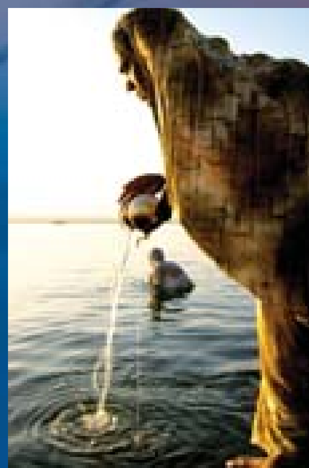
FRESHWATER under THREAT

AFRICA-ASIA SUMMARY

Vulnerability Assessment of Freshwater Resources to Environmental Change





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United Nations Environment Programme

Freshwater Under Threat: Vulnerability Assessment of Freshwater Resources to Environmental Change - A Joint Africa-Asia Report Summary

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FRESHWATER under THREAT

Vulnerability Assessment of Freshwater Resources to Environmental Change

A JOINT AFRICA-ASIA REPORT

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PREFACE


UNEP

Climate change has become one of the most critical global challenges in recent history, as emphatically demonstrated by varied climatic phenomenon ranging from, *inter alia*, droughts to floods. Climate change impacts are far reaching, including: effects on agriculture through floods or droughts, thereby endangering food security; sea level rises resulting in the submergence of ocean islands and the accelerated erosion of coastal areas; the dissemination of ecosystems; and spreading of vector-borne diseases.

Africa and Asia's major economic sectors are most vulnerable to climate sensitivity and its huge economic impacts, exacerbated by existing developmental challenges. These challenges include endemic poverty, complex governance and institutional dimensions; limited access to capital (including markets, infrastructure and technology); ecosystem degradation; and complex disasters and conflicts. In turn, these challenges have contributed to both continents' poor capacity to adapt, increasing their vulnerability to climate change.

Africa and Asia's dependence on natural resources makes their people most vulnerable to environmental change. This vulnerability includes both natural and human phenomena, including climate change and variability, pollution, population growth, competition for water resources, data availability and quality, and knowledge gaps. Vulnerability assessments of water resources are urgently needed on both continents, as ecosystems are already endangered, threatening the livelihoods of the many poor who are least capable of adapting to environmental change.

Acknowledging the urgency of the vulnerability issues affecting livelihoods and the environment, UNEP-DEWA and START initiated studies to assess the vulnerability of water resources to environmental change in Africa (UNEP 2005a) and Asia in 2003 and 2005, respectively. The aim of the studies was to facilitate the management of vulnerability risks at transboundary, national, and local river and lake basins, and groundwater aquifer levels by assessing the impacts of environmental and human-driven changes on water resources. The study is unique for Africa, as it has not been previously undertaken for the continent as a whole.

The assessments were carried out within the context of the World Summit on Sustainable Development (2002), where the international community made a renewed commitment to sustainable development, as outlined in the Rio Declaration (1992), and to the advancement of the Millennium Development Goals (2000). Within this context, it is internationally recognized that sustainable development in Africa and Asia can only be achieved by addressing peace, security and development concerns, including environmental issues, human rights and governance. In the case of Africa, this overlaps with efforts to implement a "programme of action for Africa's re-development," through the New Partnership for Africa's Development (NEPAD) initiative.

The joint Africa-Asia study is expected to be of great interest to governments and policy and decision-makers at various levels, and to affected communities, providing insights into critical issues and how they could be mitigated.

This 'Summary' provides an overview of the key messages and opportunities for action derived from the publication, 'Freshwater under Threat – Vulnerability of Water Resources to Environmental Change – Africa and Asia Reports'.

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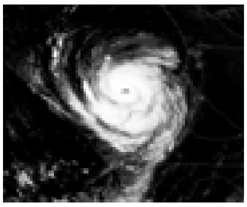
FRESHWATER under THREAT

Vulnerability Assessment of Freshwater Resources to Environmental Change

A JOINT AFRICA-ASIA REPORT

PART 1: AFRICA








1. INTRODUCTION

The publication 'Freshwater under Threat – Vulnerability of Water Resources to Environmental Change – Africa Report' (UNEP-WRC 2008) documents the status of water resources across Africa, touching on multiple dimensions of its complex issues, and highlighting at least as many common concerns as regional differences. It can be considered an atlas of assessments of sub-regions (southern, eastern, central, western, and northern Africa and the Western Indian Ocean Island States), and of major river, lake and groundwater basins (see figure below). The assessments were carried out by sub-regional groups of African researchers, utilizing natural (physiographic), anthropogenic (socio-economic) and management criteria.

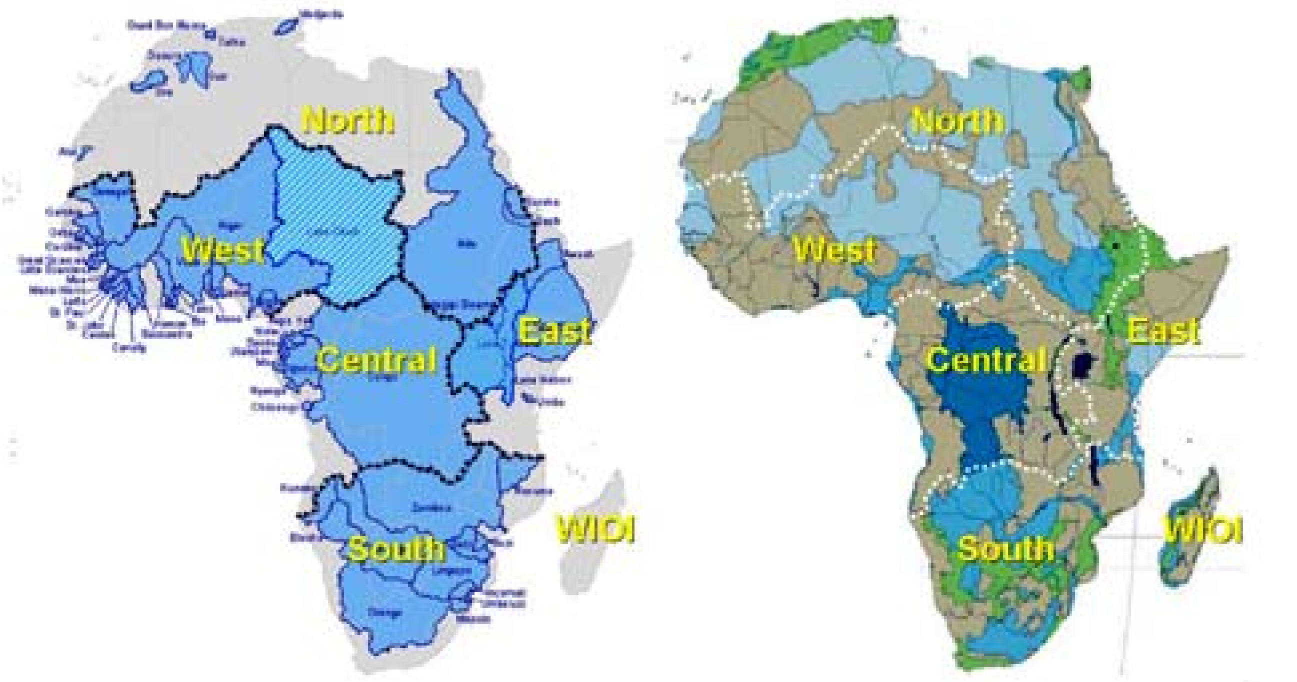


Figure 1.1: (a) Major river and lake basins (Transboundary Freshwater Dispute Database, 2000);
(b) Major groundwater aquifers (WHYMAP, 2005 BGR/UNESCO)

A rapid approach was adopted to provide a summarized overview of sub-regions and basins, culminating in key issues regarding the vulnerability of water resources to environmental changes, and ways of addressing these issues through appropriate adaptation and mitigation options. Issues, adaptation and mitigation options also were grouped under the 3 broad areas of: *physiography* (e.g., increased frequency of droughts and floods, affecting water supplies and livelihoods; wetland/land degradation; desertification; water pollution; over-exploitation of aquifers), *socio-economy* (e.g., high population growth and urbanization; HIV/AIDS and water-related diseases; poverty; increased water demands) and *management* (e.g., lack of, or weak, river basin institutions; weak legislation; lack of, or limited, data and monitoring; human resources and training).

