangladesh develops more of its hydropower resources, it will still be unable to meet all its energy needs through them. Due to this, Bangladesh is likely to consider importing hydropower from its neighbours, like Nepal and India to sustain its power needs.

India-China

China and India have set up many channels of communication on water issues, although many of the concrete agreements have to do with the exchange of information, rather than hydropower treaties. However, the interaction between the two countries over hydropower is likely to increase given the importance of the Brahmaputra, and the fact that it flows through both countries. Apart from this, China and India have both begun to invest money and resources in Nepal's burgeoning hydropower industry, an aspect that will explored in detail later.

Brahmaputra, the vast water resource lies between India and China. Thus far, the sharing of this resource, particularly in relation to hydropower generation has been a source of contention and conflict rather than cooperation. The North-Eastern region of India has a hydropower potential of 59 GW; Arunachal Pradesh alone has a potential of 50 GW. Taking into account the increasing power deficits in India, especially in the north of the country, as well as the increasing population and industry in the north-east, this potential hydropower will be vital to the country's energy needs.

India and China each have individual plans for the Brahmaputra basin in terms of hydropower. As mentioned earlier in the paper, India plans to build 140 hydroelectric plants in Arunachal Pradesh and 104 MoUs have already been signed to this effect. In China, five dams have been planned in the middle reaches of the Yarlong Tsangpo River.

Brahmaputra flows through a topography that is conducive to produce a great potential of hydropower, in both China and India. However, the border between China and India has always been a bone of contention and conflict for the two countries, be it related to water or land. Apart from this, the political differences between India and China, and the security realities of the region, particularly Arunachal Pradesh, mean that a full exploration of the potential hydropower in the region is impossible for one party on its own. Given this, the two countries have thus far approached potential hydropower deals as adversaries who have opposing interests rather than neighbours who can gain from co-operation and co-ordination. If the two countries do approach the matter from the viewpoint of cooperation in the construction of dams as well as the hydropower gained from them, then they will both co-exist well and gain immensely.

Nepal

The co-operation between Nepal and India over hydropower began several decades back. The two countries collaborated on projects on the Kosi and Gandak Rivers during the 1950s. Over the next few years, India collaborated on the Trishuli, Devighat and Phewa hydropower projects in Nepal. Nepal and India began to exchange power in limited capacities in 1971, using various points along the border between the two countries that are presently 14 in number.

The Government of India and the Government of Nepal signed a treaty in February 1996, known as the Treaty on Integrated Development of Mahakali River, which came into effect by June 1997. The Mahakali Treaty is built around the Pancheshwar Multi-purpose Project on the Mahakali river. This project has been stalled for years now, mostly because of the belief in Nepal's political circles that the deal does not hold much for the country. Those opposing the treaty have stalled the project due to what is perceived as India's overbearing attitude.

A joint commission was set up in 1988 between India and Nepal to review a project on the Karnali River, known as the Chisapani Multi-purpose Project. A final report was also prepared on the same. However, this has not been put to use by the two governments till date. Apart from this, there are various projects that are at different stages of development: the Burhi Gandaki Project that is currently stalled, the Saptakoshi High Dam Multipurpose Project on which a joint team of experts are still carrying out investigations. The West Seti High Dam project in Nepal will be the first from the private sector in Nepal that will export power to India, if it is built according to plan. The Upper Karnali Hydroelectric Project will be a joint undertaking of the Nepal Electricity Authority and the National Hydro Power Corporation of India.

The power deficit in Northern India is expected to reach 20,000 MW in 2010. In light of this, power imported from Nepal will be of great value to India. Apart from the government of India which is attempting to show Nepal its renewed interest in the sector, many private sector companies in India too are interested in investing in Nepal's power sector.

Of late, China has been showing enormous interest in collaborating with Nepal in the hydropower sector. The Chinese company, Sinohydro formed a joint venture with the Sagarmatha Power Company to develop the 50 MW Upper Marsyangdi project in Western Lamjung district. China's state-owned Exim Bank signed an MoU with Nepal's finance ministry for a loan of US $200 million, for infrastructure projects in Nepal, including a 61 MW Upper Trishuli hydropower project in Nuwakot district. The Exim Bank is funding 75% of the 750 MW West Seti Project of which The Bank of China is also a sponsor. As is evident through this recent flurry of activity, China is eager to gain a foothold in Nepal.

Bangladesh has little or no potential for hydropower due to its topography. For this reason, Bangladesh can be viewed as a potential client for Nepal, and even India.

Nepal's Hydropower Potential

Nepal's hitherto untapped hydro-electric potential has pushed the two regional powers, India and China into a tussle over its resources. This competition could further intensify in the coming years. Nepal will require heavy investment in its hydropower sector in order for it to be developed. The country will certainly welcome any foreign capital being invested into its fragile economy. Due to its immense hydropower potential, Nepal has opened up this sector as a possible focal point of foreign investment. In this regard, Nepal can be considered a 'surplus country' for hydropower in the Himalayan sub-region. India and China do not possess as much potential as Nepal in this regard, while Bangladesh's physical attributes and topography is not suited to generate enough hydropower. If all of Nepal's techno-economically feasible hydropower potential is realized, Nepal will not just become strong enough to sustain itself, but will also be able to export hydropower to India, China and Bangladesh.

At present, any investment in Nepal from either India or China could be interpreted as a competitive move by the other. As most of Nepal's rivers, including its three major ones, flow into India, it is natural that the country be viewed as its largest potential partner in any hydropower endeavour. However, this natural partnership will have to overcome certain pre-existing hurdles. Nepal has shown a deep distrust in India's partnering efforts before. Many of the previous agreements between the two countries have been stalled, one of them being the Mahakali treaty. Politically, the Maoist situation in Nepal could have ramifications for any power-sharing agreements between India and Nepal. This division has proven to be advantageous for China, with the country entering the hydropower sector of Nepal with huge investments. In January 2010, the Prime Minister of Nepal visited China, and prominent amongst the topics of discussion was the Chinese government's interest in Nepal's hydropower sector. The Chinese government is eager to expand its base in Nepal. Politically, Nepal's climate is currently more skewed towards the Chinese government, rather than the Indian government, with which it has certain political differences. Apart from this, the Maoist block of the country is also likely to be placated if business is done with China, rather than India. However, this has not prevented Nepal from welcoming Indian investment, both private and governmental, into its hydropower sector.

Nepal's total power capacity is 689 MW, with 600 MW of it coming from hydroelectricity. However, only 40% of Nepal's population has access to electricity. Large areas of Nepal still remain completely disconnected from any power grid, while those that do have access to power have to contend with uneven supply due to load shedding among other things. Even if it is assumed that Nepal's population and industry stay constant, the country will still need about 2.5 times its present power capacity just to ensure that all of its present population has proper access to electricity. This means that just to reach 100% of its population, Nepal needs 1772.5 MW of power. If infrastructure, industrialization and population growths for the next 2-4 decades are factored in, this number could easily increase manifold. At the very minimum Nepal needs to increase its capacity by over 1000 MW purely for its own needs. Given this, it is perhaps premature to contemplate a proxy war over Nepal's resources between India and China. However, if developed, Nepal's hydropower plants could easily supply 'surplus' power to both India and China. Hence, it is not hard to understand why both countries seem to be investing large capital and resources into the Nepal's hydropower sector.

Basin-wise hydropower potential in Nepal
(Theoretical Potential)

Basin	Major Rivers (GW)	Small Rivers (GW)	Total
Koshi	19	4	23
Gandaki	18	3	21
Karnali & Mahakali	32	3	35
Others	3	1	4
Total	72	11	83

Source: Pokharel, S. 'Energy in Nepal'. World Energy Council. 1998.<http://www3.ntu.edu.sg/home/mspokharel/Energy%20in%20Nepal.pdf>

It is important to consider Nepal's future hydropower sector with the facts of low season flow. Unless future hydropower plants are able to supply a minimum amount of power all year round, they will not be worth the financial input from foreign investors. Given the disparity in Nepal's high season and low season flows, it will be imperative to conduct extensive feasibility studies before embarking on any potential projects. Impacts of climate change will further exacerbate Nepal's 'too much water, too little water' issue, particularly affecting the rivers of Nepal, upon which the entire hydropower sector rests. After factoring in the effects of climate change, it is possible that in the future rivers will be unable to maintain the minimum flow required to generate power.

It still remains to be seen how this power struggle will play out in a larger regional perspective, and if Nepal will indeed become a proxy battleground for India and China to play out their regional one-upmanship. In the meanwhile, it is certain that there is likely to be marked development in Nepal's hydropower resources and its ability to export to its neighbours.

Agricultural Collaboration

Agricultural collaboration between regional players can be divided into three possible categories: irrigation, exchange of technology and exchange of proprietary research. The latter two are usually done at the academic, rather than national level, except during large trade deals, when agricultural technology is often exchanged as a part of the deal. Larger countries also tend to give technology as part of aid packages to smaller countries during times of need. Irrigation is the most prominent category in the scheme of things as it directly affects crop health, and therefore, the economy of the countries involved. Irrigation agreements are signed by the upper riparian and lower riparian states to effectively share the resources of the water body that flows through them. Therefore, these agreements would be between China and India, India and Bangladesh and Nepal and India. Most irrigation agreements are parts of larger deals, usually hydropower deals. Any barrage or dam that is constructed on a river that is trans-boundary necessarily comes with a water-sharing agreement that is specifically rooted in irrigation requirements for both the upper and lower riparian states. It stands to reason that any obstruction placed on a river, such as a dam, will require an accompanying arrangement of sharing the water that previously flowed through the two countries unobstructed.

Thus far, irrigation deals in the Himalayan sub-region have been part of larger agreements, mostly hydropower deals. Between Nepal and India, irrigation deals are part and parcel of larger hydro-electric projects such as the Mahakali Treaty, the Saptakoshi High Dam Multipurpose Project and the Burhi Gandaki Hydroelectric Project, most of which are stalled. Between China and India, irrigation agreements are a part of larger agreements between the two countries. The Brahmaputra River that is shared between the two countries is a sizable river with adequate water for both countries. However, if any construction is made on the river upstream in China, then an irrigation agreement will have to be put in place in order for India to receive adequate water to sustain its population and agriculture.

Between India and Bangladesh, the Farakka Barrage, once a point of much contention, is now an avenue to share water according to a 30-year deal signed between the two countries in 1996. According to the treaty, the water of the Ganges River will be distributed from the barrage for the two countries between January 1 and May 31 and that India will maintain the flow at Farakka at the average level of the last 40 years. At any critical period, Bangladesh will receive a minimum guaranteed flow. One of the main reasons for this agreement is the requirement of irrigation water for the lower riparian state, i.e. Bangladesh. However, it has not been smooth sailing for this agreement as Bangladesh has protested on occasion about India withholding its fair share of water. In January 2010, representatives of both India and Bangladesh met to discuss water sharing of the Teesta River. Although no deal has yet been reached, this is yet another avenue for the two countries to co-operate over irrigation water sharing.

During Strategic Foresight Group's International Workshop in Dhaka in January 2010, long-term agriculture forecasting for food security in the Himalayan sub-region was proposed. Considering the predicted decline in agricultural production in the region, and the number of people that not only depend on agriculture as their food source, but also their livelihood, increased co-operation over agriculture and food security issues is very important. The importance of demarcation for impacts of climate change on food and non-food crops on the regional context was emphasized. This again will have to be a combined regional effort, rather than just a national one.

There are dozens of international hydropower treaties in existence. It is likely that more will come into being in the next few decades, as nations have come to realize the need for moving away from thermal energy and coal, and towards more sustainable, cost-saving and eco-friendly energy. Hydropower treaties not only encompass power-sharing agreements, but also water-sharing agreements that are crucial for the harmonious co-existence of upper and lower riparian states. However, most treaties in the Himalayan sub-region seem to be mired in political conflict or complications. In order to have a better and more effective functioning of countries with issues related to trans-boundary rivers, there has to be a mechanism in place that can deal with the complex issues that accompany hydropower generation and water sharing.

Responding to Climate Change 16

Climate change is likely to alter the environmental balance of the Himalayan sub-region, with far-reaching implications on the social and economic fabric of China, Nepal, India and Bangladesh. At the global level, attempts to devise a climate change framework convention have been unsuccessful, with the most recent meeting in Copenhagen, failing to live up to expectations. Political bargaining over an 'equitable' deal continues to evade the planet, reinforcing the need to match global ambitions at both, the national as well as the regional levels. As the responsibility of governments to secure water resources becomes increasingly crucial, there will be greater incentive to enforce climate change mitigation and adaptation strategies at the domestic level, while seeking cooperation on a regional platform. All the four countries of the Himalayan sub-region are at an important juncture in their individual histories. As this paper has highlighted, each country will be affected by water scarcity – a problem likely to be exacerbated by climate change. In an effort to maintain economic and development growth trajectories, it is vital for national governments to prioritize against the impact of climate change risks.

Effective responses to climate change risks will depend on mitigation and adaptation strategies adopted by the respective countries – both of which must be actively pursued concurrently. The IPCC defines mitigation as, 'an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases.' Adaptation to climate change is defined as the 'adjustment in natural or human systems to a new or changing environment. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation.'

In the traditional sense, mitigation has been the primary focus of governments, with an emphasis on ensuring that the 'causes' of climate change are addressed – primarily through the reduction of Greenhouse Gas Emissions (GHG) as well as the aerosols that cause the Atmospheric Brown Cloud (ABC) effect. The process of 'adaptation', whereby there is a focus on minimizing the negative impact of climate change has received lesser attention than it should. However, failure to arrive at conclusive and universally- acceptable mitigation policies has prompted further attention on adaptation strategies. In addition, as the impacts of climate change become more apparent, there is a greater sense of urgency to not only adapt to it, but to make proactive adjustments which seek to dilute the consequences of long-term and short-term environmental negligence.

Climate Change Mitigation

Combating climate change requires the implementation of various strategies at the political, technological, economic, environmental and social level. On the global stage, the issue has been primarily addressed through the United Nations Framework Convention on Climate Change (UNFCCC), and the implicit understanding between nations that a reduction in GHG emissions is mutually beneficial. In addition, recognition that countries are at various stages of development has sought to ensure that mitigation strategies occur within a pre-determined time period; that global food production is not threatened and; that economic development is allowed to continue in a sustainable manner. However, enforcement of these initiatives has been difficult, with clear divisions appearing over expectations and responsibilities, between the developing and developed world.

Within the Himalayan sub-region, trans-boundary cooperation on mitigation strategies has been largely superficial, with each country's national climate change proposals taking precedence over other regional initiatives. This is not to say, however, that the four countries operate completely independent of one another. In 2009, India and China signed a five-year agreement to jointly fight climate change and negotiate international climate deals. In addition, New Delhi and Beijing set up a Joint Working Group (JWG) that will hold annual meetings alternatively in India and China, to discuss domestic policies and measures, as well as scope for cooperation. The Memorandum of Agreement (MoA) is the first of its kind between countries, and is expected to place both countries along with Nepal, Bangladesh and other members of the G-77, in a stronger negotiating position vis-à-vis the developed world. Furthermore, the JWG will also seek to promote joint research and development programmes in areas of solar and wind energy, coal technology and forestry. There will also be a focus on meetings between scientists and economists to discuss various related issues.

International Conventions

Despite the fact that leaders at the Copenhagen summit failed to arrive at a binding emissions-cut agreement, the summit did provide the developing world, and in particular the two largest countries of the Himalayan sub-region, India and China, with an opportunity to find common ground on global negotiations for mitigation strategies. Both countries urged the developed world to play a bigger role in emission reductions, while arguing that a cap on their emissions would limit economic growth. In addition, there was also renewed recognition that only reforestation could help the region combat global warming – an initiative that corresponds with the United Nations proposal for Reducing Emissions from Deforestation and Forest Degradation (REDD). Reforestation and/or initiating steps to stop forest destruction are considered one of the most cost-effective and quickest ways to combat climate change.

With forests estimated to capture 11% of carbon emissions in India and around 6% in China, the addition of approximately four million hectares of forest cover every year in China and approximately one million hectares every year in India is an important mitigation strategy for the future. Furthermore, while New Delhi and Beijing have agreed to share afforestation techniques and the use of satellite technology, the initiative should also be extended to Nepal and Bangladesh, as both the countries have a stake in the region's climate, and in particular any impact climate change could have on the Himalayan glaciers.

The willingness to cooperate between India and China on mitigation strategies is the first step towards limiting the further damage by climate change on the Himalayan sub-region. In addition to the four-nation BASIC (India, China, Brazil and South Africa) axis that emerged from negotiations at the Copenhagen summit, it is imperative that New Delhi and Beijing collaborate with Nepal and Bangladesh to ensure long-term survival of the water resources in the Himalayan sub-region. As the politically and economically larger neighbours, India and China must assume a position of regional responsibility that is matched by their aspirations. Clean technology transfer, provision of funding for environment-related projects and sharing of intellectual and scientific data should be made available to Nepal and Bangladesh, as a basic requirement for a successful mitigation campaign in the Himalayan sub-region, must involve all the stakeholders.

The world now awaits 'Mexico 2010' for an opportunity to reach an acceptable solution to reduce carbon emissions, the onus at the regional levels falls on the governments of the Himalayan sub-region. Preventive or remedial steps to improving the environmental surroundings ought to be a priority, as the further delay could cause political, social, economical and environmentally disastrous repercussions. While the position of 'common but differentiated responsibilities' should remain the focus of global negotiations, the Himalayan sub-region must enact regional initiatives which seek to safeguard water resources. India and China's decision to reduce emission intensity per unit of GDP by 20-25% of 2005 levels and 40-45% of

2005 levels respectively by 2020 is a step in the right direction. As the previous section highlighted, water scarcity will be of major concern to India, China, Bangladesh and Nepal eventually, meaning that while global mitigation initiatives are important, there must be a push for greater regional cooperation.

Greenhouse Gases and Aerosols

A major determinant of success for mitigation strategies, involves convincing people that changes to their lifestyle and behaviour patterns are in their own collective interests and, that, it could contribute towards climate mitigation. Steps in this direction have been identified by the IPCC's Fourth Assessment Report, as increasing the possibility of a positive outcome vis-à-vis climate mitigation. Expanding economies and rising incomes are contributing towards changing diets, and more specifically a growing demand and consumption of animal protein. While this trend could prove to be a major hurdle towards securing food resources, it is also considered a contributor towards GHG emissions.

Research has shown that the livestock sector is not just the single largest anthropogenic user of land, but that more importantly, it also accounts for a large consumption of water, with the production of one kg of beef for instance, consuming 15500 litres as opposed to 900 for one kg of maize. In addition, livestock contributes towards 64% of ammonia emissions in acid rain and, is economically inefficient to produce as opposed to vegetables, cereals and fruit. In an effort to highlight the importance and benefits of a less meat-intensive diet, several European cities have introduced one meat-free day in a week. Similar initiatives should be followed within the Himalayan sub-region, as experts believe that one or two meat-free days a week could be the most effective action to reduce GHG emissions and improve human health. Furthermore, as incomes rise, dietary demands are expected to change, raising the possibility that there will be greater constraints on the land and more demand for water.

As for Atmospheric Brown Clouds, scientists believe the best way to curtail them is to contain the emissions of the aerosols that contribute to their existence. Steps aimed at curbing GHGs should also effectively curb the emissions of many of the aerosols that contribute to the existence of ABCs. The simplest and most effective step would be to reduce the burning of fossil fuels. During the Beijing Olympics in 2008, Chinese authorities ordered cars off the streets of the city ahead of the games to reduce the fog around the city. Such measures, including ordering cars off the street for one or more days of the week, would go a long way towards reducing GHGs.

Climate Change Adaptation

Adaptation to climate change is of paramount importance. The process assumes greater significance as the effects of global warming are already in motion due to past emissions. However, it is important to note that adaptation strategies cannot deal with the full extent of climate change impacts, as stresses on the environment are expected to only increase in severity over time. Rather, adaptation is better suited to short-term or medium-term initiatives, which continue to evolve with the changing climatic scenario. In addition, adaptation strategies cannot exist independently of economic and social development strategies – with low per capita income countries, in this case those in the Himalayan sub-region, most vulnerable. There is potential for improved preparedness and adaptability through sustainable development practices, although as climate change is already in motion, this must occur concurrently with mitigation policies.

As development and adaptation are largely intertwined, there is a need to ensure that climate change policies are reflected in development goals. While the developed world has reiterated its commitment to support adaptation policies in the developing world through the allocation of funding, this alone is not enough. Countries of the Himalayan sub-region will have to enforce adaptation policies at both a national and regional level in order to ensure that they are more resilient towards the current climate, less susceptible towards future climate impacts and, are in a position to take advantage of opportunities. Water efficiency, improvements in infrastructure development and building codes, drought tolerant crops, reforestation and an emphasis on public transport, are some adaptation strategies that could be promoted in the Himalayan sub-region.