2. KEY MESSAGES

These assessments clearly illustrate common concerns and regional differences in the areas of water resources availability, development pressures, ecosystem health, management challenges, and knowledge gaps (UNEP-WRC 2008; Beekman and Pietersen 2007; UNEP 2006).

2.1 WATER AVAILABILITY

Africa's extreme variability in precipitation in time and space is reflected in an uneven distribution of surface and groundwater resources, from areas of severe aridity with limited freshwater resources (northern and southern parts), to the tropical belt of mid-Africa, with abundant resources. The high temporal and spatial rainfall variability has repeatedly led to extreme climatic events (droughts; floods) that pose a continuous risk to Africa's people and their livelihoods, and its national economies. Global change scenarios predict an increasing frequency of drought and flooding, thus increasing the vulnerability of Africa's water resources.

Southern Africa

This region has experienced floods in the northern and southern parts, and episodes of severe and prolonged droughts in other places. It is among the few regions in the world for which most global climate models agree that aridity will increase, further lowering the water availability necessary for livelihoods. Countries must better prepare for the increased magnitude, duration and impact of floods and droughts.

Box 2.1.1: Unforgiving weather: contrasting climatic events

(a) Floods strike Mozambique – January 2008

From left to right:

January 12 - The flood-swollen Zambezi River threatens to swallow a village in Tete, Mozambique

January 16 - Children gather amid heavy flooding in Mutarara, part of Mozambique's Tete region

January 18 - Tomas Serrao, 56, and his wife Anita, 44, rest beside two bags of sweet potatoes and the only other possessions they saved from the flood near the town of Chirembwe, Mozambique. The deluge claimed their house and their cornfield.

Source: http://news.nationalgeographic.com/news/2008/01/photogalleries/Mozambique-pictures

(b) Drought ravages Zambia - 2002

© SEAN SPRAGUE / Still Pictures

Mulondiwa Sikunga, a young farmer of Shangombo, and his brother, with their maize plants, after a long period of drought.

Western Indian Ocean Island States

Under worst case scenarios, global warming is expected to cause a 1m (3.3 ft) sea level rise by 2100, which would have dire consequences, including loss of coastal land, agricultural opportunities, groundwater resources (due to salinization), and biodiversity critical to community support and livelihoods. The social impacts of sea level rise will be displacement of people, water-related diseases and water-supply problems.

Eastern Africa

General moisture circulation models predict an increase in rainfall up to 20 per cent, a change in seasonal distribution of precipitation, and an increase in air temperature of up to 5°C (41°F) for this century. There also are indications of an increasing frequency and intensity of droughts.

Central Africa

This region is characterized by an abundance of freshwater resources, except for the northern parts where there was a decline in rainfall (shrinkage of Lake Chad) over the past 3 decades. Water demands are rising but it is unlikely that the region's freshwater availability will be affected much in the coming years. Nevertheless, pollution of these water resources is a major issue requiring special attention.

Box 2.1.2: Shrinking of Lake Chad

Lake Chad, once one of Africa's largest freshwater bodies, used to be an important source of water and economic activity, including irrigation projects and fisheries, in the 4 countries sharing the lake: Chad, Nigeria, Niger and Cameroon. The lake has dramatically decreased in size, however, since the early 1960s, from ~25 000 km^2 (9,653 mi^2) to ~1 350 km^2 (521 mi^2) in 2001.

Fifty per cent of the decrease in the Lake size is attributed to increased irrigation water use, especially during the period 1983-1994, and to overgrazing and deforestation. The remaining 50 per cent is attributed to a significant decline in precipitation since the 1960s. Future predictions of reduced rainfall and runoff, and increased desertification could mean further shrinkage of Lake Chad.

Source: www.gsfc.nasa.gov/topstory/20010227lakechad.html; UNEP 2002

Western Africa

Climate change is expected to bring about reduced precipitation and increased evaporation in the areas to the north, thereby advancing the rate of desertification in the Sahel.

Northern Africa

This is the most water-stressed region in Africa, and freshwater availability will become an even more important issue in the coming decades. Climate change scenarios for western Maghreb predict a rise in temperature of up to 4°C (39°F) this century, accompanied by a reduction in precipitation of up to 20 per cent. This would result in decreased soil moisture and reduced surface and groundwater resources. Salinization of soils, which threatens food production, is already a concern in irrigated areas, especially along the Nile River, and may get worse. Other concerns are seawater intrusion, resulting from over-exploitation of groundwater resources in coastal areas (where the main urban centres are located), and desertification.

2.2 DEVELOPMENT PRESSURES

Population growth, urbanization, and economic growth in general, all exert pressures on water resources through increased demand and pollution. Water is essential for life, and its availability for safe drinking, and for food, health and the environment, should be secured.

Box 2.2.1: Morocco Worries about Desertification

RABAT - Almost the entire country of Morocco is threatened by increasing desertification, a senior official said, indicating that efforts to combat it are proving inadequate.


© Biosphoto / Chapman Jack / Still Pictures

Abdeladim El Hafi, High Commissioner for Water and Forests, was speaking to AFP, when he noted. "Between 90 and 93 per cent of Morocco is affected by aridity and other forms of drought," blaming climate change, and overuse and misuse of land. Attempts to deal with the problem include reforestation, dune stabilization and measures against erosion. "These measures are insufficient," he added, calling for action by everyone concerned, including the use of renewable energy sources. Some 22,000 ha (85 mi^2) of arable land disappears under the desert every year in Morocco, according to official figures. Agriculture accounts for up to 20 per cent of gross domestic product, but this can drop to 13 per cent, depending on the weather.

Source: www.arabenvironment.net/archive/2006/9/95463.html

Safe Drinking Water and Sanitation

Only 51 per cent of the rural areas in Africa had water supply coverage in 2002, whereas the coverage for urban areas was 86 per cent (Figure 2.2.1). Analysis of regional water-supply data reveals that, despite progress in drinking water coverage between 1990 and 2002 (Figure 2.2.1), the improvement still falls short of the progress needed to achieve the Millennium Development Goal (MDG) of 75 per cent coverage by 2015. Regarding the MDG sanitation target, the situation is critical, and progress must be accelerated. Northern Africa is almost on track to meet both targets, although it is the most water-stressed region in Africa.

Obstacles preventing progress toward achieving the MDG targets throughout Africa, with the exception of northern Africa, include political instability, high population growth rates, poor governance, dwindling or diminishing budgetary allocations and subsequent increased demands from the agricultural and domestic sectors, and a low priority given to water and sanitation, in terms of investments in infrastructure and maintenance.

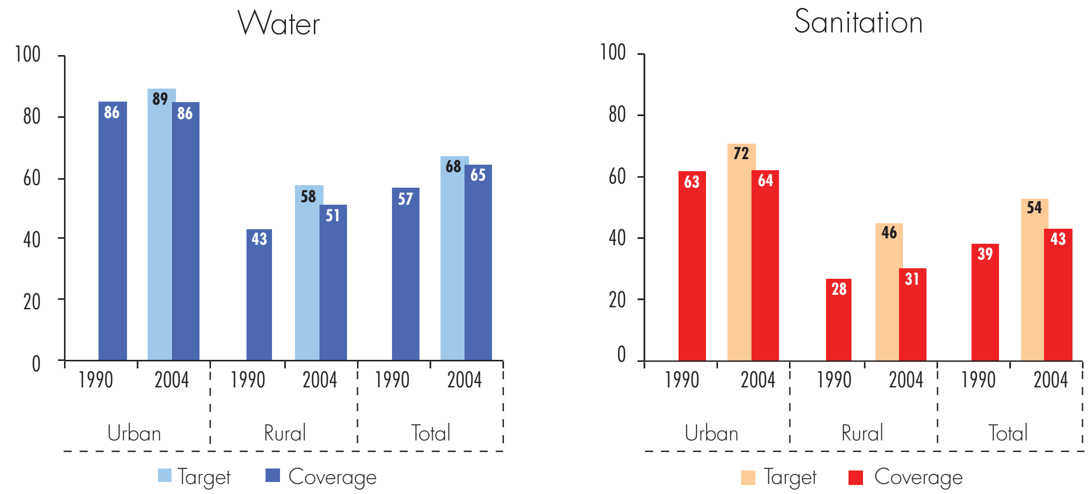


Figure 2.2.1: Water-supply coverage in rural and urban settings between 1990 and 2002 for Africa

Source: WHO/UNICEF, 2004, redrawn by UNEP

Food Security

Major crop failures, resulting from droughts and flooding, are being experienced increasingly frequently in Africa than in the past, causing famine and economic hardships to families and communities. Insufficient investments, and operational funds for irrigation infrastructure by governments in many African countries, are a major threat to the availability of water resources for irrigation. There is a pressing need throughout the continent for food security. Meeting water needs, therefore, is of paramount importance.

Public Health

The Africa continent exhibits relatively high morbidity and mortality rates, as a result of waterborne and water-related diseases (e.g., malaria; cholera; diarrhoea). It also has the world's highest incidence of HIV/AIDS. The implications of these diseases are enormous, particularly on the economic situation in Africa, since the youngest and most productive ages (15-45 years old) are most affected. Water availability to the infected and affected families is important, in order to ensure adequate hygienic conditions are maintained to curb the spread of disease. Any decline in drinking water quality or sanitation facilities will lead to increased public health risks, particularly for those with compromised immune systems.

Environmental Degradation

Environmental degradation is a serious concern for countries relying on hydropower generation for electricity. Hydropower generation requires reliable water supplies for most of the time (wet and dry seasons). Degradation of a catchment area's environment can result in declining springs, streams and rivers, with catastrophic consequences for human welfare and environmental integrity. Pollution of water resources also is a great concern, since it is a threat to both the environment and freshwater availability.

Poor land use practices have resulted in the sedimentation of river channels, lakes and reservoirs, and changes in hydrological processes. Deterioration of the quality of water resources as a result of further increases in nutrient loads from agricultural irrigation, and from the domestic, industrial and mining sectors, also has significantly depleted the available freshwater resources, contributing to increased water scarcity. Increased human activity causes the water environment to be exposed to a range of chemical, microbial and biological pollutants, as well as micro-pollutants. The mining and industrial sectors in particular produce high concentrations of waste and effluents that act as non-point sources of water quality degradation, including acid mine drainage that pollutes groundwater resources.

Thus, Africa's water resources are already facing serious risks from development pressures. Large dams (over 60 m [197 ft] high) have been built in many river basins for water supply and power generation, including the Nile, Volta and Zambezi, and new dams are currently under construction in the Niger, Orange and Oued Draa river basins. The construction of dams has caused significant changes in the flow regimes of rivers, with consequent negative impacts on the environment and the loss of ecosystems functions. Thus, there is a need for a balance between water resources development and the degradation of ecosystems that result from this development.

2.3 ECOSYSTEM HEALTH

The major threats to Africa's water resources in its lakes, rivers and wetlands include eutrophication, salinization and pollution from industrial effluents and chemical spills. Further, they extend to broader ecosystem concerns as well, including exotic weed infestation, loss of fish population, habitat destruction, and loss of biodiversity. Most, if not all, of these effects can be traced to a generalized single cause: human activities. The introduction of alien fish species, de-vegetation of catchment areas, pesticide use, and waste disposal, to cite a few examples driven by a variety of competing human needs, have severely affected these finely-balanced ecosystems. Current water usage patterns are simply unsustainable. A comprehensive assessment can help us better understand the chemistry, biology and physics of the relevant interactions. Equally challenging in this regard are the contextual socio-economic factors, including population pressures, poverty and globalization, that lie at the heart of the matter.

2.4 MANAGEMENT CHALLENGES

The fundamental issues facing water resources in Africa include not just water availability, but also human factors. The latter are related to the governance of the available water resources, including legislative and institutional frameworks, over-exploitation and pollution of the resources, conflict and political instability, inadequate technical knowledge and institutional capacity, and a low priority given to water issues in terms of human resources and budgetary allocations. Certain water-scarce regions in northern Africa, for example, have succeeded in providing adequate water resources to large segments of their population, while other parts of Africa with abundant water occurrence, such as Central Africa, have only limited water supply coverage (<50 per cent of the population).

The water supply problem in Africa appears to be mostly a problem of water resources management. It is typical for a number of different agencies to be responsible for the numerous freshwater ecosystem resources in a given country. Issues of fisheries, agriculture, industrial waste and drinking water, for example, are addressed separately, and without coordination between sectors. Government policies have generally emphasized exploitation of water resources for development purposes, at the expense of water conservation and sustainability. Further complicating matters is the fact that major freshwater ecosystems in Africa are shared by multiple nations, making their management a daunting task.

Water Sector Reform

The weak, or lacking, regulatory and management instruments, directives and institutional and human capacity, poses a threat to the realization of human expectations and needs in regard to water provision. Although water sector reforms in Africa are meant to address the above, they have been constrained by numerous factors, including internal resistance from institutional executives, lack of political will, frequent changes in governments, and dependence on development partners to fund the reforms. Other common obstacles to effective water resources management are the fragmentation of water management administration among various institutions, absence of coordination mechanisms, inadequate institutional capacity and resources, and lack of an integrated approach for water resources management.

2.5 KNOWLEDGE GAPS

One of the biggest challenges to be addressed immediately, in order to achieve the African Water Vision and the MDGs, is the lack of adequate human (technical and managerial), financial and material resources that would allow authorities to plan and implement water and sanitation policies and programmes, among other things. There is generally a shortage of knowledge and institutional strength, particularly in regard to Integrated Water Resource Management (IWRM), thereby limiting the success of water resource management initiatives. Africa also is faced with the challenge of retaining trained and highly-skilled personnel.