Economic growth within the Himalayan sub-region will correspond to an increasing middle-class population in all four countries, albeit to varying degrees and at a varying pace. As affluence rises, there will be a larger availability of disposable income, which will be reflected in the purchasing of material goods – in particular, vehicles. A study by India's National Environment Engineering Research Institute (NEERI) revealed that vehicle traffic contributes more air pollution, in the form of greenhouse gases, than industries and biomass plants in several parts of India. The sheer number of vehicles on Indian roads contributes significantly to pollution levels in the country. Similarly, China's capital receives approximately 10,000 new cars on its roads every week, with the city surpassing 4 million vehicles in December 2009. India and China are not alone however, with Nepal and Bangladesh witnessing a growth in vehicular traffic, as opposed to the traditional, environment-friendly bicycle. Traffic congestion is not only taking a toll on the environment but is also resulting in the over-saturation and degradation of roads.

Checking the additional flow of vehicles on roads within the countries is important, particularly as GHGs and ABCs are believed to be responsible for the reduction of glaciers feeding the Himalayan sub-regional rivers. At the basic level and as a medium to long-term response, there is a need to improve public transport in all the four countries. While India and China are better-equipped than Nepal and Bangladesh, there still remains considerable room for improvement. Many Indian cities have a poor public transport infrastructure, resulting in a heavy dependence on private vehicles. The promotion of a proper public transport has to correspond with sustainable development practices to be able to curb emissions, while facilitating economic progress. Alternatively, and as a more immediate response, governments should look towards simple but effective measures such as making parking more expensive; encouraging group transport and/or 'pay and ride' options thereby limiting the number of cars on the road.

In the long-term however, adaptation strategies revolve around preparing for the future. Countries in the Himalayan sub-region must acknowledge that as incomes rise, there will be a greater demand for private vehicles. It is by that measure, that cleaner and greener technology in the automobile industry must not only be developed, but also promoted, both within the industry and amongst the consumer. Companies such as Chinese automobile manufacturer BYD, claims to have produced an electric car which can go up to 400 km on a single charge. The manufacturers state that the car, which has space for five passengers, needs 7-8 hours with a domestic plug to charge the car, while specially developed charging points require one hour. The logistics of the car make it an attractive prospect for governments to promote clean and renewable energy. While BYD is yet to roll out on to the roads, such vehicles should be promoted as an alternative to those reliant on non-renewable energy sources. In addition, the governments of the Himalayan sub-region, and in particular China, should install a network of the fast chargers for the car, in an effort to promote a vehicle which could revolutionize the automobile world and, more importantly, have a significant role in reducing dependence on oil, thus helping to control carbon emissions into the atmosphere.

Water Efficiency

As this paper has repeatedly highlighted, water scarcity in the Himalayan sub-region could have dramatic consequences on China, Nepal, India and Bangladesh in the near future. An integral aspect to climate change adaptation revolves around water efficiency – a notion that is gaining prominence as water availability and the monsoons become increasingly unpredictable. As the region develops, there has to be a concerted effort at the political level, through policy initiatives, and by private citizen, to ensure that all new commercial and residential building projects are equipped with a grey water recycling plant and provisions for rainwater harvesting.

Grey Water recycling involves treatment and re-use of waste-water from bathrooms and kitchens. Polluted water is 'cleaned' in a septic and chlorine tank before it is made available for watering plants and washing cars amongst other uses. Given the growing populations in all the four countries and the increasing demands for domestic water usage, recycling water for non-essential purposes could result in long-term water efficiency and, help ensure availability of water for all

Atmospheric Brown Clouds (ABCs)

Atmospheric Brown Clouds (ABCs), previously known as 'Asian Brown Clouds', are a phenomenon where layers of air pollution form a 'brown cloud' over certain regions of the earth. The ABCs are named for the brown stain that they appear as, when viewed from outer space. These clouds are made up of black carbon, organic carbon and dust, as well as anthropogenic aerosols (contributed by human action) such as sulphates, nitrates and fly ash. ABCs are formed due to the combustion of bio-fuels, biomass burning and burning of fossil fuels. The presence of ABCs has many side-effects; among them are the reduction of ultraviolet (UV) rays and the reduction of sunlight, an effect known as dimming. ABCs also affect monsoon patterns as they influence rain-clouds. Many scientists also believe that ABCs are a contributing factor to the changing monsoon patterns in South Asia.

Most of the ABC hotspots in the world can be found in Asia, particularly in East Asia and the Indo-Gangetic Plains in South Asia. Among major cities in hotspot zones are New Delhi, Mumbai, Dhaka, Beijing, Shenzhen, and Shanghai. ABCs are also believed to have contributed to the accelerated melting of glaciers in the Himalayan region. Due to its effects on glaciers as well as rainfall, the ABC phenomenon has most certainly affected the food security of the South Asian and East Asian region.

ABCs have also had a discernible impact on human health. Long-term exposure can cause acute and chronic illnesses, including cardiovascular diseases and respiratory problems. The World Health Organization estimates that 380,000 people in China and 407,100 people in India have died from indoor air pollution that can be attributed to solid fuel use.

domestic needs, especially drinking and cooking needs. However, it is imperative for such initiatives to have the support and backing of respective governments, as there has been a reluctance to adopt such strategies voluntarily given the relatively high installation costs.

In conjunction, there have to be initiatives to harvest rainwater. As the monsoons become more and more erratic in India, river pollution and droughts take hold in China, arsenic contamination and rising sea-levels impact Bangladesh and inefficient water storage and distribution continues to plague Nepal, there should be greater emphasis on more localized access to water resources. Rainwater harvesting provides a simple solution to water woes and reduces dependence on civic supplies. As with Grey Water recycling, the water can be used for non-potable purposes such as washing, gardening and flushing toilets. In addition, lesser dependence on civic authorities for water will not only ensure greater access to the resources, but will also help reduce pressure on authorities to provide water for domestic purposes, while creating a greater potential of availability for other sectors.

It is important to note however, that water-saving initiatives such as rainwater harvesting and grey water recycling cannot be viewed as large-scale substitutes to long-term water availability. The responsibility and decision will finally rest with local authorities and governments to ensure adequate water supplies in the future. An integral step will be to revamp infrastructure and supply apparatus, which remains woefully lacking at present. Several large cities in India for instance, lose close to 900 million litres of water a day to thefts, leaks and wastage, adding up to roughly 0.33 BCM annually. Plugging the gaps in infrastructure will help bridge the shortfall in water supply. Similar initiatives must also be encouraged in Nepal, Bangladesh and China, where poor water transport facilities or lack of storage infrastructure, are two of the many inadequacies which contribute to water scarcity.

In addition, it is important to combine such measures with education on water-saving techniques, as successful adaptation will rest largely on those utilizing the resource. As mentioned earlier, as the middle class in a country grows, expectations and aspirations too will rise. Simple measures such as closing taps while brushing teeth, placing a weight in flush tanks to reduce water usage with every flush and, not using washing machines unless fully loaded, are small steps that should be practiced by all, especially since estimates suggest that 12 litres/minute is the rate at which water flows out of a tap, 10-15 litres is used in every flush and 100-150 litres is used in every washing cycle.

Saving Electricity

An adaptation measure, which could have far-reaching implications for India and China and which was recently adopted by Bangladesh in order to maximize the use of daylight and reduce electricity usage, is to have two or more different standard times and/or to put back the clocks. Both China and India continue to have one standard time, despite the fact that the respective countries are geographically vast enough to warrant separate time zones. In India for instance, the sun rises and sets more than an hour earlier in the east of the country, than in the west. While both countries have had periods in their history where Daylight Saving Time has been observed, during the 1965 and 1971 Indo-Pak wars and between 1986-1991 in China neither country has continued the practice. However, a decision to enforce multiple time zones could help both countries to cut costs and save energy, whilst being logistically more efficient. The decision by Bangladesh is expected to save the country approximately 250 MW of electricity. As such, reduction in electricity consumption eases the strain on production from coal and hydropower, thus reducing long-term atmospheric pollutants.

As the Himalayan sub-region grows increasingly vulnerable to climate change and the competition for growth-facilitating resources becomes more intense, each of the four countries will need to consider alternative and somewhat radical changes to current practices. People in the east of both India and China stay up longer – keeping lights on and using more electricity – through the sheer fact that they reside in a geographically different region. Separate time zones will ensure more efficient time management and help alleviate the costs associated with longer days and greater demand for resources.

Efforts to save electricity should occur concurrently with the adoption of sustainable agricultural practices. With the agricultural sector considered an integral part of the economies of the Himalayan sub-region, there should be more initiatives that teach farmers to conserve water and minimize the impact on groundwater, by harvesting water in small man-made ponds on their farms. Such initiatives, being promoted by NGOs, help farmers to be more economically independent, while increasing moisture content and quality of soil. As a result, farmers are better equipped during the lean season and are thus, more likely to weather the negative impacts of delayed and erratic monsoons. As water stress becomes increasingly apparent as a result of climate change, efforts at the micro level will be crucial, and should be promoted across the region.

Alternative Energy

Discussions on energy and adapting to climate change risks must include the possibility of shifting away from non-renewable energy sources and/or the implementation of cleaner and greener production practices. A major obstacle towards responding to climate change has been the over-dependence on coal-fired energy production within the Himalayan sub-region, with coal accounting for 70% of China's energy consumption as of 2006 and 63% in India. There are over 90 thermal power plants burning poor quality coal along the Indo-Gangetic plains. Nepal and Bangladesh demonstrate relatively smaller coal consumption patterns, although they have as much of a stake in India and China's policies, on account of their geographical locations. Given that coal contributes about 60% of India's carbon emissions, there is an urgent need to shift towards cleaner technologies as energy demands continue to rise in the region. Similarly, China's efficiency is also not at the level of the developed world. Japan emits 418 grams of CO_2 per kilowatt hour, the US produces 625 grams, and India 1259 grams – as compared to a world average of 919 grams. In China, while there is no clear figure for the national level efficiency, most of the top ten firms in the country produce 752 grams of CO_2 per kilowatt hour. From this, it can be reasonably concluded that China's efficiency is lesser than that of the developed world. The development of advanced 'ultra supercritical technology' is expected to bring down CO_2 emissions, with the expected result in India to be as much as 18%. In addition, the adoption of the supercritical technology reduces the consumption of coal in a power plant and also increases efficiency, both of which are needed in India and China as energy demands grow.

In the long-term, lesser dependency on thermal power plants will not only help reduce the contribution of GHGs but will lessen the likelihood of the formation of ABCs. Collaboration between China and India to utilize cleaner burning coal and cleaner technology will help the sector to become more environmentally efficient. More importantly, in the immediate future, the reduction in soot particles will have a more rapid positive impact, compared to a reduction in GHG emissions – given that the 'life-cycle' of soot is a few days or weeks, as compared to 100 years for GHGs. Therefore, in the short term, the reduction of ABCs through mitigation strategies could be achievable.

In conjunction, there has to be a willingness to adapt to alternative technologies and increase the role of water, wind and nuclear power. While coal will continue to remain an important energy source in the immediate future, alternative technologies must be viewed within a long-term time frame. The four countries of the sub-region have drawn up plans to shift towards new energy sources, although there still remains a considerable distance to go, for the benefits to be seen. Furthermore, the state of the planet has created an avenue whereby India and China can look to lead the world in clean energy production.

At SFG's Second International Workshop at Dhaka, collaborative studies on the impact of climate change on Himalayan co-riparian countries and its implications on national economy and biodiversity of the corresponding countries were proposed. Joint studies on the effect of climate change on glacial melt for environmental degradation, and the need for economic modelling of climate change adaptation needs for physical infrastructures in the Himalayan sub-region were discussed. An over-arching climate change policy for the entire Himalayan sub-region, linking climate change adaptation and mitigation strategies with socio-economic and institutional set-up at regional levels was also suggested.

Ultimately, responding to climate change will be feasible and produce favourable results only if there is a collective interest in tackling the costs involved. Governments, business and society will each play a responsible role in enforcing change and, there must be recognition at the policy level that stagnation of mitigation solutions on the international stage, should not delay adaptation practices at the regional and national level. The establishment of a regional collaborative body or, a move towards Integrated River Basin Management (IRBM) will ensure that each country has a stake in regional outcomes – be it at the political, scientific or economic level. Though each country can develop strategies on river and climate management independently, the benefits associated with pursuing IRBM collectively are likely to accrue well into the future.

Integrated River Basin Management 17

According to the Global Water Partnership, 'Integrated river basin management (IRBM) is the process of coordinating conservation, management and development of water, land and other related resources across sectors within a given river basin, in order to maximize the economic and social benefits derived from water resources in an equitable manner while preserving and, where necessary, restoring freshwater ecosystems.' It is a holistic approach that combines water and land management to develop and protect river basins as ecosystems. IRBM is considered to be a subset of Integrated Water Resources Management (IWRM). Simply put, IRBM is IWRM implemented on a river basin level.

Since IRBM rests on the holistic principle that river basin ecosystems including wetlands and groundwater are sources of freshwater, management of rivers must have as one of its central goals, maintenance of the ecosystem. The 'ecosystem approach' is a basic tenet of the Convention on Biological Diversity.

Principles of Integrated River Basin Management

The principles that act as guidelines for creating a successful framework of the IRBM initiatives vary across different regions based on the trans-boundary river basin requirements. The key principles that govern the implementation of IRBM frameworks involve participation from diverse stakeholders, creation of water resource management based on hydrological boundaries, setting up of an organizational framework at the river basin level with regulations that can be implemented at the lowest possible level and an integrated planning approach at the river basin level to create transparency and accountability.

Participation of Stakeholders

This is a key principle of the integrated river basin management, especially at the decision-making level in water resource planning. The active involvement of diverse stakeholder groups is crucial to create environmental, institutional, social, technical and financial sustainability. In addition, it deals with conflict prevention by addressing any conflict of interest right at the start of the process. Early involvement of the stakeholders reduces the overall costs and the time spent on water resource planning.

Planning based on Hydrological Boundaries

This principle identifies all types of water resources such as surface water, groundwater, glacial melt and sea water that feed the river basin as a single unit. In addition, this principle emphasizes the need to share data in order to facilitate integrated water resources planning in the river basin. A comprehensive hydrological measuring network for the monitoring of all types of water resources is required, along with sub-divisions based on the physical characteristics of the river basin, to ensure holistic planning of water resources.

Decentralization and integration

The principle of decentralization essentially guarantees effective implementation of policies with efficiency and transparency. Within the context of the IRBM, the mode of 'functional' decentralization is often applied. The decentralization is not general but is aimed at performing specific functions of administration of government authorities. This implies that the tasks, competencies and functions of water resources management are decentralized in order to shift responsibilities and encourage involvement and accountability from lower levels of administration.

Organizational framework

The functions and competencies of river basin organizations may vary from country to country based on the physical and social characteristics. However, it is crucial to set up an institutional framework that has a clear set of regulations or standard bye-laws. These regulations and bye-laws should be flexible so that they can be modified by the lower level administration when local circumstances demand it. Apart from rules for representation and functioning, bye-laws should also cover aspects of water resources planning; allocation and registration of water rights; tariff structures and fee collection; fund development and application; monitoring arrangements; penalties and sanctioning; conflict resolution and appeal procedures.

One of the targeted key outputs of a system of integrated river basin management is the production of river basin plans in which the aspects of water quantity, water quality and environmental integrity are maximally integrated. Besides this, planning should also contain a full consideration of the interests of the various parties involved. It should be established according to procedures that enable full stakeholder participation in terms of decision-making. The river basin plan should be composed of lower level sub-basin; catchment or watershed plans if the scale of the river basin makes them necessary.

Pricing of Water

This principle implies that the price for the service of having access to water or being protected against flooding or the price of treating the discharged pollution is paid by the user, beneficiary or polluter. A comprehensive system of rights and licenses is required to apply effective water-pricing and to charge for pollution. In addition, clear water allocation criteria and pollution discharge standards, as well as quality standards for the recipient water are pre-requisites for successful implementation of IRBM.

Principles of Trans-boundary River Basin Management

Most countries have water policies and strategies in place aimed at the effective implementation of integrated river basin management. The trans-boundary water management frameworks rest on basic principles that are recognized by international conventions and treaties. These principles are drawn from Helsinki Rules (1966) and Convention on the Law of the Non-navigational Uses of International Watercourses (1997) to facilitate an integrated approach for trans-boundary river basin development. Some of the most widely-acknowledged principles by international conventions, agreements and treaties are the principles of equitable and reasonable utilization, obligation to not cause significant harm, principles of cooperation, information exchange, notification, consultation and peaceful settlement of disputes.

Limited Territorial Sovereignty

This principle recognizes the rights of both upstream and downstream countries because it guarantees the right of reasonable use by the upstream country in the framework of equitable use by all interested parties. Principles of equitable and reasonable utilization and an obligation to not cause significant harm are part of the theory of limited territorial sovereignty. This principle, for example, has been adopted in the 1995 Agreement on the cooperation for the sustainable development of the Mekong River basin (Articles 4–7).

Notification, Consultation and Negotiation

The Notification, Consultation and Negotiation principle states that every riparian state in an international watercourse is entitled to prior notice, consultation and negotiation in cases where the proposed use by another riparian of a shared watercourse may cause serious harm to its rights or interest.

Cooperation and Information Exchange

Under this principle, each riparian state of an international watercourse is responsible for cooperation and exchange of data and information regarding the state of the watercourse as well as current and future planned uses along the water-course. This principle was incorporated in the 2002 framework agreement of the Sava River basin.

Peaceful Settlement of Disputes

This principle advocates that all states in an inter-national watercourse should seek a settlement of disputes by peaceful means in case states concerned cannot reach agreement by negotiation. This principle has been incorporated in the Indus Waters Treaty 1960.

Convention on Biological Diversity

The Convention on Biological Diversity, commonly referred to as the Biodiversity Treaty, defines biodiversity as, 'the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.' Under this, parties to the treaty will cooperate as far as possible and as appropriate with other contracting parties, directly or, where appropriate, through competent international organizations, in respect of areas beyond national jurisdiction. Included in the Convention are provisions for both *'ex-situ conservation'*, which is conservation of biological elements outside their natural habitats and *'in-situ conservation'*, which is conservation of ecosystems and natural habitats and the maintenance of species in their natural surroundings.

The Convention provides that each party must carry out environmental impact assessment of projects and notify and consult the potentially-affected states prior to undertaking any project that may have a trans-boundary effect. In addition, the Convention also provides for transfer of technology, exchange of results of technical, scientific and socio-economic research and exchange of information on specialized knowledge, indigenous and traditional knowledge, which is relevant to the conservation and sustainable use of biological diversity.

China, Nepal, India and Bangladesh are all parties to the Convention. The Convention rests on the premise that each country has the sovereign right to exploit its own resources in accordance to the country's own environmental policies, and not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction. Given this, if a dispute arises over any issue between contraction parties, the Convention provides for settlement of disputes through negotiation and for jointly seeking request for mediation by a third party. Further, if the dispute is not resolved by negotiation or mediation, then it should accept compulsory arbitration or submission of the dispute to the International Court of Justice as a means of dispute settlement. Failing to do this, the dispute will be submitted for conciliation.

This treaty is binding on the parties and provides ample scope for protection of biodiversity in China, Nepal, India and Bangladesh. Furthermore, in the absence of binding water treaties between the parties on trans-boundary rivers stringent application of this treaty will help in protecting the biodiversity of the lower riparian countries. Hence, this Convention necessitates a collaborative approach on utilization of water resources among the parties with shared trans-boundary waters.

Ramsar Convention

Another important convention for managing shared water courses is the Ramsar Convention on Wetlands. This convention is an inter-governmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. The Convention requires each state to determine and designate the wetlands within its territory which it wishes to be protected under the Ramsar Convention and included in the aforesaid list. China, Nepal, India and Bangladesh are contracting parties to the Ramsar convention and have 37 sites, 9 sites, 25 sites and 2 sites respectively designated as wetlands.

Under the framework of the Ramsar Convention, the 'Himalayan Wetlands Initiative' (HWI) forum was adopted to 'promote the objectives of the Ramsar Convention and to implement the Ramsar Strategic Plan through cooperation and collaboration among the countries sharing the greater Himalayan region (Hindu Kush-Himalaya and Pamir-Alay region) for the conservation and wise use of the wetlands and their complexes in the region.' This has been endorsed by India, Myanmar, Nepal and Bhutan.

The major objectives proposed by the Ramsar Convention for 2009-11 are:

- Develop information management methodologies for Himalayan wetlands;
- Develop mechanisms and facilities for cooperation, networking and capacity building;
- Promote need-based joint research, particularly for high-altitude wetlands and related river basins;
- Devise and promote best practices on Himalayan wetland management;
- Develop a participatory communication, education, participation and awareness programme for the Himalayan wetlands;
- Build support for the implementation of Himalayan wetlands conservation.

The Ramsar Convention, along with HWI is non-binding. However, these provide a formal means for understanding and undertaking research of wetlands in the greater Himalayan region. The information gathered from the joint research initiatives under HWI can be integrated within the policy framework of the IRBM in order to protect as well conserve the wetlands in the Himalayan sub-region shared between China, Nepal, India and Bangladesh.

River Basin Organizations

In the past, trans-boundary rivers have mostly been governed through international treaties. The current alternatives for trans-boundary river basin governance are River Basin Organizations (RBOs) that have been based on treaties or agreements between riparian nations and regional cooperation initiatives such as the Greater Mekong Sub-region (GMS) that aim at sustainable economic development of the river basins. Over the recent decades, many different types of RBOs have been established.

Countries have come up with various forms of governance for RBOs such as the following:

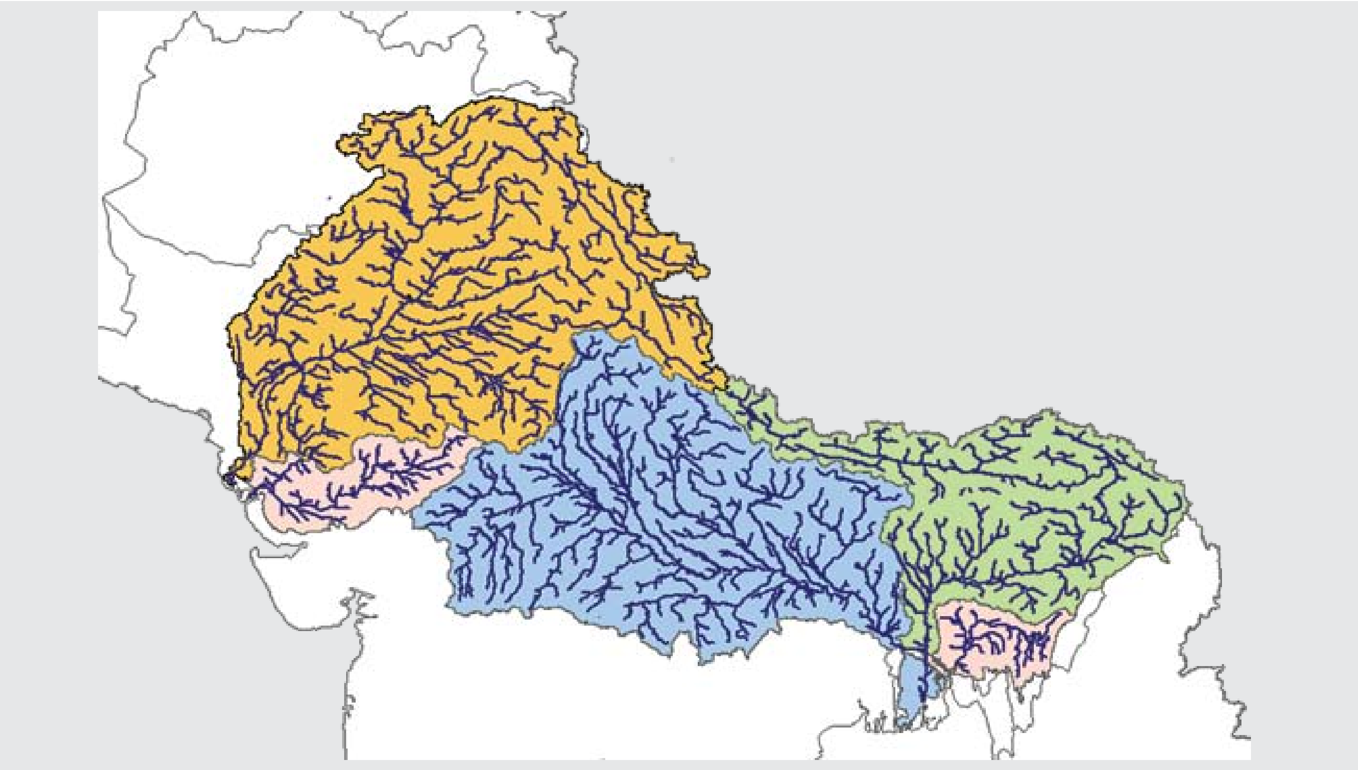
- River basin commissions in People's Republic of China
- River basin parliaments in France
- River basin committees in Australia
- River basin authorities in USA and Sri Lanka
- Lake basin development authority in Philippines
- Water resources and public corporations in Japan and Indonesia
- Inter-state RBOs like river basin tribunals in India and Murray-Darling Basin Commission in Australia
- International RBOs in the Mekong basin, the Syr and Amu Darya basins and in the Tumen basin.

Elements of Success for River Basin Organizations

Legislation

For any river basin organization to be successful, it is essential that it enjoys support among the basin governments through formal instruments, for example, legislation. The Murray-Darling Basin Commission (MDBC) in Australia has one of the most developed environmental mandates of all RBOs. One of the reasons for its success is the significant political backing and the special legislation supporting its operation. Absence of this kind of binding and formal legislation weakens the operational capacity of international RBOs. The Mekong River Commission does not have the authority to enforce any of its provisions. The 1995 Mekong Agreement that guides the Mekong River Commission lacks the legal structure necessary

Rivers and Basins in Himalaya Region



Source: Shaofeng Jia, "How to Prepare for IBM in Himalayan Sub-regions" presentation at Second International Workshop on Himalayan River Basins hosted by SFG - BIPSS at Dhaka on January 16, 2010

to enforce any of its provisions. Hence, it is inadequate and incapable of translating its aim of sustainable development into reality.

Good faith

The member countries of such river basin organizations also need to act in good faith to ensure the success of the initiative. Even though the International Commission for the Protection of the Rhine does not have any legislation in place that makes its decisions legally binding, it is successful because its members generally act in good faith.

Level of cooperation and balance of power

The level of cooperation among the members determines its success. In case there is great political and economic diversity among the member states, their goals will be different and this could make basin-wide decision-making process difficult. Unequal balance of power among basin nations creates difficulties for a river basin organization in carrying out its mission. Diverse political agendas of member states impede unified decision-making. In the case of the Mekong River Commission (MRC), the diverse political agendas of the member states have divided the basin. In such cases, it is essential that a neutral and independent chairperson be nominated so that he/she can facilitate basin-wide decision-making in an impartial manner.

Specific and achievable goals

It is important that a river basin organization has specific and achievable goals. The Murray-Darling Basin Commission has very specific aims including a limit on water diversions. In the past, lack of focus on priority areas has many a time led to problems in the functioning of river basin organizations.

Transparency

For their success, river basin organizations need to have mechanisms to foster better transparency, more public participation and accountability so that concerns of all stakeholders are taken into consideration during basin-wide decision-making. The Murray-Darling Basin Commission has established channels for public participation. The Nile Basin Initiative with 10 member-nations has included public participation in its discussions. Failure on the part of the RBOs to do this results in a failure to draw upon local knowledge and local support. On the other hand, the Mekong River Commission has failed to consult private and public stakeholders and has been criticized for its opaque handling of civil society concerns.

Political Commitment

If the members do not extend strong and sustained commitment to the organization it affects the credibility of the organization. This leads to the inability of the river basin organization to mobilize external resources and implement programmes successfully.

Political instability and civil strife have adversely affected the functioning of many river basin organizations especially the ones in Africa, including Kagera Basin Organization and the Mano River Union.

Examples of River Commissions/ Organizations

River basin organizations have diverse aims ranging from joint management to allocation of water quantity to broader, multi-faceted goals. The Indo-Bangladesh Joint Rivers Commission aims at providing joint management for the Ganges-Brahmaputra-Meghna Rivers. The Helmand River Delta Commission with Afghanistan and Iran as its members aims at measuring and dividing river flows between the two signatories.

Mekong River Commission (MRC)

The Mekong River Commission (MRC) was formed in 1995 by an agreement between the governments of Cambodia, Lao PDR, Vietnam and Thailand. The Commission aims to carry out balanced water resources development in the Mekong River basin. These nations agreed on the joint management of their shared water resources and the maximum development of the economic potential of the river. Originally, its aim was development of large-scale water resources. Presently, coordination between the four countries in the fields of hydropower, irrigation, flood control, and, collection and distribution of hydrological data are a part of the MRC's goals. The MRC consists of 3 permanent bodies – The Council, with one member from each country at the cabinet or ministerial level; the Joint Committee with one member from each country at a level equivalent to the Head of Department level and the MRC Secretariat. The MRC is impeded by the absence of the uppermost riparian country to the Mekong River – China, which is planning significant infrastructure development on the upper reaches of the river within its territory.

The International Commission for the Protection of the Danube River (ICPDR)

It is a trans-national body established to implement the Danube River Protection Convention. The Danube River Protection Convention forms the overall legal instrument for cooperation on trans-boundary water management in the Danube river basin. This convention was signed in 1994 and came into force in 1998. The ICPDR aims to ensure effective and efficient management of surface water and groundwater within the Danube River basin. The signatories to this convention have agreed to cooperate on fundamental water issues. The contracting parties to this convention are Austria, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Moldova, Montenegro, Romania, Slovakia, Slovenia, Serbia, Ukraine and the European Union (EU). All the countries have delegations to the ICPDR; there is another framework for other organizations to join the ICPDR. In 2006, the ICPDR has been nominated the platform for the implementation of the trans-boundary aspects of the European Union Water Framework Directive (WFD). The work for the successful implementation of the EU WFD is, therefore high on the political agenda of the countries of the Danube River basin district.

Indus River Commission

The Indus Water Treaty was signed in 1960 and had India and Pakistan as its signatories with the World Bank as a third-party signatory. The Indus River Commission was set up under this treaty to adjudicate disputes related to allocation of water between the two nations. In cases of disagreement, a neutral expert is called in for mediation and/or arbitration. The Commission is required to meet regularly and has been successful in surviving wars between the member nations. While the Indus Basin Commission is commonly referred to as a successful example of trans-boundary cooperation to share limited water resources, its focus is limited to water allocation and data sharing. The member nations are required to inform each other about any plans to construct engineering works on the river that could affect the other member. The Commission's aim does not include basin wide cooperation in other fields including hydropower, irrigation, navigation and fishing.

Amazon Cooperation Treaty Organization

This is an international organization aiming at promotion of sustainable development of the Amazon basin. It has 8 member states – Bolivia, Brazil, Columbia, Ecuador, Guyana, Peru, Suriname and Venezuela. The Amazon Cooperation Treaty was signed in 1978 while the organization was formed in 1995 to achieve the goals of the treaty. This treaty applies to all territories in the Amazon River basin as well as to territories with similar geographic, economic and ecological characteristics.

Southern African Development Community (SADC) Protocol on Shared Watercourse Systems

SADC's signatories include Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe. The overall objective of this protocol is to foster closer cooperation among SADC countries for the coordinated management, protection and utilization of shared watercourses, through the establishment of river basin organizations. This protocol is playing a pivotal role in guiding the establishment of institutional structures capable of jointly managing the depleting water resources in Southern Africa.

Joint Rivers Management Programme

This is an internationally-funded (EU and Technical Aid to the Commonwealth of Independent States (TACIS)) project on regional cooperation. It spans 7 countries, Russia, Ukraine, Belarus, Kazakhstan, Georgia, Armenia, and Azerbaijan; and covers 4 river basins, Kura, Seversky-Donetz, Tobol, and Pripyat. It addresses water quality management and other related pollution impacts in the four river basins.

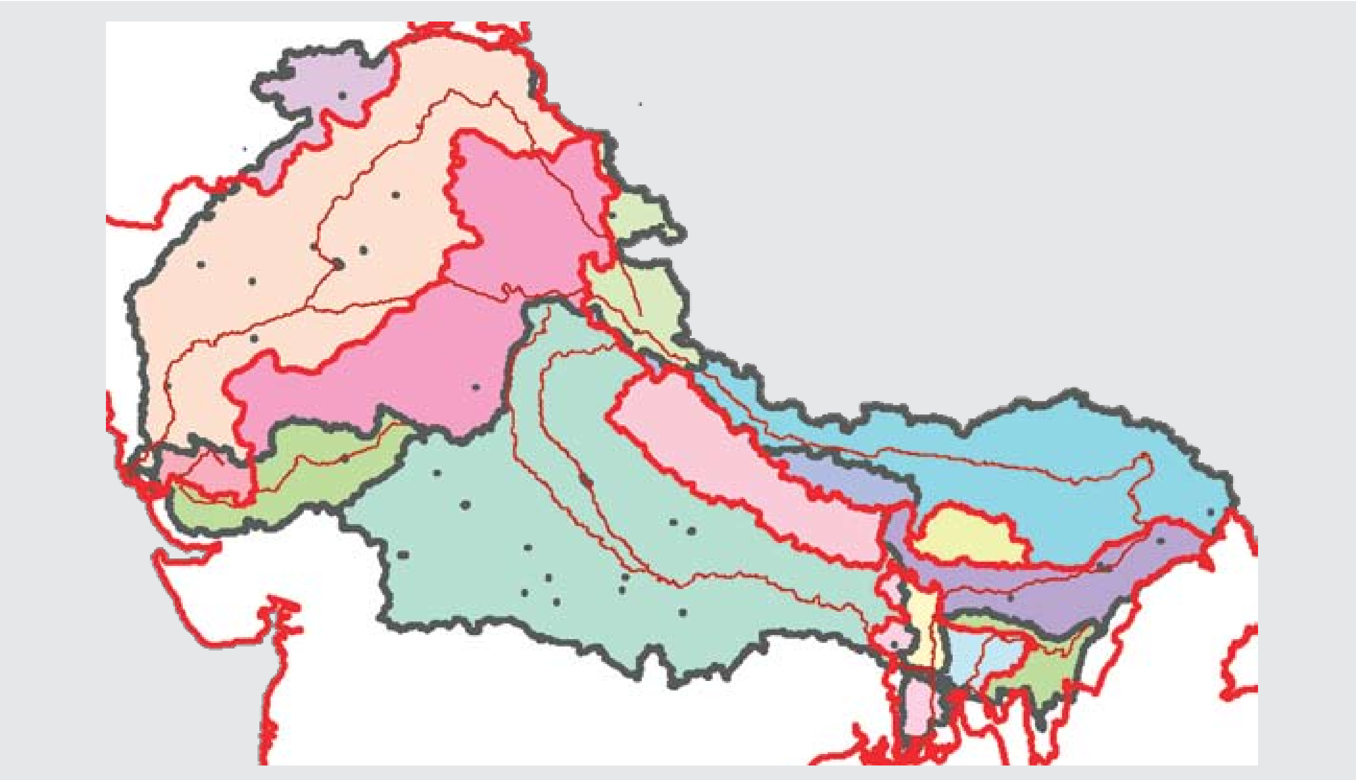
Sub-regional Cooperation

Lately, the trend is shifting to sub-regional cooperation initiatives that revolve around the sustainable economic development of a river basin. Since the 1990s, the Mekong basin has been increasingly targeted for private sector investment and development by finacial institutions. Some of the initiatives undertaken in the Mekong basin include:

Greater Mekong Sub-regional (GMS) Cooperation

The GMS organisation was set up in 1992, with assistance from Asian Development Bank. The Greater Mekong Sub-region Program aims at promoting socio-economic development in the region. It has 6 members including China, Cambodia, Vietnam, Thailand, Myanmar and Lao PDR. It is one of the world's largest regional economic infrastructure projects with an estimated total cost of US $27.6 billion. The GMS spans 9 sectors including transport, energy, tele-communication, environment, human resource development, tourism, trade, private sector investment and agriculture. The GMS is an active organization, whose primary aim is to enable better dialogue and linkages between countries to achieve economic co-operation. As allied goals, the GMS also works towards developing human resources in the Greater Mekong sub-region and sustainable and equitable development of natural resources. The GMS has priority infrastructure projects in various stages of implementation worth around US $10 billion. It has managed to incorporate into the organisation various actors, including the governments of the countries involved, regional organizations such as ASEAN and APEC, amongst others, local NGOs, and academic institutes and universities. The GMS partners with various other state actors as and when required for specific purposes. It has managed to build trust

Water Shed Divided by Country



Source: Shaofeng Jia, "How to Prepare for IBM in Himalayan Sub-regions" presentation at Second International Workshop on Himalayan River Basins hosted by SFG - BIPSS at Dhaka on January 16, 2010

and confidence among riparian nations that were once at odds with each other. It has achieved increased economic co-operation among riparian nations in terms of trade, especially cross-border trade. As an organization, GMS is future-oriented in its thinking and in the initiatives it takes on, and is strongly aligned to the prevailing regional sentiment.

ASEAN - Mekong Basin Development Cooperation (AMBDC)

Set up in 1996 for the economic development of the Mekong basin, AMBDC has Brunei Darussalam, Cambodia, China, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam as its members. Ministers of the member countries united in order to set up this body for the development of the Mekong River basin. The AMBDC's objectives include the enhancing of economically-sound and sustainable development of the basin, encouraging a process of dialogue which may result in economic partnerships resulting in mutual benefit and strengthening economic linkages between the ASEAN nations and the Mekong riparian countries.

Building Trust

The IRBM across borders acts as a means to successful sharing of limited and shared water resources. It forms a proper platform where conflict can be looked over in order to achieve cooperation. Fair water-sharing agreements have been worked out even amongst enemies. Thailand, Cambodia, Lao PDR and Vietnam, with support from the UN have been cooperating since 1957 under the framework of the Mekong Committee, now known as the Mekong River Commission. The Indus River Commission, established with support from World Bank has survived even the Indo-Pak wars. International water resources cooperation requires an institution that can develop a process of engagement; it requires a trusted third party. The discussion process takes some time since the countries involved have to build trust over a period of time and to develop a sense of ownership of the process. The Indus Agreement took over 10 years to come about. River basin organizations may act as catalysts for wider cooperation among member countries. The International Commission for the Protection of the Danube (ICPDR) has brought about cooperation among the riparian countries of the Danube River by reducing the division between Western and Eastern Europe in the post-Cold War era. It has been successful in strengthening democratic institutions in the former communist nations.

IRBM in the Himalayan Sub-region

The concept of Integrated River Basin Management (IRBM) is relatively new to the Himalayan sub-region, with the four countries in question not having any comprehensive, binding agreements to cover all facets of trans-boundary river management. However, as pressure on water resources intensifies, there is a growing case for the implementation of a management framework that will encompass the economic, environmental and social aspirations of the Himalayan sub-region. More importantly as water scarcity, intensified by climate change, becomes more prevalent, the concept of a region-specific IRBM can be looked upon as a confidence-building measure (CBM) which brings various countries together through common interests, subsequently averting the possibility of a conflict. Ultimately, Integrated River Basin Management in the Himalayan sub-region will be conducive to the developmental realities of the four countries and, should be looked upon as an opportunity, rather than an impediment to their growth.

The development of an IRBM framework for the Himalayan sub-region must be tailored specifically to the requirements of those living within the area. While there are several examples of successful IRBM strategies, particularly from the developed world, there is still no model that can be seamlessly replicated to suit the hydro-geology, demographics, socio-economics and the organization of the water sector in the developing world. In addition, a model for the Himalayan sub-region has to account for the contribution of 'green-water' - that which comes from rain and soil moisture, as well as 'blue water' – that which is tapped from rivers, lakes and aquifers. The heavy dependence on monsoons within the sub-region and the high levels of pollution within the rivers means that local water-harvesting efforts, and making the most of soil moisture, are important aspects to river resource utilization.

River basin management will have to account for the 'informal' water sectors in the rural areas, rather than just the traditional management of surface storage facilities and improving the productivity of water bodies. River organizations from the developed world have tended to different agendas, an aspect that will have to be altered as per the individual requirements of the four countries. The Himalayan sub-region's goals for IRBM will primarily revolve around providing access to safe drinking water, food production, poverty eradication and, securing water resources for future development. As such, an IRBM framework has to be designed with these goals in mind.

Collaboration on the management of the Ganges and Brahmaputra Rivers, under the umbrella of a Himalayan Rivers Commission (HRC), will enable all four countries to tap expertise which might not have been available under a nationally-driven framework. The establishment of consultative bodies working on different aspects of river management is likely to facilitate basin-wide water development. The ability to seek scientific and engineering advice at the highest level, for the collection of hydrological and climatic data, flood forecasting, environmental management, water quality monitoring and design and implementation of water projects, can facilitate a better understanding of the river basins. The idea of learning from the experiences of other countries and gaining an insight into how they are adapting to various climate changes and growing water insecurity could be mutually beneficial. The onset of more erratic monsoons for instance, a problem which will affect the entire earth, will necessitate research and development of hybrid crops and more sustainable water utilization practices. Development of hybrid crops is currently being researched and implemented in India and China and could be shared with Bangladesh and Nepal under the provisions of an IRBM framework.

Integrated River Basin Management is a powerful concept that will provide good scope for the continuation of water-based policies regardless of political developments. The Indus River Commission serves as an example of an international agreement between India and Pakistan, which has continued at the expert level, despite conflicts between the two neighbours. Similarly, an IRBM framework between China, Nepal, India and Bangladesh will ensure that access to water resources from the Brahmaputra and Ganges is not dependent on the political climate between the countries – thus ensuring independence at the societal, economic and environmental level. This would also be largely beneficial to smaller countries and lower riparian nations, although, as has been previously highlighted, the intricacies binding the countries together on the climate change front, means that the future of all countries are increasingly inter-linked.