Information Generation and Management

A key limitation at the national, regional and continental level, which is linked to inadequate financial and human capacity, is lack of sufficient and good quality data on water resources. These data are prerequisites for effective, sustainable water resources development and management. Water-related data and information are often lacking and, even when available, too weak or general (because of inconsistencies and prolonged periods of instrumentation breakdowns), thereby resulting in limited records. Conflicts in some countries cause the data to not be collected at all, or to even properly maintain the measurement instruments. Another obstacle is a shortage of facilities and skilled people at various levels to collect and analyse the information and data for longer-term water resources management.

Water Quantity and Quality

There is generally a bias toward information on water quantity, rather than quality. Information on groundwater resources also is less detailed or accurate, compared to surface water resources. More information also is needed in the areas of climate variability and change, water pollution and environmental flows. Additional longer term time-series of data and analyses also are needed, and the situation regarding often-restricted access to databases, and limited sharing of transboundary information, must be resolved.

Disaster Management

Another area lacking information and knowledge is disaster management. This is of particular importance for small islands (e.g., Western Indian Ocean Island States; low-lying coastal areas), which are among the most vulnerable to extreme climatic events and environmental disasters, as dramatically highlighted by the Indian Ocean tsunami of 26 December 2004.

3. OPPORTUNITIES FOR ACTION

3.1 WATER AVAILABILITY

With the current trend of increasing atmospheric carbon dioxide (CO_2) concentration by two parts per million per year, which contributes to global warming, it is estimated that the earth is only about three-and-a-half decades away from a threshold of 450 parts per million, the level beyond which most scientists believe future centuries will likely face the melting of the Greenland and West Antarctic ice sheets, and a subsequent significant rise in sea level (National Geographic 2007). Although it is critical that continuing efforts are made to mitigate climate change, by reducing emissions of greenhouse gases, the focus of the African water sector should instead focus on adapting to the effects of climate variability and change (DWC 2003).

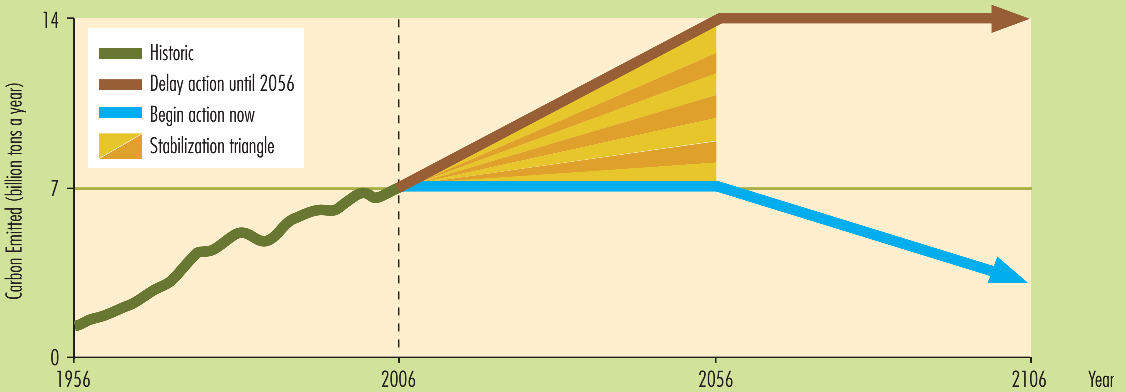
Dramatic cuts in emissions mostly concern the countries and regions that contribute most to global warming. The 3 main contributors in 2002 were North America (28 per cent), Europe (16 per cent) and East Asia (15 per cent) (Socolow and Pacala 2006). Although Africa only contributed 4 per cent to the CO_2 emissions in 2002, they also will need to reduce their emissions from their current levels, particularly South Africa.

Box 3.1.1: Mitigation of Global Warming

Robert Socolow and Stephen Pacala (Science 2004; Scientific American 2006; National Geographic 2007) assessed the possibilities for rapid and dramatic cuts in carbon emissions. They designed so-called stabilization wedges – changes big enough to really matter, and for which the technology was already available or was clearly on the horizon. These include more fuel-efficient cars, better built homes, wind turbines, and biofuels like ethanol. Other technologies are newer and less certain, an example being coal-fired power plants that can separate carbon from their exhausts, so it can be "sequestered" underground.

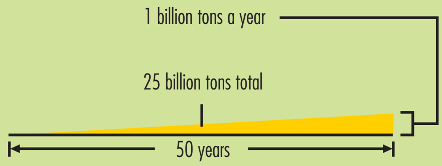
ANNUAL EMISSIONS

In between the two emission paths is the "stabilization triangle". It represents tthe total emissions cut that climate-friendly technnologies must achieve in the coming 50 yearrs.



THE WEDGE CONCEPT

The stabilization triange can be divided into seven "wedges", each a reduction of 25 billion tons of carbon emissions over 50 years. The wedge has proved to be a useful unit becuase its size and timeframe match what specific technologies can achieve. Many combinations of technologies can fill the seven wedges.



3.2 DEVELOPMENT PRESSURES

Access to Safe Drinking Water

Access to water was internationally recognized in 2002 as a human right by the United Nations Economic and Social Committee. Clean, safe drinking water for domestic use ranks as the most crucial and urgent water need. The approaches shown to be effective in accelerating progress towards achieving the water MDG include decentralizing responsibility, and providing a choice of service levels to communities on the basis of their ability and willingness to pay. As shown below, 2 examples from Zambia and Guinea illustrate how the private sector can be involved in urban water supply with the goal of improving human access to safe drinking water and to improve overall water-related services.

Box 3.2.1: Private Sector Participation in Zambian Water-supply and Sanitation Sector

About 45 per cent of Zambia's population of ~10 million people live in urban areas, of which about 50-70 per cent live in peri-urban areas. One of the major goals of water sector reforms that the Government of the Republic of Zambia (GRZ) has been implementing since 1994 is to alleviate the pressures on the water-supply and sanitation situation. The majority of the current water-supply and sanitation service provision schemes in low-income peri-urban areas have been commercialized, with the responsibilities devolved to local authorities and the private sector.

A Devolution Trust Fund (DTF) was established in 2001 by Zambia's National Water-supply and Sanitation Council, under a provision in the Water-supply and Sanitation Act of 1997, to improve water service provision in low-income peri-urban areas. The DTF assists commercial water utilities in expanding their services in these areas, and in establishing water kiosks. The latter are low-cost public outlets run by private water vendors linked by contract to the professional operators of the entire system. The kiosks can reach an acceptable service level, and also have other advantages (e.g., good water quality) if linked to the main network, as well as low investment costs.