Joint action by the different stakeholders, particularly when there is an instance of mistrust, could work as a CBM, binding countries through their common interests of the Himalayan glaciers and development of the sub-region. As the impact of water scarcity grows in the Himalayan sub-region, there is a possibility of conflict over the issue of access to water resources. However, joint action on the Himalayan glacier-fed rivers is likely to fuel greater interdependence and gradually prevent or tone down conflict. Research by the Oregon State University reports that in the last 50 years, only 37 disputes over water-involved violence, of which 30 occurred between Israel and one of its neighbours. Outside of the Middle East, researchers have found only five incidents of violence, while 157 treaties have been negotiated and signed. Cooperation on water should be looked upon as a means to peaceful co-existence. Joint water management offers scope for more people-to-people and/or expert-to-expert connections, thus creating a channel for peaceful dialogue, irrespective of political and military developments.

There are several benefits pertaining to the water resources of the Himalayan sub-region which can be derived and eventually exploited with the aid of the HRC. Purchase agreements between Nepal and India or Nepal and China for instance, over the development and sale of hydro-electricity would be beneficial to all concerned. Similarly, purchase agreements related to agricultural production offers another avenue by which the countries can cooperate.

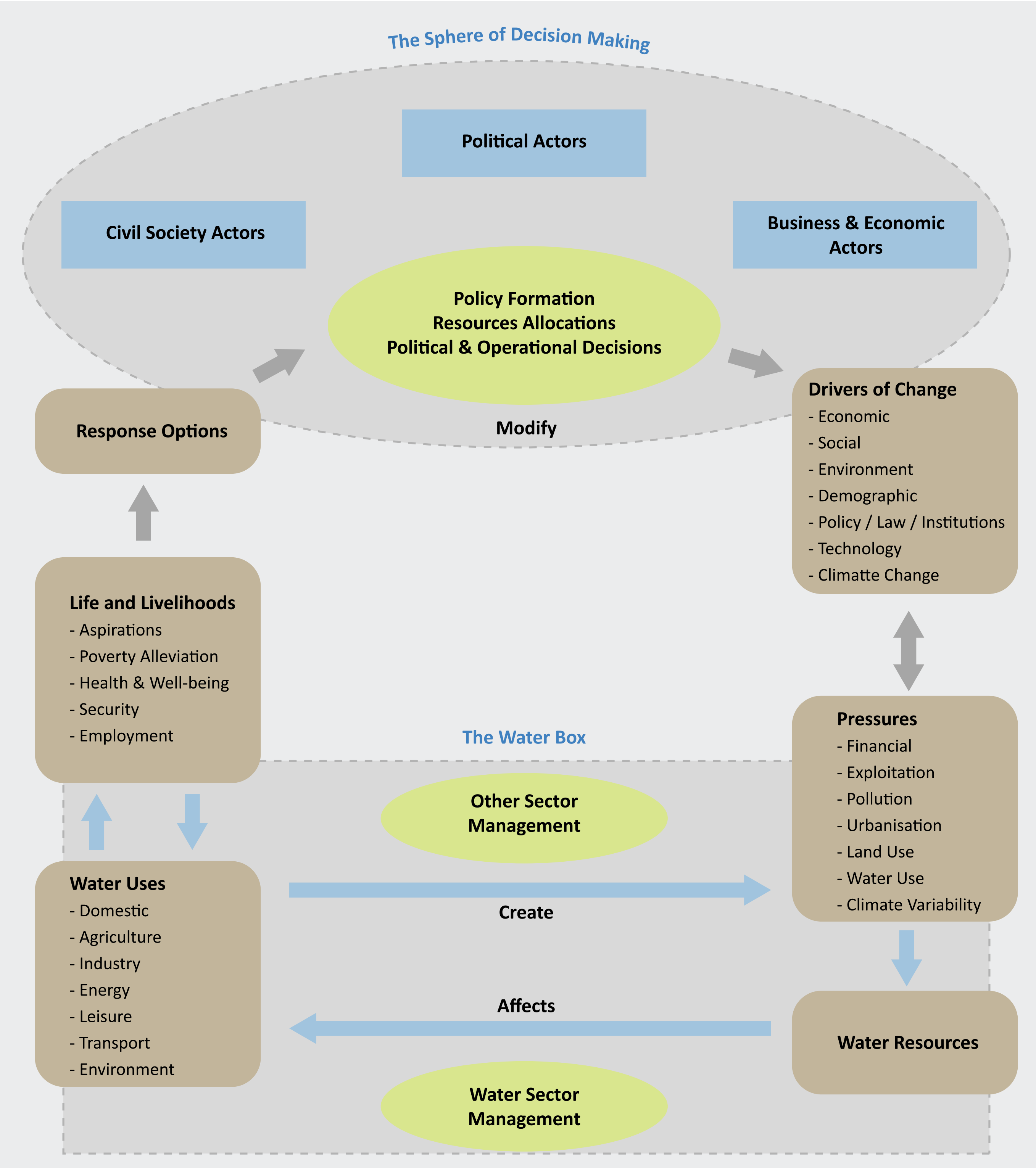
The Himalayan River Commission (HRC)

The Himalayan sub-region, with its complicated geo-politics and pressing water insecurity, is in need of a comprehensive mechanism to address its issues, with specific regard to the glacier-fed rivers of the region. The major river systems, the Ganges River basin and the Brahmaputra River basin cover four countries. While the Ganges basin extends from Nepal, to India and to Bangladesh, the Brahmaputra traverses China, India and Bangladesh. As the water resources of these four countries are reducing, a solution to the water woes faced, that is conceived and implemented by just one of the countries without the participation or contribution of the other countries, is impossible.

It has been established that this specific region of the world necessarily requires a unique and customized solution to help manage its complex trans-boundary water resources. A hybrid system of IRBM is needed to ensure that comprehensive solutions are found to existing problems, and any future issues that might occur are solved jointly, by all involved stakeholders. Such a system will facilitate interaction amongst the countries on river basin-related issues.

In order to achieve any effective solutions in the area of IRBM, especially in light of the effects of climate change, a multi-disciplinary approach will be imperative. Due in part to the disorganized nature of the water sectors in the smaller countries, and in part to traditional thinking over water issues, the approach to addressing water security in Himalayan sub-region has always been a compartmentalized exercise. Water security is an independent issue by itself and has to be dealt with separately from food security, health security, conflict management, migration and human security issues. This approach has not reaped sufficient rewards as it is fundamentally at odds with the true nature of the issue. Since these different aspects of human security are vitally inter-linked, a comprehensive solution to problems in any one area

Water Box



Source: Dipak Gyawali, "UN World H_2O" presentation at Second International Workshop on Himalayan River Basins hosted by SFG - BIPSS at Dhaka on January 16, 2010 can not be found without taking all the other areas into consideration as well.

At Strategic Foresight Group's Second International Workshop in Dhaka, the closed nature of the 'Water Box' was used by a participant to illustrate the chasm between the present water resources decision-making sector and various stakeholders who are yet to be initiated into the process. The 'Water Box' is essentially closed and needs to be opened up to include stakeholders from all different sectors.

Therefore, any sub-regional Commission intended to deal with integrated river basin management will need to function as a mechanism to co-ordinate the activities of various disciplines with the aim of producing a synchronized response to water security issues. This proposed new hybrid system will have to be a series of multi-layered 'mini-commissions', with specific foci, under the umbrella of a larger Himalayan Rivers Commission (HRC), of which China, India, Nepal and Bangladesh are member countries with equal rights and standing. The Commission will have a rotating President or Chairman, like the EU, of Ministers of Water Resources (or an equivalent post) of the four countries. It is vital that the scope of the Himalayan Rivers Commission (HRC) be expansive in order to cover not just the availability of water in the rivers, but also the impacts of water scarcity on other aspects of life in the river basins.

As has been addressed before, each of the two major trans-boundary river systems will have to be addressed as one entire ecosystem, rather than as separate national entities. In order to further this approach, two of the organizations contained under the larger Commission will have to focus on each of the two major river basins, i.e. the Ganges and the Brahmaputra. Each of these organizations (RBO) will have their member countries as those that the specific river passes through, i.e. the Ganges River Basin Organization will have India, Nepal and Bangladesh as its members, while the Brahmaputra River Basin Organization will have China, India and Bangladesh as its members. The focus of these two organizations will be basin-specific. Each of them will have a scientific and technical branch, governed by and administered to by prominent academics and experts. The organisations will also have data collection branches, whose sole purpose will be to ensure the timely collection and open exchange of data pertaining to the river. Apart from this, each of these RBOs will have an open channel to the other, larger Commissions within the HRC, such as the ones involving agriculture, economic activities and glaciers.

Apart from the River Basin Organizations, there will also be larger Commissions within the HRC, for areas of collaboration such as agriculture, economic activities and glaciers. Since all these are areas of interest for all four countries, their focus and work will be more expansive. All the four countries will have an equal stake in the work done by these Commissions. These Commissions will also be comprised of scientific and technical experts who will work on all matters pertaining to the Himalayan River basin system within the four countries. There will also be a branch devoted exclusively to data collection that will also extend across all four countries. As mentioned before, each of these larger Commissions will connect with the RBOs as and when required.

Under the umbrella of the HRC, will also be a separate organization for the development of the Yangtze and Yellow River basins. Even though both these rivers begin and end within sovereign Chinese territory, there will still be a mechanism instituted to work out joint solutions in order to restore the health of these rivers. An integrated river basin management plan that was proposed for the Yangtze River never came to fruition, thus any success that is found through the HRC can be replicated in China for both the Yangtze and the Yellow. As these are also Himalayan glacier-fed rivers, many of the troubles facing their basins are similar to the ones facing the Ganges and Brahmaputra basins, and an attempt to find solutions for them might yield solutions for the Yangtze and Yellow, and vice versa. Since China is a larger and significant part of the organization, this will also provide greater incentive for it to be involved.

Due to the frequent and increasing occurrence of extreme weather events in China, Nepal, India and Bangladesh, as floods, droughts or typhoons, the HRC will also have an organization exclusively for the purpose of joint emergency response. This Emergency Response Organization will comprise of scientific and technical advisers from all countries that will work on a data collection and forecasting system that will keep all four member countries apprised of any impending extreme weather event. It will also comprise of a team of disaster management experts that will be able to co-ordinate with all four countries in the event of a disaster, and will provide necessary information and aid during the event itself.

The HRC will also have a taskforce on desertification within its umbrella, as this is a problem confronting the region, and one that has a direct impact on the economy of the region. This taskforce will be allied closely to the Agriculture Commission as their work will be inter-linked. The aim of this taskforce will be to gather information and help invent solutions for all of the member countries in order to combat desertification.

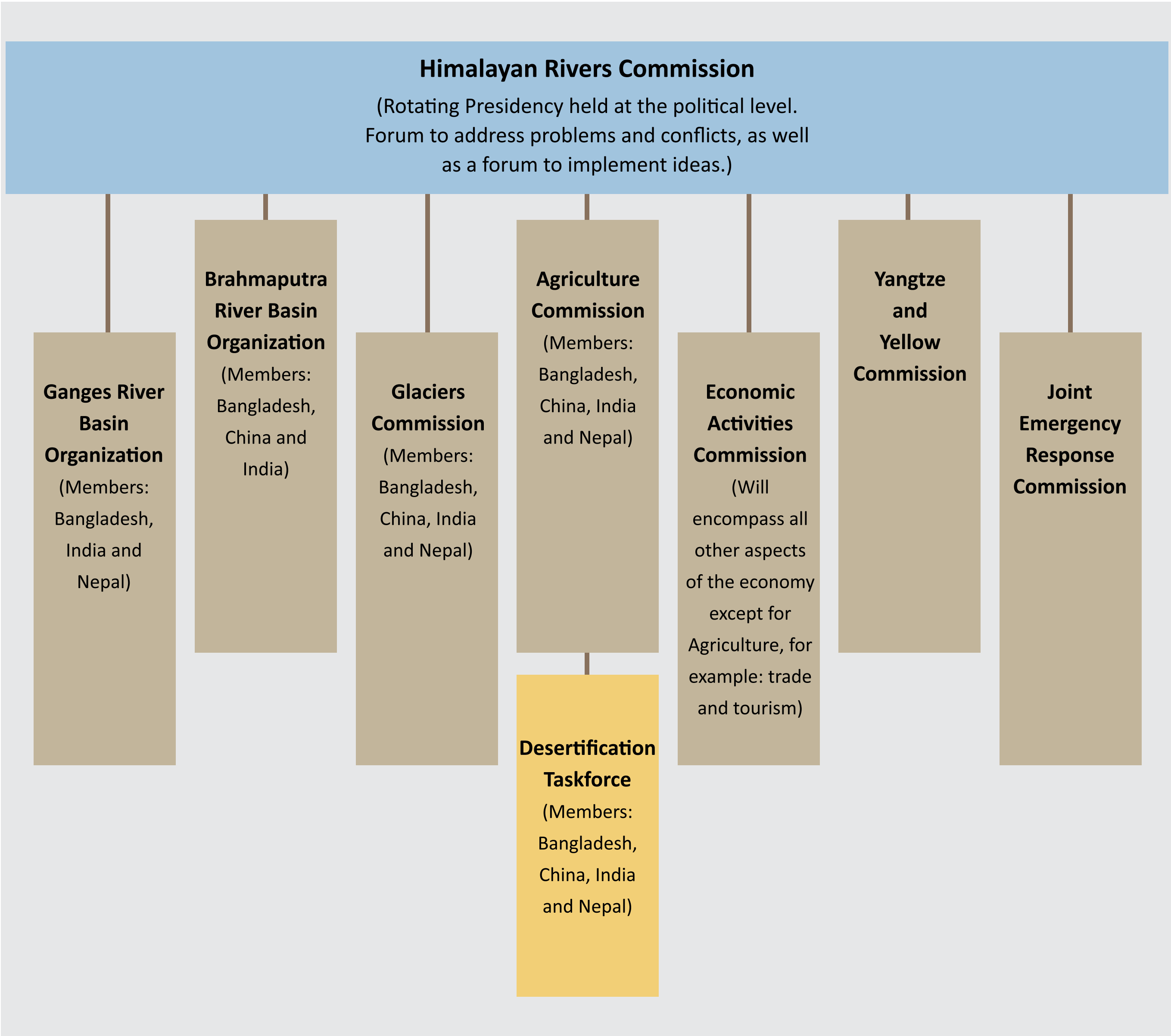
A vital feature of the HRC will be the frequency of meetings between the members of the various organizations under its aegis. Each of the smaller organizations, Commissions and branches will meet frequently at the academic and technical levels, as and when required in order to maintain constant communication as well as the flow of information and ideas. Another critical aspect of the HRC will be its attempt to ensure that all of the stakeholders of the region are represented. This will mean that NGOs, farmers' unions, women's organizations, and local leaders will all be invited to partner under the HRC's umbrella in order to ensure the maximum results, with the best information possible. This aspect of the HRC will be extremely important, especially due to the different terrains, the adversity of conditions, and the socio-economic realities, apart from the sheer number of the people that live in the basin. Due to the unique circumstances in the Himalayan River Basins system, the involvement of the people that live directly off the land from all four countries will be necessary.

The main function of the larger HRC will be as a forum to address complaints, negotiate and execute an implementation of joint ideas. Any of the members of the organizations will be able to put forth their ideas to the HRC in order for them to be implemented in a joint sustainable way within the four countries, and also, in a way that is politically plausible. Similarly, any issues or problems being faced by any of the four member countries or any of the organizations within the HRC will be brought to the attention of the HRC for negotiation, or mediation as and when required. This will be a vital function and will require experts from the four countries, who are aware of political realities on the ground, as well as have diplomatic experience.

The HRC will also be able to bring on guest countries as and when the interests of the HRC intersect with the interests of the guest country. A workable example of this arrangement is the one that SAARC has with China. Similarly, the HRC will retain the discretion to invite a guest country to partner with one of its organizations for a specific purpose or project. Potential guest countries in the region include Pakistan and Bhutan.

While many more elements can be added to the present form of the proposed Himalayan Rivers Commission in order to make it more inclusive, expansive and effective simultaneously, it will be equally important to strengthen the organization from the core through transparency and accountability. Since this will be a regional organization, for it be effective, it is important for all parties to be willing and open to invest their finances, manpower, technology and political capital to ensure that the Himalayan River Commission becomes not just successful but also sets an example worthy of being emulated.

Framework for the Himalayan River Basin Commission



Annexure 1: Kathmandu Report

Experts Call for Himalayan Sub-Regional Cooperation

Strategic Foresight Group had organized the first international workshop on Challenges of Water Stress and Climate Change in the Himalayan River Basins at Hotel Dwarika's, Kathmandu, Nepal, on August 6-7, 2009. It was a component of the collaborative dialogue process launched under the auspices of the Asian Security Initiative of John D and Catherine T MacArthur Foundation. The World Bank and International Union for the Conservation of Nature, Nepal, cooperated with the Strategic Foresight Group in convening the workshop, which was attended by leading experts on water and climate change from Bangladesh, India, China, Nepal and the World Bank, including former Ministers of Water Resources.

The participants overwhelmingly emphasized the need to promote Himalayan Sub-regional Cooperation to ensure water security and a climate of peace and progress. There is no alternative to cooperation in view of the retreat of glaciers, resulting decline in river flows in parts of the four countries and flooding in other parts, tectonic changes in the Himalayan region, sedimentation, threat to food security and the risk of increase in inequity.

The experts expressed serious concern for paucity of climate data in mountain regions, as the present emphasis is on national averages which tend to be influenced by the situation in the plains. There is a risk of economic collapse of several mountain communities. The experts were alarmed that engineering and climate modeling techniques, knowledge of clouds and fog are either outdated or inadequate.

The experts urged to overcome the present tendency to resist the sharing of scientific and technical data in a context where national solutions are not feasible. Several experts recommended the use of local tradition to preserve livelihood, action research, treatment of the eco-system as a whole involving all stakeholders, and the use of instruments of international cooperation such as the UN Biodiversity Convention and the Ramsar Convention.

In brief, participants recommended building blocks of regional cooperation beginning with water dialogues, data sharing, and awareness building in affected communities, slowly enhancing it to the level of collaborative river basin management. Strategic Foresight Group announced in response that it would continue with the collaborative dialogue process and convene the second workshop in early 2010.

Date: 6-7 August, 2009

Participants

Bangladesh

1. Maj Gen A N M Muniruzzaman, President, Bangladesh Institute for Peace and Security Studies
2. Mr Tauhidul Anwar Khan, Secretary General, Bangladesh Water Partnership
3. Mr Malik Fida A Khan, Head, Climate Change Study Division, Center for Environmental and Geographic Information Services

China

1. Mr Zhang Shuang, Director, The Nature Conservancy, China Program
2. Dr Zheng Yan, Associate Research Fellow, Research Centre for Sustainable Development
3. Dr Xiaohong Chen, Director, Department of Water Resources and Environment, Sun Yat-Sen University
4. Prof Jinxia Wang, Associate Professor, Center for Chinese Agricultural Policy, Chinese Academy of Sciences
5. Dr Shaofeng Jia, Professor, Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences
6. Mr Ma Jian, Manager of Conservation and Climate Project, The Nature Conservancy China Program
7. Dr Xiaoquan Zhang, Senior Climate Change Scientist, The Nature Conservancy China Program

India

1. Mr Sompal, former Minister of Agriculture and Water Resources of India
2. Prof Jayanta Bandyopadhyay, Professor, Centre for Development and Enviornmental Policy, IIM Calcutta
3. Mr Ashok Jaitly, Distinguished Fellow and Director, Water Resources Division, The Energy and Resources Institute
4. Dr Chandan Mahanta, Head, Department of Environment, IIT-Guwahati
5. Dr Sushil Kumar Gupta, Visiting Scientist, Physical Research Laboratory
6. Mr Ganesh Pangare, Regional Coordinator, Water and Wetlands Program, International Union for the Conservation of Nature, Asia Regional Office

Nepal

1. Mr Dipak Gyawali, former Minister for Water Resources, Member Nepal Academy of Science and Technology, Member Board of Directors, Nepal Water Conservation Foundation
2. Mr Som Nath Poudel, Former Executive Secretary, Water and Energy Commission Secretariat and General Secretary, Jalsrot Vikas Sansthan
3. Mr Kanak Mani Dixit, Editor, Himal
4. Mr Ajaya Dixi, Nepal Water Conservation Foundation
5. Dr Bishnu Bhandari, Chief Technical Advisor, International Union for the Conservation of Nature
6. Mr Jay Pal Shrestha, Regional Environmental Affairs Specialist, U.S. Embassy
7. Dr Madhav Karki, Deputy Director General Programmes, International Centre for Integrated Mountain Development (ICIMOD)
8. Dr Mandira Shtestha, Water Resources Specialist, Water and Hazards, International Centre for Integrated Mountain Development (ICIMOD)

World Bank

1. Dr Claudia Sadoff, Lead Economist, South Asia Unit
2. Mr Shyam Ranjitkar, Sr. Irrigation Engineer, South Asia Sustainable Development Unit

Strategic Foresight Group

- Ms Ilmas Futehally, Executive Director
- Mr Shrikant Menjoge, Senior Advisor
- Ms Sahiba Trivedi, Research Analyst

Annexure 2: Dhaka Declaration

Dhaka Declaration on Water Security

Strategic Foresight Group (SFG) and Bangladesh Institute of Peace and Security Studies (BIPSS) organized the Second International Workshop on Himalayan Sub-regional Cooperation for Water Security in Dhaka on 15-16 January, 2010. This is part of a long term process to build confidence and cooperation between countries that make up the Himalayan River Basin.

This process is supported by the John D and Catherine T MacArthur Foundation, USA.

25 distinguished water experts from India, Bangladesh, China and Nepal, including former ministers of Water Resources of India, Bangladesh and Nepal, participated in the workshop.

The following statement is made by the Conference:

1. **Recognised** the critical significance for water security of the Himalayan River Basin.
2. **Recommended** the formation of an experts committee to prepare a road map for data sharing and scientific exchange and to prepare guidelines for introducing transparency regarding relevant data.
3. **Acknowledged** the importance of a collaborative approach in addressing technical, scientific and other multi-disciplinary aspects of the complex issues involved.
4. **Suggested** the establishment of joint research projects involving all the countries represented to acquire, collect, generate and process appropriate up-to-date data for taking the process forward.
5. **Recommended** joint efforts for the exchange of data and information on flow of Himalayan Rivers in low season.
6. **Recognised** the need for political commitment of the Basin countries to driving forward collective approaches to the challenges.
7. **Acknowledged** the serious consequences of climate change for water security across the Basin countries and encouraged concerted collective action in addressing these.
8. **Underscored** the need to defend equal interests of all Basin countries especially the lower riparian ones.
9. **Understood** the potential the potential for conflict over resources, if the problems are not resolved in a cooperative manner.
10. **Recommended** strongly integrated cooperative Basin management mechanism for the Himalayan Basin Area.

Sundeep Waslekar
President
Strategic Foresight Group
Date: 16 January, 2010

Major General ANM Muniruzzaman (Retd.)
President
Bangladesh Institute of Peace and Security Studies
Date: 16 January, 2010

Participants

Bangladesh

1. Maj Gen Muniruzzaman, President, Bangladesh Institute of Peace and Security Studies (BIPSS)
2. Mr Tauhidul Anwar Khan, Secretary General, Bangladesh Water Partnership
3. Mr Malik Fida A Khan, Head, Climate Change Study Division, Center for Environmental and Geographic Information services
4. Dr Mahfuz Ullah, Regional Councillor, International Union for Conservation of Nature(IUCN)
5. Major Hafiz Uddin Ahmad, Former Minister of Water Resources, Government of Bangladesh
6. Mrs Hasna Moudud, President, ARDMA
7. Dr Mahmud Ali, Former Senior Editor, Asia-Pacific Region, BBC World Service, and Director Research, BIPSS

China

1. Mr Zhang Shuang, Director, The Nature Conservancy, China Program
2. Dr Xiaohong Chen, Director, Department of Water Resources and Environment, Sun Yat-Sen University
3. Dr Shaofeng Jia , Professor, Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences
4. Prof Xi Chen, State Key Laboratory of Hydrology, Water Resources and Hydraulic Engineering, Hohai University
5. Ms Kezhen Cao, Chief Reporter, The Green Herald

India

1. Mr Sompal, former Minister of Agriculture and Water Resources of India
2. Prof Jayanta Bandyopadhyay, Professor, Centre for Development and Enviornmental Policy, IIM Calcutta
3. Dr Chandan Mahanta, Head, Department of Environment, IIT-Guwahati
4. Mr Ganesh Pangare, Regional Coordinator, Water and Wetlands Program, International Union for the Conservation of Nature, Asia Regional Office, Bangkok
5. Dr Sanjoy Hazarika, Chair, Centre for North East Studies at Jamia Millia Islamia, New Delhi
6. Prof Nayan Sharma, Professor, Indian Institute of Technology Roorkee
7. Dr Dulal Goswami, Former Professor & Head of Department of Environmental Science, Gauhati University

Nepal

1. Mr Dipak Gyawali, former Minister for Water Resources, Member Nepal Academy of Science and Technology, Member Board of Directors, Nepal Water Conservation Foundation
2. Dr Bishnu Bhandari, Wetlands Specialist Integrated Water and Hazard Management (IWHM), International Centre for Integrated Mountain Development
3. Mr Som Nath Poudel, Former Executive Secretary, Water and Energy Commission Secretariat and General Secretary, Jalsrot Vikas Sansthan
4. Mr Ajaya Dixit, Director, Nepal Water Conservation Foundation

MacArthur Foundation

- Mr Matthew Stumpf, Programme Officer, Asian Security Initiative

Strategic Foresight Group

- Mr Sundeep Waslekar, President
- Mr Shrikant Menjoge, Senior Advisor
- Ms Ilmas Futehally, Executive Director

SOURCES

Section 1

INTRODUCTION

'People's Republic of China: River Basin Water Resources Allocation and Management Policy'. Project number 40687. Asian Development Bank Technical Assistance Report. September 2008.

'China warned of water crisis by 2030'. People Daily. 6 June 2006.

'Water Availability per person per year'. UNESCO. <http://www.unesco.org/bpi/wwdr/WWDR_chart1_eng.pdf>

'Per Capita Water Availability In Selected Countries'. Central Water Commission, India. <http://cwc.nic.in/Water_Data_Pocket_Book_2006/C28.pdf>

Mu, Y. & Song, T.S. 'China's Looming Water Crises'. EAI. Background Brief No. 386. 12 June 2008.

'Scientifically Exploiting Hydropower Resource to Promote the Sustainable Utilization of Water Resources and the Sustainable Development of Economy and Society'. Yangtze Forum. 13 August 2006. <http://www.cjw.gov.cn/ad/yangtzeforum/detail/20060813/67237.asp>

Shrestha, Madan Lall & Shrestha, Arun Bhakta. 'Recent trends and potential climate change impacts on glacier retreat/glacier lakes in Nepal and potential adaptation'. Department of Hydropower and Meteorology, Nepal. November 2004. <http://www.oecd.org/dataoecd/0/17/33993644.pdf>

Siddiqi, Toufiq A & Tahir-Kheli, Shirin. 'Project on Water and Security in South Asia (WASSA)'. Carnegie Corporation of New York. <http://www.gee-21.org/publications/pdf%20files/FinalExecutiveSummaryJanuary2004.pdf>

'Nepal: Initial National Communication to the Conference of the Parties of the United Nations Framework Convention on Climate Change'. Ministry of Population and Environment, Nepal. <http://unfccc.int/resource/docs/natc/nepnc1.pdf>

FAO Aquastat. <http://www.fao.org/nr/water/aquastat/data/query/results.html>

Mall, R.K. Gupta, A. Singh. R. Singh.R.S. & Rathore, L.S. 'Water resources and climate change: An Indian perspective'. Current Science, Vol.90, No.12, 25 June 2006.

'Water Availability – Basinwise'. Ministry of Water Resources, Government of India. <http://wrmin.nic.in/index3.asp?subsublinkid=397&langid=1&sslid=331>

'India'. Food and Agriculture Organisation of the United Nations. <http://www.fao.org/nr/water/aquastat/countries/india/index.stm>

Briscoe, John & Malik, R.P.S 2008. 'India's Water Economy – Bracing for a turbulent future', The World Bank, Oxford University Press.

'Total Actual Renewable Water Resources'. UNESCO. <http://www.unesco.org/water/wwap/wwdr/indicators/pdf/D1_Total_Actual_Renewable_Water_Resources.pdf>

Lisheng Suo. 'River Management and Ecosystem Conservation in China'. Proceedings of the Ninth International Symposium on River Sedimentation, pp. 3-10. Tsinghua University Press, Beijing. October 2004.

'Yellow River Basin'. CGIAR Challenge Program on Water and Food. <http://www.waterandfood.org/research/basins/yellow-river-basin.html>

Bongartz, K. Flügel, W.A. Pechstädt, J. Bartosch, A. & Eriksson, M. 'Analysis of climate change trend and possible impacts in the Upper Brahmaputra River Basin – the BRAHMATWINN Project'. World Water Forum. <http://wwc2008.msem.univ-montp2.fr/resource/authors/abs435_article.pdf>

'General Introduction of Rivers in China'. The Ministry of Water Resources of the People's Republic of China. <http://www.mwr.gov.cn/english/>

'Protect Our Precious Freshwater Resources'. China.org. 28 December 2006.

Eric, F. Chris, M. and Dan, F. 'Invest in Water: A special situations report on our most precious resource'. Agora Financial Publications.

Smakhtin, V. & Anputhas, M. 'An Assessment of Environmental Flow Requirements of Indian River Basins'. International Water Management Institute.

A, Upali. 'Spatial Variation in Water Supply and Demand across River Basins of India'. International Water Management Institute. <http://www.icid.org/report_upali_nov03.pdf>

Kumar, Rakesh. Singh, R.D. & Sharma, K.D. 'Water Resources of India'. National Institute of Hydrology, Roorkee.

Bhusal, Jagat K. 'Renewable Surface Waters of Nepal -Uses and Constrains to 21st Century'. Department of Hydrology and Meteorology. <http://www.riob.org/forum2/jk-sciii.htm>

'Nepal'. Nepal National Committee of ICID. <http://www.icid.org/v_nepal.pdf>

Rajbanshi, K.J. 'Zoo-geographical distribution and the status of coldwater fish in Nepal'. Royal Nepal Academy of Sciences and Technology. <http://www.fao.org/docrep/005/y3994e/y3994e0r.htm>

Chapter 1: THE FUTURE OF GLACIERS

'Shrinking glacier threat to rivers'. China Daily. 2 November 2007.

Jianchu, Xu. Shrestha, Arun. & Eriksson, Mats. 'Assessment of Snow, Glacier and Water Resources in Asia'. UNESCO. 2009. <www.mtnforum.org/rs/ol/counter_docdown.cfm?fID=5412.pdf>

Jain, Sharad. 'Impact of retreat of Gangotri glacier on the flow of Ganges River.' Current Science, vol.95 no.8. October 2008.

Wax, Emily. 'A sacred river endangered by global warming'. The Washington Post. 17 June 2007. <http://www.washingtonpost.com/wp-dyn/content/article/2007/06/16/AR2007061600461.html>

Yongjian, D. Shiyin, L. Changwei, X. Yong, Z. & Jian, W. 'Yellow River at Risk- An Assessment of the Impacts of Climate Change on the Yellow River Source Region'. Green Peace. 2005.

Jibin, Yang. 'Searching for the source'. China Dialogue. 11 March 2009.

'Preliminary consolidated report on effect of Climate Change on Water Resources'. Ministry of Water Resources, Government of India. June 2008.

Srinath. M.G. 'Satellite images show Himalayan glacier receded 1.5km in 30 years'. Earth Times. 5 December 2009. <http://www.earthtimes.org/articles/show/297875,satellite-images-show-himalayan-glacier-receded-15-km-in-30-years.html>

'Glacier meltdown scale arouses debate'. China.org.cn. 13 October 2009. <http://www.china.org.cn/environment/2009-10/13/content_18694439.htm>

Xu, Z.X. Zhao, F.F & Li, J.Y. 'Impact of Climate Change on streamflow in the Yellow River Basin'. <http://ifwf2.org/addons/download_presentation.php?fid=1077>

Khoday, Kishan. 'Climate Change and the Right to Development. Himalayan Glacial Melting and the Future of Development on the Tibetan Plateau'. Human Development Report 2007-2008. Background Paper for 2007 UNDP Global Human Development Report. United Nations Development Programme. 2007.

'Himalayan Gangotri Glacier'. Global Warming. <http://www.global-greenhouse-warming.com/himalayan-gangotri-glacier.html>

'An Overview of glaciers, glacier retreat and its subsequent impacts in the Nepal, India and China'. WWF Nepal Program. World Wildlife Fund. 2006. <http://assets.wwfindia.org/downloads/an_overview_of_glaciers_glacier_retreat.pdf>

Seidel, K. & Martinec, J. 'NOAA/AVHRR monitoring of snow cover for modelling climate-affected runoff in Ganges and Brahmaputra Rivers'. EARSeL-LISSIG Workshop. March 2002.

Mahanta, Chandan. 'Water Resources in the Northeast: State of the knowledge Base.' Indian Institute of Technology, Guwahati, India. August 2006.

Alam, Mozarahul & Regmi, Bimal Raj. 'Adverse Impacts Of Climate Change On Development Of Nepal: Integrating Adaptation Into Policies And Activities'. Bangladesh Centre for Advanced Studies. 2004. <http://www.ccnn.org.np/admin/download/237CC_policy.pdf>

BOX: Glacial Lake Outburst Floods

Schild, Andreas. 'Glacial Lake Outbursts and its Impacts on Human Security in South Asian Countries'. ARC Asia Pacific Future Research Network. October 2008. <http://www.sueztosuva.org.au/south_asia/ehs_conference/papers/Schild.pdf>

Khadka, N.S. 'Himalaya Glaciers Melt Unnoticed'. BBC. 10 November 2004. <http://news.bbc.co.uk/2/hi/science/nature/3998967.stm>

Adhikari, D.P. 'Impacts of Climate Change on Water Resources and Challenges for Mainstreaming Adaptation Concerns in the Nepal Himalaya'. UNESCO. 2007. <http://www.meguro-unesco.com/E-lectures/2007/06/impacts_of_climate_change_on_w.html>

Chapter 2: RAINFALL

Lisheng Suo. 'River Management and Ecosystem Conservation in China'. Proceedings of the Ninth International Symposium on River Sedimentation, pp. 3-10. Tsinghua University Press, Beijing. October 2004.

Fu, Guobin & Chen, Shulin. 'Water Crisis in the Yellow River: Facts, Reasons, Impacts and counter-measures'. IWA Publishing Online Journals.

Lida, Weng. 'Protection and Development of Yangtze River'. Yangtze Forum. 25 June 2006.

Erfeng, Zhang. & Xiqing, Chen. 'Water discharge changes of the Changjiang River downstream Datong during dry season'. Institute of Geographic Sciences and Natural Resources Research, CAS. 2003. <http://www.igsnrr.ac.cn/menu9/book5.jsp?id=1142>

Climatic and Hydrological Atlas of Nepal. 1996.

'Nepal Case Study'. NAPA Workshop. September 2003. <http://www.napa-pana.org/files/workshops/buthan/09_Nepal_Case_Study.pdf>

Arman, Muhammad Mizanur. 'Rio Ganges: Reduccion de Conflictos a Traves de la Gestion Integrada del Agua'. November 2007.

'Climate Change and Its Possible Impact on India', Greenpeace. <http://www.greenpeace.org/india/campaigns/choose-positive-energy/what-is-climate-change/climate-change-its-possible>

Ravindranath, N.H. Joshi, N.V. Sukumar, R & Saxena, A. 'Impact of Climate Change in Forests in India'. Current Science. Vol. 90. No. 3. 10 February 2006.

'The Peoples Republic of China: Initial National Communication on Climate Change'. Government of The Peoples Republic of China. <http://www.ccchina.gov.cn/WebSite/CCChina/UpFile/File176.pdf>

The National Adaptation Programme of Action (NAPA) report. Ministry of Environment and Forest (MOEF). Government of Bangladesh. November 2005.

Agarwala, Shardul. Raksakulthai, Vivian. van Aalst, Maarten. Larsen, Peter. Smith, Joel & Reynolds, John. 'Development and Climate Change in Nepal: Focus on Water Resources and Hydropower'. Organisation for Economic Co-operation and Development. 2003.

'Yangtze Conservation and Development Report 2009'. Wereld Natuur Fonds. <http://www.assets.wnf.nl/downloads/english_brief_of_yangtze_report_2009.doc>

Chunzhen, Liu. 'Study on Climate Change and Water in China'. <http://www.mairs-essp.org/UserFiles/File/Study%20on%20climate%20change%20and%20water%20in%20China.pdf>

'Climate Change Country Profile: China'. World Health Organization. <http://www.wpro.who.int/NR/rdonlyres/5C2F1B84-6507-4EAB-A27D-7EBEFC457EA9/0/CHN.pdf>

Xu, ZX. Zhao, FF. & Li, JY. 'Impact of Climate Change on streamflow in the Yellow River Basin'. <ifwf2.org/addons/download_presentation.php?fid=1077>

Smakhtin, V. & Anputhas, M. 'An Assessment of Environmental Flow Requirements of Indian River Basins'. International Water Management Institute.

'40 million hectares in India flood prone' Thaindian. 30 March 2009. <http://www.thaindian/com/newsportal/uncategorized/40-million-hectares-in-india-flood-prone_100173385.html>

'Monsoon rains spread havoc in Uttar Pradesh' Thaindian. 23 August 2008. <http://www.thaindian/com/newsportal/india-news/monsoon-rains-spread-havoc-in-uttar-pradesh_10087702>

Parua, P.K. 'Flood management in Ganges-Brahmaputra-Meghna Basin: Some aspects of regional cooperation'. United Nations Economic and Social Commission for Asia and the Pacific.

'Orissa flood toll 29; Uttar Pradesh, Delhi face Yamuna fury.' Thaindian. 22 September 2008. <http://www.thaindian.com/newsportal/uncategorized/orissa-flood-toll-29-uttar-pradesh-delhi-face-yamuna-fury-roundup_10098617.html>

'Impact of climate change on disasters and agriculture in Bangladesh'. CEGIS. 2009.

'Bangladesh Country Water Resources Assistance Strategy' World Bank. 2005.

'Development and Climate Change in Bangladesh: Focus on Coastal Flooding and the Sundarbans' OECD. 2003.

Anwar Ali, 'Climate change impacts and adaptation assessment in Bangladesh'. Climate Research. Vol. 12. 109–116. 1999.

Asian Development Bank. 2008.

BOX: 'TOO MUCH WATER, TOO LITTLE WATER'

'Water Availability per person per year'. UNESCO. <http://www.unesco.org/bpi/wwdr/WWDR_chart1_eng.pdf>

Shrestha, S.D. 'Water Crisis in the Nepal Himalayas – A case of too much, yet too little'. Florida International University. <http://www.fiu.edu/~sukopm/seminar/Suresh.pdf>

Adhikari, R.B. 'Rainwater harvesting as the only option for livelihood enhancement for the Manung VDC'. INWEB. Aristotle University. <http://www.inweb.gr/twm4/abs/SWEETY%20KC.pdf>

Regmi, Kushal. 'Climate disaster looms but Nepal oblivious to danger'. MTN Forum. 29 April 2009. <www.mtnforum.org/rs/ol/counter_docdown.cfm?fID=3830.pdf>

Chapter 3: GROWING DEMAND

'Charting Our Water Future – Economic frameworks to inform decision-making'. Water Resources Group. 2009.

'Per Capita Water Availability in Selected Countries'. Central Water Commission. India. <http://cwc.nic.in/Water_Data_Pocket_Book_2006/C28.pdf>

Sharma, Bharat. Amarasinghe, Upali & Sikka, Alok. 'Indo-Gangetic River Basins: Summary Situation Analysis'. International Water Management Institute.

'Spatial Variation in Water Supply and Demand across River Basins of India'. International Water Management Institute. 2005. <http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/pub083/RR83.pdf>

'World Urbanization Prospects: The 2007 Revision Population Database'. United Nations. <http://esa.un.org/unup/p2k0data.asp>

Hydrology and Water Resources Information System for India. <http://www.nih.ernet.in/nih_rbis/basin%20maps/Ganges_about.htm>

Kumar, B. 'Isotopic characterisation of different sources in a river basin for its better management: a case study from India.' Geophysical Research Abstracts. Vol. 7. 10517. 2005.

UN Habitiat. 'TERI conclusions based on a comprehensive case study on Yamuna'. <http://www.unhabitat.org/content.asp?typeid=19&catid=460&id=2172>

Narula, Kapil. 'Water Resources development in the Yamuna river basin in India.' The Energy Research Institute.

Amarasinghe, U. 'Spatial Variation in Water Supply and Demand across the River Basins of India'. International Water Management Institute. 2003. <http://www.icid.org/report_upali_nov03.pdf>

Yang Mu and Teng Siow Song. 'China's Looming Water Crises'. EAI Background Brief. No. 386. 12 June 2008

'Scientifically Exploiting Hydropower Resource to Promote the Sustainable Utilization of Water Resources and the Sustainable Development of Economy and Society'. Yangtze Forum. 13 August 2006. <http://www.cjw.gov.cn/ad/yangtzeforum/detail/20060813/67237.asp>

Yardley, Jim. 'Beneath booming cities, China's future is drying up'. International Rivers. 28 September 2007.