© JORGEN SCHYTTE / Still Pictures

Two young boys drinking water from a waterpump in Lusaka, Zambia

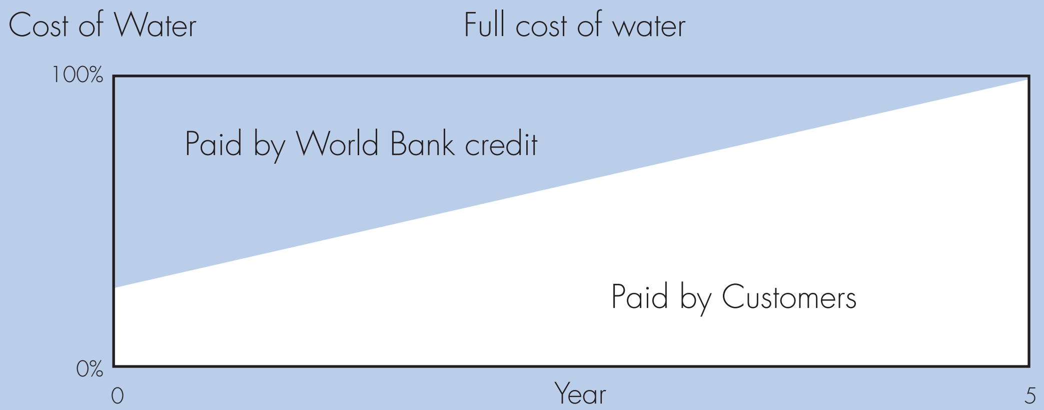
Source: SOWAS-GTZ (2004)

Food Security

Meeting irrigation water needs for food security and economic development is another important issue. Several basins are used for irrigated agriculture, an example being the Limpopo Basin, which has 82 per cent of its potential irrigation area of ~0.3 million ha (~1,158 mi^2), and over 50 per cent of the 10 million ha (38,610 mi^2) of the Nile River Basin, with Egypt using 70 per cent of the 4.4 million ha (16,988 mi^2) of its basin land area, and Sudan using 70 per cent of its 2.8 million ha (10,811 mi^2). There is less utilization of potential irrigation areas in other, being only about 0.4 per cent of the Congo, 5 per cent of the Zambezi, and 33 per cent of the Niger River basins, respectively. With its 30.3 million km^2 (11,698,895 mi^2) of land with irrigation potential, Africa provides considerable opportunities for further expansion of irrigated agriculture.

Box 3.2.2: Moving from a Vicious to Virtuous Cycle – Conakry (Guinea) Water Supply

A common problem for developing water utilities is how to escape from a "low-level equilibrium trap." A low-level trap begins with poor quality of services, causing people to be unwilling to pay, thereby resulting in low revenues which, in turn, cause even poorer-qualitiy services, etc. The innovative approach used by the city of Conakry illustrates how creative financing can assist in breaking out of this vicious cycle. The government water utility functioned poorly in 1987, with the quality of services in Conakry being abysmal. The Government of Guinea decided to involve the private sector. No private company, however, would be interested in a contract for which the revenues were only a fraction of the costs. The solution to this problem is illustrated in the figure below. The private operator was assured of sufficient revenues, by a combination of (initially low, but rising) revenues from users, and (initially high, but declining) subsidies from the government (largely paid out of a World Bank credit). The incentive was to use a time-bound, transparent "transition subsidy" to improve services, and then to raise tariffs for the improved services. Thus, the vicious cycle was replaced by a virtuous cycle of good services and reliable revenues.



Source: Briscoe (2000), redrawn by UNEP

Energy

Another opportunity for meeting urgent water needs is hydropower generation. Only 7.6 per cent of Africa's economically-feasible hydropower potential of 1 million gigawatt hours.yr^{-1} is currently being utilized. This situation provides great opportunities for expansion amid competing demands on Africa's environmental resources. Of the total electricity generated in the year 2000 (2,484 gigawatt hours) in Tanzania, for example, 86 per cent was hydro-generated. It should be noted that, for sustained economic development, the freshwater supply must be guaranteed, which can only be achieved with effective forest and watershed management.

Alternative Technologies

To meet urgent water needs, there is scope for alternative technologies (e.g., rainwater harvesting; wastewater recycling; desalination; leakage detection). Wastewater recycling is particularly practised in the SADC region. Botswana, for example, plans to recycle about 60 per cent of its urban wastewater discharges by 2020, while Windhoek (capital city of Namibia), recycles all its wastewater for irrigation purposes. Artificial groundwater recharge may be applied to enhance aquifer sustainability and water yields.

Opportunities for Action

- Ensure sustainable access to safe and adequate water and sanitation services for all.
- Secure food production through the potential for irrigation expansion, and consider focusing on small-scale irrigation projects over the short term.

- Utilize economically-feasible hydropower potential by ensuring sustainable forest and watershed management (include multi-disciplinary and multi-stakeholder approaches that link forest, water, environment and people).
- Conserve water by:
  - investing in development and maintenance of infrastructure for urban and rural water-supplies;
  - improving agricultural techniques (e.g., cropping patterns; selecting crops that consume less water);
  - introducing water demand management measures (e.g., applying intermediate technologies, new technologies based on traditional systems and involving the community) and introduce water pricing;
  - reducing water leakages to within 10-15 per cent; and
  - enhancing public awareness.
- Control pollution by investing in domestic and industrial effluent treatment and disposal facilities, and introducing economic incentives and disincentives (polluter-pays and user-pays principles).
- Explore and expand alternative technologies such as water harvesting (including artificial recharge and wastewater recycling).

Box 3.2.3: Inga Hydroelectric Facility

The Democratic Republic of Congo (DRC) currently has ~2 thousand megawatts (MW) of electricity-generating capacity at its Inga Hydroelectric Facility. Operated by the DRC's Societé Nationale d'Electricité (SNEL), Inga domestically provides power to Kinshasa and other portions of western DRC. It also provides power to the power grid of its neighbouring Republic of Congo. This interconnection supplies nearly one-third of the electricity consumed in Congo. Inga also exports power to the southern African countries of Zambia, Zimbabwe and South Africa.

An expansion of the existing facility (Grand Inga) to the full potential of the Congo River of 39,000 megawatts would be twice as much as that produced by the massive Three Gorges Dam hydropower project on China's Yangtze River, clearly demonstrating the possibility for exporting electricity. Feasibility studies indicate the Grand Inga project, and a connection to Egypt, are viable, with a Northern Energy Highway (NEH) passing through Congo, Central African Republic and Sudan. A high voltage DC connection from Inga to Nalubale, Uganda, also is feasible. Grand Inga will be implemented in four phases at a cost of ~US$ 8 billion, while the NEH and related infrastructure would cost ~US$ 20 billion USD.

Source: www.eia.doe.gov/emeu/cabs/inga.html

3.3 ECOSYSTEM HEALTH

Climate change and variability, population growth and increasing water demands, over-exploitation, and environmental degradation have significantly contributed to the worsening state of freshwater resources in Africa, leading to an increasing number of African countries whose water demands exceed their available water resources.

Pollution

Not only is freshwater quantity a fundamental instrument in the development of all African sub-regions, the quality of the resource also is important. Water resources deterioration results from increased salinity and nutrient loads from agricultural irrigation, and from the domestic, industrial and mining sectors. It significantly depletes the available resources and increases water scarcity. For the more-arid countries, which are highly dependent on underground aquifers for drinking water supplies, groundwater pollution is a particular concern. Disposal of sewage effluent into rivers and reservoirs has resulted in the flourishing of water hyacinth (alien weed species) and algal blooms that choke the rivers and reservoirs. Aquatic life is invariably seriously affected by polluted water resources. The economic dependence of African communities on the fishing industry also is being affected. The Lake Victoria Environmental Management Programme (LVEMP) provides a good example of how to manage and secure good quality water in a lake environment.

Box 3.3.1: Lake Victoria Environmental Management Programme

Lake Victoria is the world's second largest body of freshwater. The lake and its catchment support 30 million people, with fisheries and agriculture being the main economic activities. In 1995, the 3 riparian countries, Kenya, Uganda and Tanzania, established the Lake Victoria Environmental Management Programme (LVEMP), a long-term programme directed to improving the sustainable use of the basin's natural resources.