Yongjian, D. Shiyin, L. Changwei, X. Yong, Z. Jian, W. 'Yellow River at Risk - An Assessment of the Impacts of Climate Change on the Yellow River Source Region'. Green Peace. <http://www.greenpeace.org.br/clima/pdf/impactos_yellow.pdf>

The United Nations World Water Development Report 3. 'Facing the Challenges'. UNESCO. 2009.

Brown, Lester. 'Plan B 2.0 Rescuing a Planet Under Stress and a Civilization in Trouble'. Chapter 3 Emerging Water Shortages. Earth Policy Institute

Falkenmark, Malin and Guterstam, Björn. 'Yellow River Shows Signs of Life'. Stockholm International Water Institute. June 2003

Ministry of Population and Environment. 'Initial National Communication to the Conference of the Parties to the United Nations Framework Convention on Climate Change'. July 2004. <http://unfccc.int/resource/docs/natc/nepnc1.pdf>

'Nepal'. Nepal National Committee of ICID. <http://www.icid.org/v_nepal.pdf>

Siddiqi, Toufiq A & Tahir-Kheli, Shirin. 'Project on Water and Security in South Asia (WASSA)'. Carnegie Corporation of New York. <http://www.gee-21.org/publications/pdf%20files/FinalExecutiveSummaryJanuary2004.pdf>

'Nepal: Initial National Communication to the Conference of the Parties of the United Nations Framework Convention on Climate Change'. Ministry of Population and Environment, Nepal. <http://unfccc.int/resource/docs/natc/nepnc1.pdf>

Regmi, Ashok Raj. 'Water Security and Farmer-Managed Irrigation Systems of Nepal' 2007. <http://dlcvm.dlib.indiana.edu/archive/00002198/01/W07-5_Regmi_DLC.pdf>

'Irrigation & Drainage in the World – A Global Review'. International Commission on Irrigation and Drainage (ICID). <www.icid.org/i_d_bangladesh.pdf>

'Global Warming Accelerates China's Sea Level Rise'. China.org. 2 April 2002. <http://russian.china.org.cn/english/30646.htm>

Chapter 4: SHIFTING SECTORS

'Research of China Water Resources Supply and Demands'. Chinese Academy of Sciences, Institute of Geographic Sciences and Natural Resources Research.

Amarasinghe, U. Giordano, M. Liao, Y. & Shu, Z. 'Water Supply, Water Demand and Agricultural Water Scarcity in China: A Basin Approach'. International Water Management Institute. December 2005.

'China Facts and Figures 2004'. <http://www.china.org.cn/english/en-shuzi2004/sh/sh.htm>

Sharma, Bharat. Amarasinghe, Upali & Sikka, Alok. 'Indo-Gangetic River Basins: Summary Situation Analysis'. International Water Management Institute. 2007.

Bhattarai, Damodar & Goutam, Sagar Raj. 'Water Resources of Nepal: Opportunities and Challenges'. Department of Water Induced Disaster Prevention, Nepal. <http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0156pdf/ks0156016.pdf>

FAO Aquastat. <http://www.fao.org/nr/water/aquastat/data/query/results.html>

United Nations Population Division. <http://esa.un.org/unpp/>

Chapter 5: POLLUTION AND INEFFICIENCY

'China: New Landscapes'. Sustainability. November 2007. <http://www.sustainability.co.uk/downloads_public/insight_countrystudies/SustainAbility_ChinaNewLandscapes_November2007.pdf>

'Pollution worsens on the Yellow River system'. China.org. 24 November 2008. <http://www.china.org.cn/environment/news/2008-11/24/content_16814683.htm>

Larmer, Brook. Bitter Waters: Can China save the Yellow—its Mother River?'. National Geographic. May 2008.

Branigan, Tania. 'One-third of China's Yellow river 'unfit for drinking or agriculture''. Guardian. 25 November 2008.

'China's Yangtze river extensively polluted: study'. Reuters. 15 April 2007. <http://www.reuters.com/article/environmentNews/idUST30958220070415>

'Develop an Integrated River Basin Management Strategy in the Yangtze River Basin'. Series on Biodiversity. Kushiro International Wetland Centre. 2004.

Kumar, V. 'Water Pollution of Yamuna'. <http://www.brajdhamsewa.org/index.php/shri-yamuna-ji/4371-water-pollution-in-yamuna-ji-an-artical-by-vipan-kumar>

Priyadarshi, Dr. Nitish. 'Ganges river pollution in India-A brief report'. American Chronicle. 08 July 2009. <http://www.americanchronicle.com/articles/view/109078>

B.K. Pradhan. R.K. Siddhi. M. Shrestha & R.L. Shilpakar. 'River water quality policies, and pressures and impacts in the Hindu Kush-Himalayan Region'. Volume II: Country Reports. Alternate Hydro Energy Centre.

Bhaumik, S. 'Dead fish surface on Indian river'. BBC News. 19 December 2007. <http://news.bbc.co.uk/2/hi/south_asia/7151240.stm>

'Water pollution and scarcity'. Bangladesh State of Environment Report. UNEP. 2001. <http://www.rrcap.unep.org/reports/soe/bangladesh_water.pdf>

Tarafdar, M. R. 'Polluted rivers, risky water'. The Daily Star. 05 June 2009. <http://www.thedailystar.net/story.php?nid=91247>

Rahaman, M.M. 'Bangladesh – from a country of flood to a country of water scarcity – sustainable perspectives for solution'. Helsinki University of Technology. 2005. <http://users.tkk.fi/~mizanur/Rahaman_Hamburg.pdf>

Alam, J. B. Hossain A. Khan, S. K. Banik, B. K. Islam, Molla R. Muyen, Z. & Rahman, M. Habibur. 'Deterioration of water quality of Surma river'. Environ Monit Assessment. Springer Science. 2007.

Kattel, Dambaru. 'Water Borne Disease a Major Health Problem in Nepal'. Ohmynews. 12 June 2007. <http://english.ohmynews.com/articleview/article_view.asp?at_code=415879&no=364595&rel_no=4>

Fry, E. Mayer, C. & Denning, D. 'Invest in Water: A special situations report on our most precious resource'. Agora Financial Publications.

McAlister, John. 'China's water crisis'. Deutsche Bank China Expert Series. 22 March 2005. <http://www.cbiz.cn/download/aquabio.pdf>

'Free Flow'. India Environment Portal. June 2003. <http://www.indiaenvironmentportal.org.in/node/6191>

Saini, Kushal. ''Water on earth is limited unless we bring it from moon''. One World South Asia. 10 October 2009. <http://southasia.oneworld.net/weekend/water-on-earth-is-limited-unless-we-bring-it-from-moon>

'Issues and Challenges for Water Resources in North China –

Case of the Yellow River Basin'. JBIC Institute. March 2004.

'Improving the Performance of China's Urban Water Utilities'. World Bank. June 2008. <http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2008/07/16/000334955_20080716065002/Rendered/PDF/447330BRI0Box31UBLIC10PNOTE111China.pdf>

Mu, Yang & Siow Song, Teng. 'China's Looming Water Crises'. EAI Background Brief. National University of Singapore. <http://www.eai.nus.edu.sg/BB386.pdf>

McAlister, John. 'China's water crisis'. Deutsche Bank China Expert Series. 22 March 2005. <http://www.cbiz.cn/download/aquabio.pdf>

Foster, V. Ragupathi, U. Brocklehurst, C. & Hommann, K. 'Cost Recovery and Subsidies for Water Supply: A Scorecard for India'. World Bank.

'Cheapest pickings'. Down To Earth Supplement, Centre for Science and Environment. 15 February 2004. <http://www.cseindia.org/dte-supplement/industry20040215/cheapest-picking.htm>

Kumar, Ritu. 'Climate Change and India: Impacts, Policy Responses and a Framework for EU-India Cooperation'. Policy Department Economic and Scientific Policy. European Parliament. January 2008. <http://www.europarl.europa.eu/activities/committees/studies/download.do?file=19208>

'Status of Rainwater Harvesting in Nepal'. Ministry of Physical Planning and Works. May 2009. <http://www.moppw.gov.np/pdf/Status_of_RWH_in_Nepal.pdf>

Sampath, A. Kedarnath, B. Ramanujam, C. Haidery, H. Rao, R. Arunachalam, R. Govindaraju, S. Thirumalavan, V. & Jeet, V. 'Water Privatization and Implications in India'. University of Texas. <http://studentorgs.utexas.edu/aidaustin/water/water_privatization.pdf>

'China, UN providing rainwater harvesting education for African nations'. People's Daily Online. 15 May 2009. <http://english.people.com.cn/90001/90776/90883/6659024.html>

'China holds rainwater harvesting courses for African, Central Asian countries'. 22 July 2009. <http://en.ce.cn/National/Politics/200907/24/t20090724_19618342.shtml>

'Rainwater Harvesting And Utilisation-An Environmentally Sound Approach for Sustainable Urban Water Management'. United Nations Environment Programme. <http://www.unep.or.jp/i/publications/urban/urbanenv-2/9.asp>

Fu, Guobin. Liu, Changming. & Chen, Shulin. 'Water Crisis in the Yellow River: Facts, Reasons, Impacts, and Countermeasures'. Water Practice & Technology. Vol. 1, No. 2. 2006. <http://www.riversymposium.com/2004/index.php?element=Fu+Guobin>

Brown, Lester. 'Plan B 2.0: Rescuing a Planet Under Stress and a Civilization in Trouble'. Earth Policy Institute. <http://www.earth-policy.org/index.php?/books/pb2/pb2ch9_ss3>

McKenzie, D. & Ray, I. 'Urban Water Supply in India: Status, Reform Options and Possible Lessons'. University of California, Berkeley. 2009. <http://erg.berkeley.edu/publications/Isha%20Ray/McKenzieRay-India-urbanwater-forWP.pdf>

'Nepal: State of the Environment 2001.' United Nations Environment Programme. <http://www.rrcap.unep.org/pub/soe/nepal_water.pdf>

Datoo, J. & Kauffmann, C. 'Stocktaking of the water and sanitation sector and private sector involvement in selected Asian countries Background'. Asian Development Bank. 5 March 2008. <http://www.adb.org/Documents/events/2008/ADB-OECD/Stocktaking.pdf>

BOX: ARSENIC CONTAMINATION

'An overview of Arsenic Issues and Mitigation Initiatives in Bangladesh'. NGOs Arsenic Information & Support Unit (NAISU). WaterAid. 2003. <http://www.wateraid.org/documents/arsenic2002.pdf>

'Arsenic contamination in Bangladesh' WaterAid. <http://www.wateraid.org/international/what_we_do/where_we_work/bangladesh/2546.asp>

Maharjan, M. Ahmad, A. Watanabe, C. Shrestha, R.R. and Ohtsuka, R. 'Arsenic contaminated ground water and rainwater harvesting as an alternative water resources to take a safe drinking water in Nepal'. International Water Association.

'Nepal: Supreme Court orders government to tackle arsenic contamination in water'. IRC International Water and Sanitation Centre (IRC). 12 November 2008. <http://www.irc.nl/page/45242>

BOX: RIVER POLLUTION IN DHAKA

'Bangladesh river pollution threatens millions'. China Daily. 19 May 2009. <http://www.chinadaily.com.cn/world/2009-05/19/content_7792698.htm>

Roy, Pinaki. 'Pollution gets to groundwater'. TheDailyStar. 26 April 2009. <http://www.thedailystar.net/newDesign/news-details.php?nid=85624>

Chapter 6: DESERTIFICATION

Genxu, W. Yongjian, D. & Shiyin, L. 'The Land Ecological Evolutional Patterns in the Source Areas of the Yangtze and Yellow Rivers in Recent 15 Years, China'. ISEIS. Environmental Informatics Archives. Volume 2 (2004). Pg. 551-563.

Yongjian, D. Shiyin, L. Changwei, X. Yong, Z. & Jian, W. 'Yellow River at Risk- An Assessment of the Impacts of Climate Change on the Yellow River Source Region'. Green Peace. 2005.

'Down to Earth'. Newsletter 19. United Nations Convention to Combat Desertification. December 2003. <http://www.unccd.int/publicinfo/newsletter/no19/news19eng.pdf>

O'Brien, Chris. 'The mysterious disappearance of China's largest freshwater lake'. Beijing Newspeak. 18 December 2007.

Li, Y. T. and Deng, J. Y. 'Ecological Environment Change & Flood and Sedimentation Disaster in Yangtze River Basin'. Environmental Informatics Archives. Volume 2. Pages 471-478. 2004.

Poudel, Krishna. 'Watershed Management in Nepal: Challenges and Constraints'. Asian Regional Workshop on Watershed Management. <http://www.fao.org/forestry/media/11740/1/0/>

'National Action Programme on Land Degradation and Desertification in the context of United Nations Convention to Combat Desertification (UNCCD)'. Ministry of Population and Environment, Nepal. April 2004. <http://www.unccd.int/actionprogrammes/asia/national/2004/nepal-eng.pdf>

Rainwater Harvesting. 'Water requirement and sources of water in Delhi'. Centre for Science and Environment. <http://www.rainwaterharvesting.org/index_files/about_delhi.htm>

National Report on Implementation of United Nations Convention to Combat Desertification. Ministry of Environment and Forests, Bangladesh. July 2001.

'China Says It's Slowing Rate of Desertification'. Environmental News Network. 30 May 2006. <http://www.enn.com/top_stories/article/4369>

'Nepal'. Mongabay. <http://rainforests.mongabay.com/deforestation/2000/Nepal.htm>

BOX: MISFORTUNE OF MAQU AND WOES RUO'ERGAI WETLAND

'Sand Chokes Yellow River's Cistern'. The Administrative Center for China's Agenda 21. 20 July 2004. <http://english.acca21.org.cn/pic/news20040720-7.htm>

'Sand Wall Appears in the Yellow River'. China.org. 23 July 2003. <http://www.china.org.cn/english/2003/Jul/70829.htm>

'Grassland deterioration strikes Maqu prairie in NW China'. Xinhua. 25 July 2009. <http://news.xinhuanet.com/english/2009-07/25/content_11771929.htm>

'Ambitious Plan to Save Reserve'. China.org. 09 May 2007. <http://www.china.org.cn/english/environment/210194.htm>

Chapter 7: LOSS OF BIODIVERSITY

Yongjian, D. Shiyin, L. Changwei, X. Yong, Z. & Jian, W. 'Yellow River at Risk- An Assessment of the Impacts of Climate Change on the Yellow River Source Region'. Green Peace. 2005.

'Facing the Challenges'. United Nations Water Development Report 3. UNESCO. 2009. <http://www.unesco.org/water/wwap/wwdr/wwdr3/case_studies/pdf/WWDR3_Case_Study_Volume.pdf>

'Seven from Mountain to Sea'. World Wildlife Fund. 2004. <http://assets.panda.org/downloads/ap_river_bigwins.pdf>

'Endemic Dolphin 'Extinction' Mirrors Yangtze Health Decline' China.org.cn. 22 January 2007. <http://china.org.cn/english/environment/196843.htm>

'Managing Rivers Wisely: Ganges case study' Living Wisely. World Wildlife Fund. <http://assets.panda.org/downloads/mrwGangescasestudy.pdf>

Kumar, Meenakshi. 'Look closely, you may never see these again'. Times of India. 4 October 2009.

Goswami, D. C. and Das, Partha .J. 'The Brahmaputra River, India'. Kalpavriksh. 2003. <http://www.kalpavriksh.org>

Hosterman, H. R. McCornick, P.G. Kistin, E.J. Pant, A, Sharma, B. and Bharati, L. 'Water, Climate Change, and Adaptation'. Nicholas Institute for Environmental Policy Solutions. Duke University. 2009.

Chowdhury, N.T. 'Water management in Bangladesh: an analytical review'. Water Policy. 2009.

'National Action Programme on Land Degradation and Desertification in the context of United Nations Convention to Combat Desertification (UNCCD)'. Ministry of Population and Environment, Nepal. April 2004. <http://www.unccd.

int/actionprogrammes/asia/national/2004/nepal-eng.pdf>

Ruqiu, Ye. 'Studies on climate change problems and response measures in China'. Risoe Centre on Energy, Climate and Sustainable Development. UNEP. <http://uneprisoe.org/copenhagenconf/yeruqiu.htm>

'Bangladesh Has Rich But Dwinding Biodiversity'. USAID. Bangladesh. <http://www.usaid.gov/bd/programs/environ.html>

Ahmed, Ahsan Uddin. 'Climate Change Impacts and Vulnerability'. Climate Change Cell, Department of Environment. 2006.

'Regional Impacts of Climate Change'. Special Reports on Climate Change. Intergovernmental Panel on Climate Change (IPCC). <http://www.grida.no/publications/other/ipcc_sr/?src=/Climate/ipcc/regional/299.htm>

BOX: SUNDERBANS: BEREFT OF BEAUTY

Rahman, Md. Saidur. 'Ecology and management of Sundarban: A Rich Biodiversity of the World's Largest Mangrove Ecosystem'

Raaj, Neelam. 'Warming a threat to natural wonders: WWF'. The Times of India. 6 April 2007. <http://timesofindia.indiatimes.com/India/Warming-a-threat-to-natural-wonders-WWF/articleshow/1862816.cms>

Chapter 8: FOOD SECURITY

'Nepal Labor Force Survey Report 1998/99'. Central Bureau of Statistics, Nepal. <http://www.cbs.gov.np/nlfs_%20report_employment.php>

Haq, Zia & Choudhury, Gaurav. 'Trouble on the farm, output set to fall'. Hindustan Times. October 24, 2009.

National Sustainable Development Strategy Report, Department of Environment, MOEF, Bangladesh, 2008.

Press Trust of India. 'Poor Monsoon to hit growth, says Montek'. Hindustan Times. 18 August 2009. <http://www.hindustantimes.com/StoryPage/StoryPage.aspx?sectionName=BusinessSectionPage&id=c5a47169-6f6f-4f8d-91d0-1af892e18976&Headline=Poor-monsoon-to-hit-growth-says-Montek>

Zhai, F; Lin, Lin, T; & Byambadorj, E. 'A General Equilibrium Analysis of the Impact of Climate Change on Agriculture in the People's Republic of China'. Asian Development Review. Vol. 26, no. 1, pp. 206-225.

Sharma, Bharat. Amarasinghe, Upali & Sikka, Alok. 'Indo-Gangetic River Basins: Summary Situation Analysis'. International Water Management Institute. 2007.

Bhattarai, Damodar & Goutam, Sagar Raj. 'Water Resources of Nepal: Opportunities and Challenges'. Department of Water Induced Disaster Prevention, Nepal. <http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0156pdf/ks0156016.pdf>

FAO Aquastat. <http://www.fao.org/nr/water/aquastat/data/query/results.html>

'China Economy 2009'. <http://www.theodora.com/wfbcurrent/china/china_economy.html>

Haub, Carl & Sharma, O.P. 'Population Bulletin'. Population Reference Bureau. Vol.61, No.3, September 2006

Thapaliya, Bhuwan. 'Rising Food Insecurity in Nepal'. Global Politican. <http://www.globalpolitician.com/25802-nepal>

Johnston, Paul & Gopal, Vinuta. 'Monsoon Wager: Climate Change and the Indian Monsoon'. Greenpeace India. 2009.

Regmi, Hem Raj. 'Rising Food Price and its Consequence'. The Journal of Agriculture and Environment Vol: 9. June 2008. <http://www.moac.gov.np/publications/journal/12hem_raj.pdf>

Bradsher, Keith. 'A Drought in Australia, a Global Shortage of Rice'. New York Times. April 17, 2008. <http://www.nytimes.com/2008/04/17/business/worldbusiness/17warm.html>

Hijmans, Robert. 'Relocating rice production in China'. IRRI. December 31, 2007. <http://beta.irri.org/news/index.php/200712305433/rice-today/maps/relocating-rice-production-in-china.html>

Erda, L; Yinlong, X; Shaohong, W; Hui, J; & Shiming, M. 'China's National Assessment Report on Climate Change (II): Climate change impacts and adaptation'. Advances in Climate Change Research. 2007. <http://www.climatechange.cn/qikan/manage/wenzhang/02.pdf>

Press Trust of India. 'NE faces worst-ever rainfall deficit in 30 years'. The Times of India. 21 July 2009. <http://timesofindia.indiatimes.com/NEWS/Environment/Global-Warming/NE-faces-worst-ever-rainfall-deficit-in-30-years-/articleshow/4803914.cms>

'Monsoon serves up bitter brew – no luck with rain & shine for Assam tea plantations this season too'. The Telegraph. 23 July 2007. <http://www.telegraphindia.com/1070723/asp/guwahati/story_8093681.asp>

Malla, G. 'Climate Change And Its Impact On Nepalese Agriculture'. The Journal of Agriculture and Environment

Vol: 9. Jun.2008. <http://www.moac.gov.np/publications/journal/9malla_g.pdf>

Milmo, Cahal. 'Too Late To Avoid Global Warming'. The Independent. September 19, 2007.

Jin, J; Wu, R; & Liu, R. 'Rice Production and Fertilization in China'. Better Crops International. Vol. 16. May 2002. <http://www.ppi-ppic.org/ppiweb/bcropint.nsf/$webindex/BD1D60B1CA86D2D185256BDC007762DC/$file/BCI-RICEp26.pdf>

Karim, Z. Hussain, S. G. and Ahmed, M. 'Assessing impacts of climatic variations on foodgrain production in Bangladesh'. Journal of Water, Air, and Soil Pollution. Pg. 53-62. 1996.

'Appendix A: Preliminary assessment of ASPS-II Components vulnerability to Climate Change'. Draft Inception Report of Agricultural Sector Programme Support, Phase II. Bangladesh. 2008.

Sharma, Bharat & Sharma, Devesh. 'Impact of Climate change on water resources and glacier melt and potential adaptations for Indian agriculture'. International Water Management Institute.

Kulkarni, Prasad. 'Fewer rainy days in future: Study'. The Times of India. 21 May 2009.<http://timesofindia.indiatimes.com/Health--Science/Earth/Global-Warming/Fewer-rainy-days-in-future-Study/articleshow/4558013.cms>

Wamer, Koko. 'In Search of Shelter-Mapping the Effects of Climate Change on Human Migration and Displacement'. United Nations. May 2009.

Jain, SK. Sharma, BR. Zahid, A. Jin, M. Shreshtha, JL. Kumar, V. Rai, SP. Hu, J. Luo, Y. & Sharma, D. 'A comparative analysis of the hydrogeology of the Indus-Gangetic and Yellow River basins'. A comparative analysis of the hydrogeology of the Indus-Gangetic and Yellow River basins. CRC Press. June 8, 2009.

'Droughts put China on red alert'. Xinhua net. Feb 2, 2009.

'Ganges River' 2009. Encyclopedia Britannica. <http://www.britannica.com/EBchecked/topic/225359/Ganges-River>

Faisal, I.M. and Praveen, S. 'Food Security in the Face of Climate Change, Population Growth, and Resource Constraints: Implications for Bangladesh'. Environmental Management. Vol. 34, No. 4, pp. 487-498, 2004.

Gathara, S.T. Gringof, L.G. Mersha, E. Sinha Ray, K.C. Spasov, P. 'Impacts of Desertification and Droughts and other extreme meteorological events'. World Meteorological Organisation, Geneva Switzerland. December 2006.

'Brahmaputra threatens prized tea heartland'. Rediff News. 31 October 2000. <http://www.rediff.com/news/2000/oct/31ass.htm>

Joshi, VK. 'Fury of Brahmaputra'. Boloji. 2 March 2008. <http://www.boloji.com/environment/165.htm>

Soil Erosion in India'. Indianetzone. 15 May 2009. <http://www.indianetzone.com/41/soil_erosion_india.htm>

Qureshi, A. and Hobbie. D. 'Potential Impacts of Climate Change in Bangladesh'. Asian Development Bank (ADB) (ed.). Climate Change in Asia. Chapter 2, pp. 10-42. 1994.

Hassan, Ahmadul. 'The Historical Climate Risks in Bangladesh'. CEGIS. 2008

Huq, SMI. Rahman, A. Sultana, N. & Naidu, R. 'Extent and Severity of Arsenic Contamination in Soils of Bangladesh'. Virtual Library of Sustainable Development and Environmental Health. Panamerican Health Organization. <http://www.cepis.ops-oms.org/bvsacd/arsenico/arsenic/huq.pdf>

Khaliquzzaman, M & Khan, AH. 'Arsenic Exposure of Bangladesh Population through Food Chain'. SEARO, WHO. October 2003.

Rainwater Harvesting. 'Water requirement and sources of water in Delhi'. Centre for Science and Environment. <http://www.rainwaterharvesting.org/index_files/about_delhi.htm>

Zhang, X. Mount, T. & Boisvert, R. 'Industrialization, urbanization and land use in China'. International Food Policy Research Institute. March 2000.

Xie, G; Yu, J. Yan, J. Wang, H. & Zhu, X. 'Direct seeding of aerobic rice in China'. IRRI. 2004. <http://www.irri.org/publications/wrrc/wrrcPDF/session6-04.pdf>

Pandey, Geeta. 'India's 'drought-resistant rice'. BBC News. 5 August 2009. <http://news.bbc.co.uk/2/hi/south_asia/8182840.stm>

'Under the Weather and the Rising Tide – Adopting to a changing climate in Asia and the Pacific'. Asian Development Bank. 2009. <http://www.adb.org/Documents/Books/Under-Weather-Rising-Tide/Under-Weather-Rising-Tide.pdf>

'China faces rising temperatures'. China Daily. May 18, 2006. <http://www.chinadaily.com.cn/china/2006-05/18/content_594730.htm>

'NEPAL: Government must focus on food'. IRIN. <http://www.irinnews.org/Report.aspx?Reportid=85565>

'Rice Production in China'. Volume 12, Number 25: 24 June 2009. <http://www.co2science.org/articles/V12/N25/EDIT.php>

Long, Guoqiang. 'Will China Liberalize Its Grain Trade?'. Brookings Institute. 1999.

Mall, R.K. Gupta, A. Singh, R. Sindh, R.S & Rathore, L.S. 'Water Resources and climate change: An Indian perspective'. Current Science, vol.90. No.12, 25 June 2006.

FAO Aquastat. <http://faostat.fao.org/site/339/default.aspx>

Chapter 9: HEALTH SECURITY

'Waterborne Diseases'. Lenntech. <http://www.lenntech.com/library/diseases/diseases/waterborne-diseases.htm>

'Food, water-borne diseases cause 3,000 deaths in Nepal'. People Daily. 8 August 2005. <http://english.peopledaily.com.cn/200508/08/eng20050808_200835.html>

'Bangladesh cholera linked to rivers'. Science News. 9 November 2009. <http://www.upi.com/Science_News/2009/11/09/Bangladesh-cholera-linked-to-rivers/UPI-89691257792419/>

'Country Health Information Profiles – China'. Regional Office for the Western Pacific, World Health Organization. <http://www.wpro.who.int/NR/rdonlyres/8B629793-2B62-4CB1-94A7-F036E7A48DCE/0/9finalCHNpro09.pdf>

'India – National Health System Profile'. Regional Office for South-East Asia, World Health Organization. <http://www.searo.who.int/LinkFiles/India_CHP_india.pdf>

'Health Alerts'. Passport Health. 16 January 2009. <http://www.passporthealthusa.com/localvaccines/travel-health-alerts.php#14331>

'Nepal – National Health System Profile'. Regional Office for South-East Asia, World Health Organization. <http://www.searo.who.int/LinkFiles/Nepal_Profile-Nepal.pdf>

'Climate change and vector-borne diseases: A regional analysis'. SciDev Net. 9 September 2009. <http://www.scidev.net/en/key-documents/climate-change-and-vector-borne-diseases-a-regiona.html>

'Impact of Climate Change on Vector Borne Diseases with Emphasis on Malaria'. National Institute of Malaria Research.<http://www.mrcindia.org/MRC_profile/profile2/Impact%20of%20climate%20change%20on%20vector%20borne%20diseases%20with%20emphasis%20on%20malaria%20.pdf>

'India to see increase in water-borne diseases: WHO'. Indiainfo. 7 April 2008. <http://news.indiainfo.com/2008/04/07/0804071552_health-climate.html>

'Bangladesh – National Health System Profile'. Regional Office for South-East Asia, World Health Organization. <http://www.searo.who.int/LinkFiles/Bangladesh_CountryHealthSystemProfile-Bangladesh-Jan2005.pdf>

Sah, O.P. Subedi, S. Morita, K. Inone, S. Kurane, I. & Pandey, B.D. 'Serological study of dengue virus infection in Terai region, Nepal'. Nepal Medical College Journal. 2009. <http://www.nmcth.edu/nmcj_articles_pdf/volume_wise/nmcj_vol11_no2_June_2009/op_sah.pdf>

'Trend of Dengue case and CFR in SEAR Countries - Nepal'. South East Asia Regional Office, World Health Organization. <http://www.searo.who.int/en/Section10/Section332/Section2277_13402.htm>

'Threat of Pollution in the Yangtze'. World Wildlife Fund. <http://www.panda.org/about_our_earth/about_freshwater/freshwater_problems/river_decline/10_rivers_risk/yangtze/yangtze_threats/>

Larmer, Brook. 'Bitter Waters: Can China save the Yellow-its Mother River?'. National Geographic Magazine. May 2008. <http://ngm.nationalgeographic.com/2008/05/china/yellow-river/larmer-text>

'Bangladesh'. Water.org. <http://water.org/projects/bangladesh/>

Rahman, Atiq. 'Climate change and its impact on health in Bangladesh'. Regional Health Forum, South East Asia Regional Office, World Health Organization. Vol. 12, No. 1. 2008. <http://www.searo.who.int/LinkFiles/Regional_Health_Forum_Volume_12_No_1_Climate_change_and_its_impact.pdf>

'Cyclone Aila in Bangladesh and India'. Oxfam International. <http://www.oxfam.org/en/emergencies/cyclone-aila>

'Diarrhea Spreads In Parts Of Bangladesh In Cyclone Aila's Aftermath'. Medical News Today. 2 June 2009. <http://www.medicalnewstoday.com/articles/152302.php>

Caravotta, J. 'Battling water-borne diseases in cyclone-affected West Bengal'. UNICEF. 07 August 2009. <http://www.unicef.org/infobycountry/india_50730.html>

Jones, Dick. 'Water Scarcity Will Create Global Security Concerns: We Have Very Little Time,' Says Nobel Winner'. Science Daily. 6 October 2009. <http://www.sciencedaily.com/releases/2009/10/091006155858.htm>

'India'. Water.org. <http://water.org/projects/india/>

Chapter 10: DAMS AND DIVERSIONS

'Rivers at Risk: Dams and the future of freshwater ecosystems'. World Wildlife Fund. <http://assets.panda.org/downloads/riversatriskfullreport.pdf>

'Watersheds of Asia and Oceania'. Water Resources eAtlas, World Resources Institute. 2003. <http://pdf.wri.org/watersheds_2003/as10.pdf >

'The Ganges'. <http://haridwar.nic.in/Gangesji.htm>

'Tehri Dam'. IRN Fact Sheet, International Rivers Network. October 2002. <http://www.internationalrivers.org/files/TehriFactsheet2002.pdf>

'Rihand Project'. 5 October 2009. <http://www.indianetzone.com/4/the_rihand_project.htm>

Biello, David. 'Damming the Yangtze: Are a Few Big Hydropower Projects Better Than a Lot of Small Ones?'. International Rivers Network. 13 October 2009. <http://www.internationalrivers.org/en/node/4730>

'Jinsha River Dams'. International Rivers Network. 16 July 2009. <http://www.internationalrivers.org/en/node/3221>

'World's Largest Dam on Brahmaputra River'. Sinlung. 16 October 2009. <http://www.sinlung.com/pickledreadings/worlds-largest-dam-on-brahmaputra-river.html>

'Bhagirathi Bachao Sankalap'. M.C. Mehta Environment Foundation. <http://www.mcmef.org/index.htm>

'Tehri Dam and Hydropower Project'. TDHC India Ltd. 30 November 2009. <http://thdc.gov.in/English/Scripts/Project_Smallhydro.aspx>

Bhaskar, U. & Ghosh, P. 'Panel to work for stronger prior use claim on Brahmaputra'. Live Mint. 8 January 2010. <http://www.livemint.com/2010/01/07213335/Panel-to-work-for-stronger-pri.html>

'Cooperation with Neighbouring Countries'. Central Electricity Authority. 31 October 2009. <http://www.cea.nic.in/hydro/nepal.pdf>

'India, Nepal clear decks for hydel power project'. The Economic Times. 23 November 2009. <http://economictimes.indiatimes.com/news/news-by-industry/energy/power/India-Nepal-clear-decks-for-hydel-power-project/articleshow/5262098.cms>

'Cooperation with Neighbouring Countries'. Central Electricity Authority. 31 October 2009. <http://www.cea.nic.in/hydro/nepal.pdf>

'Work on Upper Tamakoshi to commence from June 10'. Nepal News. 2 December 2009. <http://www.nepalnews.com/main/index.php/news-archive/3-business-a-economy/2704-work-on-upper-tamakoshi-to-commence-from-june-10.html>

'Frequently Asked Questions'. International Rivers Network. <http://www.internationalrivers.org/en/node/480>

Hance, Jeremy. 'New Yangtze River dam could doom more endangered species'. Mongabay. 22 June 2009. <http://news.mongabay.com/2009/0622-hance_dam_yangtze.html>

Bezlova, Antoaneta. 'China's Three Gorges Dam comes of age'. Asia Times. 4 November 2009. <http://www.atimes.com/atimes/China/KK04Ad01.html>

'One dam mistake after another leaves $4.4bn bill'. The Sydney Morning Herald. 22 May 2004. <http://www.smh.com.au/articles/2004/05/21/1085120121829.html>

Larmer, Brook. ' Bitter Waters: Can China save the Yellow—its Mother River?'. National Geographic. May 2008. <http://ngm.nationalgeographic.com/2008/05/china/yellow-river/larmer-text>

'Three Gorges Dam'. International Rivers Network. <http://www.internationalrivers.org/en/china/three-gorges-dam>

Susan Jakes. 'China's Water Woes'. Time Magazine. 2 October 2006.

Srinath, M.G. 'India Shelves Inter-Linking Of Rivers'. OhmyNews.com. 8 October 2009. <http://english.ohmynews.com/articleview/article_view.asp?no=385688&rel_no=1>

'PM cautious about river linking projects'. Hindustan Times. 30 October 2009. <http://www.hindustantimes.com/News-Feed/newdelhi/PM-cautious-about-river-linking-projects/Article1-470874.aspx>

Tarafdar, M.R. 'The Proposed Tipaimukh Dam'. The New Nation. 6 July 6. <http://nation.ittefaq.com/issues/2009/07/06/news0123.htm>

Alamgir, Mohiuddin. 'Tipaimukh: another Farakka in the offing?'. The New Age. 12-18 June 2009. <http://www.newagebd.com/2009/jun/12/jun12/xtra_cover.html>

Rahman, Anisur. 'India Criticises 'Politics' Over Tipaimukh Dam Issue'. Outlook India. 22 June 2009. <http://news.outlookindia.com/item.aspx?661587>

Rahman, Zulfiqur. 'India, Bangladesh and Tipaimukh Dam'. IPCS. 17 August 2009. <http://www.ipcs.org/article_details.php?articleNo=2945>

Chapter 11: MIGRATION AND SOCIAL INSTABILITY

'Climate Refugee'. Global Warming. 2009. <http://www.global-greenhouse-warming.com/climate-refugee.html>

'As Ranks of 'Environmental Refugees' swell worldwide, calls grow for better definition, recognition, support'. United Nations University. <http://www.ehs.unu.edu/index.php/article:130?menu=44>

United Nations Population Division. <http://esa.un.org/unup>

Report on National Adaptation Programme of Action. Ministry of Environment and Forest, Bangladesh. 2005

Shaohua, Zhan. 'Rural labour migration in China: Challenges for policies'. UNESCO Policy Paper. 2005.

Siciliano, Michael. 'First Development, Then Environment-Environmental and Water Scarcity Issues in China'. The Heinz Journal. Vol. 3, Issue 1. 15 March 2006. <http://journal.heinz.cmu.edu/articles/first-development-then-environment/#fn29>

Massey D. Axinn, W. & Ghimire, Dirgha. 'Environmental Change and Out-Migration: Evidence from Nepal'. Population Studies Centre, University of Michigan. January 2007. <http://www.psc.isr.umich.edu/pubs/pdf/rr07-615.pdf>

Poudel, Krishna. 'Watershed Management in Nepal: Challenges and Constraints'. Asian Regional Workshop on Watershed Management. <http://www.fao.org/forestry/media/11740/1/0/>

Kashyap, S.G. 'Assam losing 8000 hectare to Brahmaputra every year'. The Indian Express. 1 June 2007. <http://www.indianexpress.com/news/assam-losing-8-000-hectare-to-brahmaputra-every-year/32377/2>

Rahman, Wasim. 'After floods, fear of erosion looms large over Majuli'. The Times of India. 16 July 2009. <http://timesofindia.indiatimes.com/news/city/guwahati/After-floods-fear-of-erosion-looms-large-over-Majuli/articleshow/4786224.cms>

'The Majuli Island'. Majili.org. 2009. <http://www.majuli.org/>
Bhaumik, Subir. 'Erosion fears for Ganges villagers'. BBC News. 1 September 2005. <http://news.bbc.co.uk/2/hi/south_asia/4197538.stm>

'Erosion caused by River Ganges renders hundreds homeless in Jharkhand'. AndhraNews.net. 19 September 2009. <http://www.andhranews.net/India/2009/September/19-Erosion-caused-River-29507.asp>

'Climate Change and Security'. BIPSS. Issue Brief. Issue no.7. September 2009. <http://www.bipss.org.bd>

Zaman, M. 'Climate Change, Cross border Migration and Regional Conflicts: Risks and Strategies for Bangladesh'. Presentation made at Environmental Studies Association of Canada (ESAC). 2009.

Black, R.K. Skeldon, D. Coppard, R. Murata, D. & Schmidt-Verkerk, K. 'Demographics and Climate Change: Future Trends and their Policy Implications for Migration'. Development Research Centre on Migration, Globalisation and Poverty. Working Paper T27. June 2008.

'Climate Change and Security'. BIPSS. Issue Brief. Issue no.7. September 2009. <http://www.bipss.org.bd>

Joshi, V.K. 'Fury of Brahmaputra'. Boloji. 2 March 2008. <http://www.boloji.com/environment/165.htm>

Johnston, P. & Gopal, V. 'Monsoon Wager: Climate Change and the Indian Monsoon'. Greenpeace India. 2009.

Press Trust of India, 'Erratic monsoon to impact economy'. NDTV. 21 July 2009. <http://www.ndtv.com/news/india/erratic_monsoon_to_have_big_impact_on_economy.php>

Ducanes, G. & Abella, M. 'Prospects for Future Outward Migration Flows: China and Southeast Asia'. ILO/EU Asian Programme on the Governance of Labour Migration. December 2008.

'Global Warming Accelerates China's Sea Level Rise'. China.org. 2 April 2002. <http://russian.china.org.cn/english/30646.htm>

Chauhan, Chetan. 'Ganges, Brahmaputra basins sinking fast'. Hindustan Times. 22 September 2009.

Reuters. 'Rising sea salinates Ganges'. The Times of India. 2 February 2009. <http://timesofindia.indiatimes.com/Health--Science/Earth/Developmental-Issues/Rising-sea-salinates-Ganges/articleshow/4065204.cms>

Karim, Nehal. 'Cyclonic Storms in the Coastal Areas of Bangladesh: Socio-Economic Impact'. International Symposium on Disaster Reduction on Coasts. Monash University, Melbourne, Australia. November 2005. <http://civil.eng.monash.edu.au/drc/symposium-papers/drckn3-karim.pdf>

Agrawala S, et al. 'Development and Climate Change in Bangladesh: Focus on Coastal Flooding and the Sundarbans'. Organisation for Economic Co-operation and Development (OECD). 2003.

'Economic Modeling of Climate Change Adaptation Needs for Physical Infrastructures in Bangladesh'. Climate Change Cell. Center for Environmental and Geographic Information Services (CEGIS). Ministry of Environment and Forests, Bangladesh. November 2008.

Kim, Jih-Un. 'China's Water Scarcity and 'Hexie Shehui' (Harmonious Society)'. All Academic Research.

Cannon, Kathleen. 'Water as a Source of Conflict and Instability in China'. Institute for Defence Studies and Analyses. 2006. <http://www.idsa.in/publications/strategic-analysis/2006/apr-jun06/KathleenCannon.pdf>

Economy, Elizabeth. 'China's Environmental Challenge: Political, Social and Economic Implications'. Council on Foreign Relations. 27 January 2003.

'Climate Change and Security in Bangladesh'. Bangladesh Institute of International and Strategic Studies and Saferworld. 2009.

'World in Transition: Climate change as a Security Risk'. German Advisory Council on Global Change. 2007. <www.wbgu.de/wbgu_jg2007_kurz_engl.pdf>

Gulia, Urvashi. 'Water riots: 35 areas identified'. The Times of India. 26 March 2004. <http://timesofindia.indiatimes.com/NEWS/City/Delhi/Water-riots-35-areas-identified/articleshow/584664.cms>

Sainath, P. 'The largest wave of suicides in history'. Counterpunch. 12 February 2009. <http://www.counterpunch.org/sainath02122009.html>

Meeta and Rajivlochan 'Farmers Suicide: Facts & Possible Policy Interventions'. Yashwantrao Chavan Academy of Development Administration. 2006.