The first phase (1997-2004) of the project (LVEMP-1) focused on fisheries, water hyacinth management and control, and management of lake pollution and use.

The results of the first phase include:

- A water quality model for Lake Victoria for addressing various uses; establishment of 56 water quality monitoring stations; and standardized monitoring procedures; and
- Reduced infestation of water hyacinth by 80 per cent from 1998-2002 levels, and establishment of a Regional Water Hyacinth Surveillance System.

Three major transboundary issues associated with the 2 upstream countries (Rwanda; Burundi) were identified during LVEMP-1, including the influx of water hyacinth, and siltation and deforestation. Thus, both countries will be included in the second phase of the project (LVEMP-2). Some of the other issues to be considered in LVEMP-2 are:

- Establishment of national steering mechanisms;
- A focus on investment for high priority environmental issues (e.g., effluent treatment); and
- Development of a management information system.

Source: www.lvemp.org; Nyirabu (2002)

Land Degradation

Increased pressures on finite arable land because of increasing human population are causing unprecedented land degradation. Communities seeking agricultural land on slopes and wetlands result in desertification, soil erosion and siltation of river systems and reservoirs, and disappearance of the wetlands. This seriously affects both the ecological and hydrologic balances.

Opportunities for action

- Establish effective institutions to monitor water resources pollution and land degradation.
- Establish monitoring standards and enforcing systems.
- Establish tertiary industries that would add value to agricultural produce, in order to lessen dependence on agriculture as the prime employment industry.
- Effect land tenure systems that promote effective land management.
- Establish and maintain waste disposal infrastructure.
- Involve communities in ecosystems management, with projects that directly benefitting them forming an integral part of the management effort.
- Introduce economic incentives and disincentives (polluter-pays and user-pays principles).
- Enhance public awareness.

3.4 MANAGEMENT CHALLENGES

Governance

Governance is a central water resources issue in Africa, especially in light of water scarcity and environmental changes. An increasing number of countries are developing new policies, strategies and laws for water resources development and management, based on the principles of IWRM that focus on decentralization, integration and cost-recovery. Countries undergoing water sector reforms usually restructure their institutional and legal frameworks, including establishment of river and lake basin organizations.

The multiplicity of transboundary water basins in Africa has led to international cooperation and action plans, examples being establishment of the Africa Ministerial Council on Water (AMCOW), and the Africa Water Task Force to steer the processes. Through NEPAD, a Short Term Action Plan (STAP) was prepared, aiming to strengthen the enabling environment for effective cooperative management and development of transboundary water resources, and to initiate the implementation of prioritized programmes. The Southern African Development Community (SADC) Protocol on Shared Watercourses, and the Nile River Basin Initiative (NBI), are examples of transboundary cooperation that unlock development potential and seek win-win benefits.

Groundwater

Significant scope exists to incorporate groundwater considerations in water treaties and protocols. Africa has a number of transboundary groundwater basins that must be managed in a cooperative manner, and for which management systems will need to be developed. Although it is necessary to manage water resources at national and sub-regional levels, their management also is effective at the local level. Community-based natural resources management, especially water management, plays a critical part, within holistic and integrated approaches, for solving water-scarcity problems. Key components of successful local water management include decentralized decision-making, accountability, and fostering ownership.

Opportunities for action

- Establish improved legislative and institutional frameworks with enhanced transparency and accountability that address:

- basic principles, such as equity and efficiency, in water allocation and distribution;
- regulatory regimes such as surface and groundwater use, pollution control, etc.;
- the roles of government, civil society and the private sector and their responsibilities regarding management and administration of water resources.

- Implement an IWRM approach at local, national and transboundary levels by:
  - using the catchment and basin as basic management units;
  - increasing international cooperation in managing shared water courses and basins;
  - balancing different water uses (e.g., for socio-economic development versus maintenance of ecosystem integrity);
  - decentralizing responsibilities to lowest appropriate levels;
  - ensuring broad stakeholder participation and involvement in water resources programmes and projects.
- Establish risk management frameworks to accommodate climate variability and change, and water-related disasters.

Box 3.4.1: Nile Basin Initiative

The Nile River is the world's longest river, transversing almost 6,700 km (4,163 mi) through 10 countries, from the Kagera River in Burundi and Rwanda, to the delta in Egypt. The Nile River Basin is home to 160 million people, and in spite of the basin's extraordinary natural endowments, they face considerable challenges, including poverty, political instability, rapid population growth, and frequent natural disasters, all placing additional strains on the water resources.

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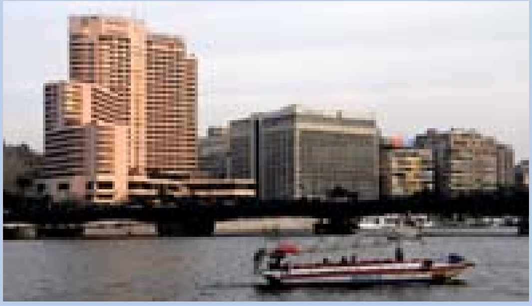

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Nile River: From Khartoum to Cairo

Over the past 4 decades, various Nile countries have engaged in cooperative activities. In 1999, however, all riparian countries united in the common pursuit of long-term development and management of the Nile waters, establishing the Nile Basin Initiative (NBI). The NBI provides a basin-wide framework guided by a shared vision; namely "To achieve sustainable socio-economic development through the equitable utilization of, and benefit from, the common Nile basin water resources."

To translate the NBI's vision into action, a Strategic Action Programme has been formulated to identify and prepare cooperative projects in the basin. These include projects addressing issues related to efficient water use for agriculture; water resources planning and management; stakeholder involvement; environmental management; and power trades. Some projects, including those aimed at harnessing energy, are nearing implementation.

The inclusion of all countries in a joint dialogue opens up new opportunities for realizing win-win solutions. It also holds the promise for potential greater economic and political integration of the region, with benefits exceeding those derived solely from the river itself.

Source: www.nilebasin.org/SVP_Overview.html; Photos: Len Abrams

3.5 KNOWLEDGE GAPS

Capacity Building and Partnerships

The opportunity should be taken to strategically link capacity-building to water resources management, through its systematic inclusion in IWRM plans. The capacity should be developed at all levels. Tailor-made capacity-building programmes for Africa can be developed and sustained which include institutional, human (technical and managerial), material and technological, as well as financial aspects. Creative approaches can be applied, including: (i) networking of education and training institutions, nationally and internationally (such as CapNet, GWP); (ii) establishing and sustaining national and international centres of excellence for critical issues; (iii) enhancing distance education (e.g., UN Water Virtual Learning Centre); and (iv) strengthening partnerships with international training institutions (e.g., UNESCO IHE Institute for Water Education).

Opportunities should be taken to establish partnerships with civil society and the private sector, in order to enhance the implementation of community projects, particularly targeting the poor.

Because of past neglect, political will and a strategic approach are essential to address the issue of capacity strengthening and retention. Progress has been made in the Pan African Conference on Implementation and Partnership on Water (PANAFCON 2003), where delegates concurred that the biggest challenge to be immediately addressed in order to achieve the African Water Vision and the MDGs is human and institutional capacity-building.