BOX: SALINITY IN BANGLADESH

'Climate Change and Security'. BIPSS. Issue Brief, Issue no.7, September 2009. <http://www.bipss.org.bd>

Chapter 12: GEO-POLITICAL RISKS

'Hydropower Potential in Nepal'. Arun Valley Hydropower Development Co. Ltd. 2007. http://www.arunhydro.com.np/index.php?link=aboutus>

'China increases aid to Nepal by 50%'. Express India. 19 April 2009. <http://www.expressindia.com/latest-news/China-increases-aid-to-Nepal-by-50/448796/>

Majagaiya, Kundan Pokhrel. 'FDI in Nepal's Hydropower Sector: A Focus on the Product'. Nepal Monitor. <http://www.nepalmonitor.com/2009/01/fdi_in_nepals_hydropower.html>

'World in Transition: Climate change as a Security Risk'. German Advisory Council on Global Change. 2007

Press Trust of India. 'Climate-induced crises could topple governments: Pentagon'. Financial Express. 10 August 2009. <http://www.financialexpress.com/news/climateinduced-crises-could-topple-governments-pentagon/499970/>

Friedman, Lisa. 'A global 'national security' issue lurks at Bangladesh's border'. E&E Publishing LLC. <http://www.eenews.net/special_reports/bangladesh/part_four>

'Climate Change and Security'. BIPSS. Issue Brief. Issue no.7, September 2009. <http://www.bipss.org.bd>

Section 2

Chapter 13: DATA SHARING AND SCIENTIFIC EXCHANGE

'Getting Transboundary Water Right: Theory and Practice for Effective Cooperation'. Stockholm International Water Institute. August 2009. <http://www.siwi.org/documents/Resources/Reports/Report25_Transboundary_Waters_with_WWW.pdf>

South Asian Association for Regional Cooperation. <http://www.saarc-sec.org/main.php>

'Expert Consultation on Climate Change and Water: Stimson Center & the Energy and Resources Institute (TERI)'. The Henry L. Stimson Center. September 2008. <http://www.stimson.org/rv/pdf/Climate_Change_Meeting_Report_final_for_web.pdf >

Izzadeen, Ameen. 'SAARC: Just a bark'. The Sunday Times Online. Vol. 41. No 44. April 2007. <http://sundaytimes.lk/070401/Columns/issue.html>

'Getting Transboundary Water Right: Theory and Practice for Effective Cooperation'. Stockholm International Water Institute. August 2009. <http://www.siwi.org/documents/Resources/Reports/Report25_Transboundary_Waters_with_WWW.pdf>

'Stockholm Water Front: A Forum for Global Water Issues'. Stockholm International Water Institute. May 2009. <http://www.siwi.org/documents/Resources/Water_Front/Water_Front_1_lowres.pdf>

Layton, Kimberley. 'Tibetan Waters: Coming Conflict?'. Institute of Peace Conflict Studies. July, 2009. <http://ipcs.

org/article/india/tibetan-waters-coming-conflict-2923.html>

'International Cooperation'. <http://india.gov.in/sectors/water_resources/international_corp.php>

Rahman, Mirza Zulfiqur. 'Quiet Flows the Brahmaputra?'. Institute of Peace and Conflict Studies. 2 October 2008. <http://ipcs.org/article/south-asia/quiet-flows-the-brahmaputra-2695.html>

Abrol, Dinesh. & Rupal, Purnima. 'China and India set the pace in South–South cooperation'. SciDev Net. May 2008. <http://www.scidev.net/en/middle-east-and-north-africa/opinions/china-and-india-set-the-pace-in-south-south-cooper.html>

'China and India: Research cooperation'. Advancing Science, Serving Society. <http://shr.aaas.org/article15/Exemplars/internationalcooperation.html>

'Impact of Global Warming on Glaciers'. Press Information Bureau. November 2009. <http://pib.nic.in/release/release.asp?relid=54766>

'China Offers Bangladesh River Data For Flood Forecasts'. Terra Daily. 13 March 2006. <http://www.terradaily.com/reports/China_Offers_Bangladesh_River_Data_For_Flood_Forecasts.html>

Thapa, A.B. 'Global Warming and GLOF Danger to Nepal'. Nepal Disaster. <www.nepaldisaster.org/download/Global.doc>

Shrestha, Hiranyalal. 'Water Resource in Nepal-China Relation'. Telegraph Nepal. May, 2008. <http://www.telegraphnepal.com/news_det.php?news_id=3381>

Islam, Syful. 'Ganges water flow much below agreed quantum'. The New Nation. January, 2010. <http://nation.ittefaq.com/issues/2010/01/13/news0034.htm>

Singh, Richa. 'Trans-boundary Water Politics and Conflicts in South Asia: Towards 'Water for Peace'. Centre for Democracy and Social Action.

'Nepal: Basic Facts about Country'. <http://www.docstoc.com/docs/2259636/1-NEPAL-BASIC-FACTS-ABOUT-COUNTRY>

Michel, D. & Pandya, A. 'Troubled Waters: Climate Change, Hydropolitics, and Transboundary Resources'. The Henry L. Stimson Center. January 2009. <http://www.stimson.org/rv/pdf/Troubled_Waters/Troubled_Waters-Complete.pdf>

Qaddumi, Halla. 'Practical Approaches to Transboundary Water Benefit Sharing'. Overseas Development Institute. July 2008. <http://www.odi.org.uk/resources/download/1929.pdf>

'South Asia Transboundary Water Quality Monitoring (SATWQM) Project'. <http://www.pi.energy.gov/documents/EWSLsouthasia.pdf>

'Convention on the Protection and Use of Transboundary Watercourses and International Lakes'. UNECE. <http://www.unece.org/env/water/>

'UNEP effort to strengthen transboundary freshwater governance'. International Water Law Project Blog. May 2009. <http://www.internationalwaterlaw.org/blog/?cat=10>

Morton, Katherine. 'An uncertain future on the Plateau'. China Dialogue. 28 April 2009. http://www.chinadialogue.net/article/show/single/en/2961

'Abu Dhabi Host the 4th Dialogue on Southern Asia Water Cooperation'. Environment Agency. Abu Dhabi. 22 October 2009. <http://www.ead.ae/en/news/dialogue.on.southern.asia.water.cooperation.aspx>

Chapter 14: TRADE, TRANSIT AND ECO-TOURISM

'Road to progress'. Frontline. Volume 26 - Issue 04. 2009. <http://www.hinduonnet.com/fline/fl2604/stories/20090227260406400.htm>

'Ministry seeks inclusion of Water Transport in Nepal Treaty' Financial Express. 03 October 2003. <http://www.financialexpress.com/news/ministry-seeks-inclusion-of-water-transport-in-nepal-treaty/94128/0>

'Revival of Inland Water Transport: Options and Strategies'. Department of Sustainable Development. World Bank. 29 May 2007.

Singh, Laishram Rajen. 'The Kunming Initiative: Prospects for Sub-regional Cooperation'. The Asian Scholar. Issue No. 3. <http://www.asianscholarship.org/asf/ejourn/articles/rajen_sl.pdf>

'Policies and Actions taken by Individual Countries, and by International Organizations to improve Transit Transport Systems'. United Nations Conference on Trade and Development. 1999. <http://www.unctad.org/en/docs/tbldcac1d14&a1.en.pdf>

Rao, Rama. 'India to allow Nepal's transit trade through Vizag port' Asian Tribune. 24 August, 2009. <http://www.asiantribune.com/news/2009/08/23/india-allow-nepal%E2%80%99s-transit-trade-through-vizag-port>

'Trade Facilitation Problems of Indian Exporters'. National Seminar on Trade Facilitation. Ace Global Private Limited, New Delhi. 2005.

Thein, C. C. 'Regional Cooperation in Transport: Myanmar Perspective on BIMSTEC'. Discussion Paper 42. Centre for Studies in International Relations and Development (CSIRD). September 2008.

'Briefing Paper on the ADB's SASEC Tourism Development Plan and its Potential Impacts on India's NE'. EQUATIONS. December 2006. <http://www.equitabletourism.org/stage/files/fileDocuments350_uid10.pdf>

Inland Navigation Europe. <http://www.inlandnavigation.org/en/factsandfigures/network.html>

Nitish Sengupta Arindam Banik. "Regional Trade and Investment Case of SAARC". Economic and Political Weekly November 15, 1997

'Delhi to get access to Ashuganj port, Dhaka to Nepal, Bhutan' Priyo. 11 September 2009. <http://priyo.com/news/2009/sep/11/30413.html>

'China's Installed Power Capacity to Top 800 Million KW by End of 08'. AsiaPulse News. May 2008. <http://www.highbeam.com/doc/1G1-178791584.html>

Habib, H. 'Sheikh Hasina defends agreements with India'. The Hindu. 17 January 2010. <http://www.thehindu.com/2010/01/17/stories/2010011761150800.htm>

'India and Bangladesh sign five agreements'. BBC News. 12 January 2010. <http://news.bbc.co.uk/2/hi/8451105.stm>

Chapter 15: HYDROPOWER AND AGRICULTURE

'China to Double Hydropower Capacity in One Decade'. Interesting Energy Facts. September 2009. <http://interestingenergyfacts.blogspot.com/2009/09/china-to-double-hydropower-capacity-in.html>

'Power Sector At a Glance: All India'. Ministry of Power, Government of India. 2009. <http://www.powermin.nic.in/indian_electricity_scenario/introduction.htm>

'Hydropower in Nepal'. <http://www.ippan.org.np/HPinNepal.html>

'Developing Small Scale Hydropower in Nepal'. International Technical Co-operation (ITECO). 2009. <http://www.iteco.ch/en/renewable-energies/projects/smallhydropowernepal.html>

'Hydropower in South Asia: Potential for Exports'. South Asian Regional Initiative for Energy Co-operation and Development. USAID. <http://www.sari-energy.org/successdocs/IStudy_SouthAsianHydroResources.pdf>

Singh, Richa. 'Trans-boundary Water Politics and Conflicts in South Asia: Towards 'Water for Peace''. Centre for Democracy and Social Action.

Joshi, Saroj K. 'Solutions for Nepal's Present Power Crisis'. <http://www.hindi.net/Solution%20for%20Nepal%27s%20Present%20Power%20Crisis.htm>

Chapter 16: RESPONDING TO CLIMATE CHANGE RISKS

'Climate Mitigation and Adaptation'. 'Global Warming'. <http://www.global-greenhouse-warming.com/climate-mitigation-and-adaptation.html>

Pereira, Michael. 'India, China sign 5-yr pact to tackle climate change'. 22 October 2009. <http://www.tcktcktck.org/stories/climate-news/httpwwwbusiness-standardcomnewsindia-china-sign-5-yr-pact-tackle-climate>

'India, China ink MoA on climate change'. Outlook India. 21 October 2009. <http://news.outlookindia.com/printitem.aspx?668100>

Krishnan, Ananth. 'India, China to collaborate on environment'. The Hindu. 27 August 2009. <http://www.thehindu.com/2009/08/27/stories/2009082754841100.htm>

Pachauri, R.K. 'Cold, necessary cuts'. Hindustan Times. 4 December 2009.

'Adaptation and Mitigation', 'Global Warming'. <http://www.global-greenhouse-warming.com/adaptation-and-mitigation.html>

'Questions and Answers on the White Paper on climate change adaptation'. EUROPA. <http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/09/145&format+HTML&aged=0&language=EN&guiLanguage=en>

Mitra, Soubhik. 'Vehicles pollute more than industries: NEERI study'. Hindustan Times. 26 December 2009.

Harrabin, Roger. 'Harrabin's Notes: Electric promise'. BBC News. 20 October 2009. <http://news.bbc.co.uk/go/pr/fr/-/2/hi/science/nature/8315947.stm>

Jain, Bhavika. 'Down the Drain'. Hindustan Times. 4 December 2009. <http://www.hindustantimes.com/News-Feed/mumbai/Down-the-drain/Article1-482776.aspx>

'Indian Standard Time'. Wikipedia. 29 December 2009. <http://en.wikipedia.org/wiki/Indian_Standard_Time>

'China Standard Time'. Wikipedia. 29 December 2009. <http://en.wikipedia.org/wiki/China_standard_time>

'Bangladesh to turn back clock to save energy'. Zee News. 25 December 2009. <http://www.zeenews.com/news590264.html>

Sahu, P.R. 'In arid fields, bumper crop'. Hindustan Times. 11 November 2009. <http://www.hindustantimes.com/StoryPage/Print/478602.aspx>

'China – Background'. US Energy Information Administration – Independent Statistics and Analysis. July 2009. <http://www.eia.doe.gov/emeu/cabs/China/Background.html>

'India Coal Energy'. Energy Alternatives India. 2009. <http://www.eai.in/ref/fe/coa/coa.html>

Airy, Anupama. 'Clean coal, the next big step to save our planet'. Hindustan Times. 8 December 2009.

Branigan, Tania. 'China's three biggest power firms emit more carbon than Britain, says report'. The Guardian. 28 July 2009. <http://www.guardian.co.uk/environment/2009/jul/28/china-greenhouse-gas-emissions-greenpeace>

BOX: ATMOSPHERIC BROWN CLOUDS

"Atmospheric Brown Clouds: Regional Assessment Report With Focus on Asia". United Nations Environment Programme (UNEP). 2008. <http://www.unep.org/pdf/ABCSummaryFinal.pdf>

Chapter 17: INTEGRATED RIVER BASIN MANAGEMENT (IRBM)

'Integrated River Basin Management (IRBM)'. World Wildlife Fund. <http://www.panda.org/about_our_earth/about_freshwater/rivers/irbm/>

Cassar, Angela. 'Transboundary Environmental Governance: The Ebb and Flow of River Basin Organizations'. Earth Trends, World Resources Institute. July 2003. <http://earthtrends.wri.org/features/view_feature.php?fid=46&theme=10>

Hooper, Bruce. 'Integrated river basin governance and key performance indicators'. DHI Australia. 2006.<http://australia.dhigroup.com/~/media/DA4AD931E9EE418A9C5E0AAA4322AEE9.ashx>

'Managing Rivers Wisely: Lessons from WWF's work for integrated river basin management'. WWF International. 2003.

Jaspers, F.G.W. 'Institutional arrangements for integrated river basin management' Water Policy 5. Pages 77–90. 2003.

Salman, S.M.A. 'The Helsinki Rules, the UN Watercourses Convention and the Berlin Rules: Perspectives on International Water Law'. Water Resources Development. Vol. 23, No. 4. Pages 625–640. December 2007.

The Ramsar Convention on Wetlands. <http://www.ramsar.org/cda/ramsar/display/main/main.jsp?zn=ramsar&cp=1^7715_4000_0__>

Harris,C. Bhandari, B.B. Hua, O and Sharma, E. 'Himalayan Wetlands Initiative – conservation and wise use of natural water storage in the HKH region'. Water Storage No. 56. Sustainable Mountain Development. ICIMOD. 2009.

'NARBO Annual Report'. Network of Asian River Basin Organizations. 2007. <http://www.narbo.jp/narbo/annualreport/report/ar_narbo2007.pdf>

Hirsch, Phillip & Jensen, K.M. 'National Interests and Transboundary Water Governance in the Mekong'. University of Sydney. May 2006.

Ncube, Mkhululi. 'Role of River Basin Organisations'. Economic Commission for Africa. <http://knowledge.uneca.org/member-states/observatory-on-regional-integration/harmonisation-of-sectoral-policies/harmonisation-of-sectoral-policies-in-natural-resources/water/role-of-river-basin-organisations>

Nette, Andrew. 'Mekong Commission Fends Off Credibility Charges'. Inter Press Service News Agency. 11 May 2008. <http://ipsnews.net/news.asp?idnews=42321>

Mekong River Commission. <http://www.mrcmekong.org/>

'International River Basin Organizations Data'. Program in Water Conflict Management and Transformation, Oregon State University. <http://www.transboundarywaters.orst.edu/research/RBO/RBO_Asia.html>

Onishi, Kayo. 'Hydropolitics of China and Downstream Countries in the Mekong River Basin'. Role of Water Sciences in Transboundary River Basin Management, Thailand. 2005.

'Transboundary threats to security in the Greater Mekong Subregion (GMS)'. Stimson Centre. <http://www.stimson.org/?SN=SE200803251533 >

'Water Without Borders'. International Year of Water. 2003 <http://www.wateryear2003.org/en/ev.php-URL_ID=3679&URL_DO=DO_TOPIC&URL_SECTION=201.html>

'The Challenges of Integrated River Basin Management in

India'. Water Policy Briefing, Issue 3. IWNI-Tata Water Policy Program. <http://www.iwmi.cigar.org/Publications/Water_Policy_Briefs/PDF/wpb03.pdf>

Wolf, Aaron. Kramer, Annika, Carius, Alexander & Dabelko, Geoffrey. 'Peace in the Pipeline'. BBC News. 13 February 2009.<http://www.news.bbc.co.uk/go/pr/fr/-/2/hi/science/nature/7886646.stm >

Shrestha, Hiranyalal. 'Water Resource in Nepal-China Relation'. Telegraph Nepal. 7 May 2008. <http://www.telegraphnepal.com/news_det.php?news_id=3381>

Hilton, Isabel. 'Building regional cooperation'. China Dialogue. 25 August, 2009. <http://www.chinadialogue.net/article/show/single/en/3229>

Strategic Foresight Group

Strategic Foresight Group was established in 2002 to create new forms of intellectual capital. In a short span, it has created intellectual and political assets to draw input from all continents and deliver output to decision makers anywhere in the world.

We have advised governments around the world and produced scenarios and innovative policy concepts that have been discussed in august bodies including the Indian Parliament, the European Parliament, Oxford University, UK House of Commons, World Bank, the League of Arab States, Bibliotheca Alexandrina, World Economic Forum, Swedish Defence Commission, Global Futures Forum, Geneva Security Forum and others. Our research findings and views have been covered by the world media including BBC World Television, CNN, International Herald Tribune, Financial Times, New York Times, The Straits Times, Gulf News, Khaleej Times, Asahi Shimbun and almost all major newspapers in India and Pakistan.

Strategic Foresight Group undertakes forward-looking research in geopolitical, economic, technological and societal changes. Our research examines future trends and discontinuities in spaces where geopolitics intersects with business, economy, society, religion, the environment and technology. In addition to specific client-driven research projects, SFG also publishes public reports. Its publications include reports on Global Security and Economy 2011-2020, An Inclusive World: Where West, Islam and the Rest Have a Stake, Managing Global Challenges, Cost of Conflict in the Middle East, and reports on the future of South Asia.

SFG launches initiatives for dialogue and policy change to address specific challenges. The initiatives are backed by innovative research and engage senior level policy makers who are most relevant to bring about a change. These may include cabinet ministers, members of legislature, advisers to Heads of Government, leaders of multilateral organisations, and leaders of business groups. SFG also engages in direct consultation with Heads of Government.

Since 2003, SFG has been involved in a complex initiative to address the deficit of trust between Western and Islamic countries. Since 2004, SFG has launched several initiatives to sensitise policy-makers in conflict zones about cost of conflicts. Since 2009, SFG has launched two new initiatives on water security in the Himalayan River Basins and the Middle East. It is poised to launch an initiative on major global shifts.

Strategic Foresight Group

www.strategicforesight.com

The Himalayan River Basins in Bangladesh, China, India and Nepal are home to about 1.3 billion people - i.e. almost 20% of the world's population and almost 50% of the total population of these countries. In the next 20 years, the four countries in the Himalayan sub-region will face the depletion of almost 275 billion cubic meters (BCM) of annual renewable water. For comparison, this is more than the total amount of water available in one of the countries – Nepal – at present. The cumulative effect of water scarcity, glacial melting, disruptive precipitation patterns, flooding, desertification, pollution, and soil erosion will be a massive reduction in the production of rice, wheat, maize and fish. Both India and China will face drop in the yield of wheat and rice anywhere between 30-50% by 2050. At the same time demand for food grains will go up by at least 20%. As a net result, China and India alone will need to import more than 200-300 million tonnes of wheat and rice, driving up the international prices of these commodities in the world market. This will have adverse impact on the poor all over the world and will result in a risk of displacement of 100-200 million people in the himalayan region by 2050. This report opens our eyes to the challenges of the next half century and proposes innovative solutions to prevent or at least mitigate crisis.

Strategic Foresight Group is a think tank based in India, with global reach. It helps policy makers to plan future in uncertain times. Its voice has been heard in the chambers of the Indian Parliament, House of Commons, House of Lords, European Parliament, United Nations, World Economic Forum and other important institutions. SFG believes in a collaborative approach and engaged 25 leading experts from Bangladesh, China, India and Nepal in preparatory workshops for this report. Strategic Foresight Group is also involved in initiatives to promote water security in other parts of the world.

India Rs 1,500
Abroad US $30

Strategic Foresight Group

ISBN 978-81-88262-13-7