Monitoring and Assessment of Water Resources

A constraint facing Africa to date has been that authorities lack adequate human (technical and managerial), financial and material resources to plan and implement water and sanitation policies and programmes. Another constraint is the problem of retaining trained and highly-skilled personnel. Linked to inadequate human and financial capacity is lack of adequate data on water resources for planning, developing and implementing projects. Monitoring and assessment programmes must be improved, and often re-established.

To establish adequate monitoring and assessment programmes to answer today's questions, and to prepare for tomorrow's challenges, new and emerging monitoring technologies (e.g., ESA/UNESCO TIGER/SHIP Earth Observing Programme) exist that can be exploited (PANAFCON 2003 recommendation). Further, certain institutions have been established (e.g., International Institutions for Geo-Information Science and Earth Observations) that can underpin such advances, providing on-the-ground monitoring, assessment and associated capacity development.

Mainstreaming Gender

Central to integrated, basin-level water management is the interests of the people who carry the water to their homes or fields, in order to ensure a minimum level of welfare. Women are usually the ones most directly concerned with a family's water-supply. They also play a pivotal role in agriculture, by providing labour in fields. Although the pivotal role of African women in providing and safeguarding water for domestic and agricultural use is widely recognized, they have a much less influential role in the management and decision-making processes related to water resources, compared to that of men.

Sustainable water resources management requires that the role of women be reflected in institutional arrangements for developing and managing water resources. Further, men and women alike must have influential roles at all levels in water resources programmes, including decision-making and implementation. Mainstreaming gender concerns can accelerate achievement of sustainable water management by improving the access of women and men to water and water-related services to meet their essential needs.

In realizing the active and effective participation of women in IWRM, consideration must be given to how societies assign certain social, economic and cultural roles to men and women. These social and cultural differences require tailor-made approaches, mechanisms and activities for women to participate in IWRM.

Box 3.5.1: Boxed Mindset: Times are Changing

Water provision has traditionally been a woman's responsibility in many societies. In fact, it is not the men in developing countries who spend an estimated 40 billion hours a year hauling water from distant and frequently polluted sources. Rather, women have been reported as spending as much as 8 hours a day carrying up to 41 kg (88 lb) of water on their heads or hips.


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Source: www.treehugger.com/files/2006/12/the_hippo_water.php

Box 3.5.2: Progress with Disaster Management in the Seychelles

For about 20 years after its independence, the Seychelles Islands were fortunate in escaping major environmental and natural hazards. This situation changed with the 1997 El Nino floods that struck the Seychelles, raising public and government awareness about the necessity of strategic disaster management. A National Strategy for Risk and Disaster Management was drafted in 2004, and in October of the same year, Seychelles created a National Disaster Secretariat. The Secretariat acts as the operational arm of a National Disaster Committee. Mahé, the largest island in Seychelles, took the full force of the tsunami on 26 December 2004. The seawater was driven hundreds of metres up into the city drainage system, blocking pipes with silt and flooding roads, shops and houses.

Source: After the Tsunami: Rapid Environmental Assessment (UNEP 2005b)

Opportunities for action

- Enhance capacity and develop tailor-made capacity-building programmes by:
  - strengthening networking of education and training institutions, nationally and internationally, and strengthening partnerships;
  - developing human and institutional capacity for IWRM at appropriate levels;
  - mainstreaming gender issues in IWRM capacity-building, and at all levels in water resource policies and programmes, including decision-making and implementation;
  - secure and retain skilled and motivated water professionals;
  - enhance research and development.
- Develop effective systems for monitoring, collection, assessment and dissemination of data and information on water resources by improving or re-establishing water resources monitoring and assessment, and improving access to, and sharing, water-related information and data.

- Specific opportunities for actions include:
  - strengthening and establishing basin institutions with adequate capacity to function well;
  - establishing better and longer term time-series of water-related data and information, especially on water quality (pollution) and groundwater resources;
  - establishing the impact; of climate variability and change on water resources, and strengthening disaster management for extreme environmental events (e.g., early warning systems);
  - exploring different mechanisms that fit into the social and cultural context of communities for increasing women's access to decision-making processes and participation in IWRM.

4. CONCLUDING REMARKS

The assessments clearly illustrate that Africa's water resources are already facing serious risks, with the situation only expected to worsen. Thus, the results of this study should be regarded as a significant starting point for undertaking comprehensive vulnerability assessments of Africa's river, lake and aquifer basins, in order to inform the management of vulnerability risks at various levels. Further, more data must be collected and analysed, both to better understand the changes that have already occurred in these ecosystems, and to establish baseline data for assessing future changes. If policy and management decisions are to have any hope of ensuring sustainable use of water resources, they will have to be informed by sound scientific assessments that call for a more comprehensive evaluation, focusing on specific issues at the sub-regional level, from which specific action at local and sub-regional levels can be developed.

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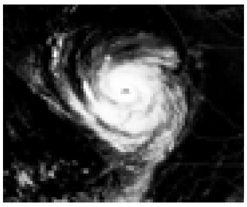
FRESHWATER under THREAT

Vulnerability Assessment of Freshwater Resources to Environmental Change

A JOINT AFRICA-ASIA REPORT

PART 2: ASIA








North East Asia • South Asia • South East Asia

KEY MESSAGES

Rapid population growth and progressive economic development, coupled with unsustainable management of water resources in Asia, have escalated the sensitivity of freshwater systems to environmental changes. This summary highlights new insights into the vulnerability of the freshwater systems in nine major river basins [Chang Jiang (Yangtze) (CRB); Huang He (Yellow) (HRB); Orkhon (ORB); Songliao (SLB); Tuul (TRB); Ganges-Brahmaputra-Meghna (GBM); Helmand; Indus; Mekong (MRB)] of North East, South and South East Asia, providing critical points of reference to identify policies to reduce vulnerability.

The case study basins illustrated a variety of water-related challenges to Asia that encompass floods in the monsoon, water scarcity in the summer, sedimentation and erosion in the rivers and flood plains, drainage congestion in low-lying areas, and environmental and water quality issues.

- **Water availability in the basins is very uneven across space and time, often leading to extreme events.** Although water is abundant over the annual cycle in most of the case study basins, there is considerable spatial and temporal variation of water availability within an individual basin. In the GBM basin, for example, about 30 per cent of the basin area - home to about 40 per cent of its population - is water-stressed. In the Indus basin, half of the water resource is consumed in the upper portion of the basin. On a temporal scale, the influence of intense monsoons is prominent in some of the basins, an example being the Mekong River, where more than 80 per cent of the annual water in the basin is generated during the monsoon. Intense monsoon also is responsible for large floods in parts of CRB, SLB, GMB, Indus, and MRB. It is anticipated that global warming will further affect the water balance, exacerbating the extreme situations in these basins. Thus, policies are essential for equitable use of water resources throughout the basins, as well as advocating preparedness as the chief response to extreme events.

- **A large number of people still lack access to safe drinking water and improved sanitation.** In South Asia, a total of 128 million people in the three case study basins still lack access to safe drinking water. This represents about 17, 13 and 43 per cent, respectively, of the population in the GBM, Indus and Helmand basins. Access to improved sanitation paints an even more dismal picture. About 454 million inhabitants of the three South Asian basins lack access to improved sanitation. In the MRB of South East Asia, about 26 and 29 million people still lack access to safe drinking water and improved sanitation, respectively. In North East Asia, more than 700 million people in the five case study basins have difficulties in accessing drinking water and improved sanitation. Fortunately, attributable to activities geared towards achieving the Millennium Development Goals (MDGs), about 350 million people in the North East region have benefited since 1995. However, although considerable attention is now given by national and international institutions to the achievements of the water supply MDG, and the Johannesburg target on sanitation, much still needs to be done, especially to remove the anomaly existing in regard to the sanitation goal. Moreover, the situation still calls for priority interventions and investments in water infrastructure, as well as good governance for water supply and sanitation.

- **Uncontrolled groundwater mining is leading to declining levels and groundwater contamination.** Groundwater levels in the case study basins have declined because of intense pumping, posing a threat to soil and water quality. The Indus basin illustrates an extreme situation, with well development in some areas being so intense that water tables are continuously declining, while other areas suffer from the paradox of having high water tables. Localized over-exploitation of groundwater resources has already lowered groundwater tables 2-4 m (6.5-13 ft) in some places, and there have been reports of deteriorating groundwater quality because of intrusion of water from saline groundwater zones. In North East Asia, the economic loss of land subsidence in the Changjiang Delta Region of CRB has reached as high as US$ 42.7 billion (350 billion Chinese yuan [RMB]). Major policy changes in the water sectors are needed in the near future to balance basin-wide groundwater uses, and stabilize declining groundwater levels.

- **Irrigated agriculture is responsible for over-exploitation and low water use efficiency.** Compared to the world average GDP production per unit of water use (about US$ 8.6m^{-3}), most case study river basins in Asia have relatively low water use efficiency (US$ 0.19-3.7m^{-3}). This might be attributed to the large irrigation water usage, where up to 75 per cent of the total irrigation water use is wasted. Up to 97 per cent of the total water use in South Asia is for irrigation, with water use efficiency being as low 35.5 per cent in Pakistan. Irrigated agriculture also represents major water use in North East Asia, where up to 90 per cent is used for this purpose, with the use efficiency being even lower (25 per cent). In MRB, water consumption for irrigation is expected to increase rapidly across the basin, which may restrict current trends of irrigated agriculture expansion in the Mun Chi and Mekong delta sub-basins. Thus, improving water use efficiency through research and development (R&D), economic policy adjustment, and rationalization of economic structures, among others, is one of the keys to reduce freshwater vulnerability in the future.

- **The development of large-scale infrastructure intended to support industrialization and lift society out of poverty may pose risk.** Large-scale infrastructure development, and alterations of the natural water regime, have provoked ecological degradation in many Asian Basins. Cambodia's Tonle Sap (Great Lake), the nursery of the lower Mekong's fish stocks, and Vietnam's Mekong Delta, its "rice bowl," are particularly at risk from alterations in the Mekong River's unique cycle of flood and drought. Stringent implementation of environmental impact assessment before dam construction, consideration of the impacts on the natural river flow, and policy options for sustainable hydropower reservoirs management, and development of alternative source of energy, may reduce the potential risks.

- **Water pollution remains the greatest environmental threat to human and ecosystem health.** Degradation of the Indus delta ecosystem, and loss of its biodiversity, is already a visible phenomenon. Variability of water supply from precipitation, and its management, are considered major factors in the desiccation of Sistan wetlands in the Helmand basin. The poor quality surface water in the GBM basin, resulting from pollution from domestic and industrial sources, has led to increasing groundwater extraction for agricultural and domestic consumption. This has resulted in mineral arsenic at higher than safe levels being mobilized into groundwater areas with alluvial soil. Increasing salinity in the coastal ecosystem is responsible for degradation of mangrove forests and biodiversity of the Sundarbans. According to 2006 official statistics, only 41 per cent of the waterbodies in 7 major water systems in China are classified under water quality standard III (i.e., source of drinking water, swimming zone, aquaculture areas), 32 per cent are in standard IV and V (i.e., water for industrial use and recreation without direct contact; water for agriculture and landscape), while 27 per cent are worse than standard V. As a result, many endemic and endangered species of fish, amphibian, waterfowl, and aquatic mammals are being threatened with extinction. The great majority of well-studied species are declining in distribution, abundance or both. The population of Changjiang River dolphin (Lipotes vexillifer Miller), for example, has rapidly declined from about 100 in 1995, to near extinction in 2006. A vigorous implementation of wastewater management (reuse, recycling and treatment), and policies to encourage ecosystem preservation, could improve ecological health in the basins.

- **Meaningful cooperation among the riparian countries for integrated basin management is lacking.** Agricultural and economic development poses challenges to equitable sharing of water among the riparian countries in transboundary basins. In the GBM and Helmand basins, for example, transboundary coordination remains a major issue among the riparian countries. For the GBM basin in particular, this includes sharing of river waters, cooperative development of water resources, and sharing of data and information on common rivers to facilitate flood forecasting and water quality control. In addition to lack of integrated management of water resources in the upper portion of the basin, cooperation between Afghanistan and Pakistan in the Indus Basin is essential for the sustainable management of the Kabul sub-basin. Competition over water resources between the various water uses and users among riparian countries in the MRB has increased rapidly in recent times, especially during the dry season. Off-stream uses are directly competing with in-stream flows for hydropower production, fisheries, wetlands and navigation. The water demand for balanced river ecology, and for combating saltwater intrusion and sustaining estuarine and coastal ecosystems, is a major concern in the Mekong River Basin. In North East Asia, although not considered international basins, CRB and HRB also are faced with inter-province management issues. The water use among the provinces is unbalanced, due to the varying status of economic development, and consequent differential water demands. These aspects call for water-centered and water-based cooperation among all countries or province in the basins. A broad-based policy adoption involving participation at all decision levels, more transparency in operation, better rational management approaches, and a win-win tool for sharing of information among stakeholders will be crucial.

- **Urgent policy attention and accelerated research into climate change impacts on water infrastructure and management practices is a pre-requisite if serious water-related vulnerability are to be avoided in the future.** Studies in Asian basins show overwhelming that water-related vulnerability will be exacerbated because of global climate changes. Yet, most countries in Asian basins lack the adaptive capacity to cope with future impacts, and have paid inadequate attention to adaptation policies and measures. Such lack of attention can be largely attributed to the current state of knowledge regarding likely future spatial and temporal distributions of climate and hydrological variables over a country as a whole, let alone for specific management units considered for planning purposes. What is needed is not restricted only to future annual average climate and hydrological information, but also includes the extent of likely inter-annual and intra-annual variations. Thus, reducing water vulnerability in the future will require additional knowledge, and relevant needed research must receive much higher priority from both national governments and external support agencies.

1. INTRODUCTION

Asia's underdeveloped condition has escalated its people's sensitivity to environmental changes. Environmental changes affect the ability of water resource systems to effectively and efficiently function, making water resources vulnerable in terms of quantity (over-exploitation, depletion, etc.) and quality (pollution, ecological degradation, etc.). Thus, understanding the vulnerability of water systems in Asia is essential for developing policy actions at the local, national and transboundary levels. With serious consideration of this fact, the study is undertaken to enhance our understanding of the factors determining water resources vulnerability in Asia, and to serve as a point of reference to identify proactive appropriate remedial measures.

The objectives of the assessment are closely related to the commitment of the international community to implement Integrated Water Resources Management (IWRM). The focus, therefore, is on river basin scale assessments. Nine river basins from North East, South and South East Asia are considered for this first assessment. Unlike traditional assessments, the study relied to some extent on informed estimates, which were later validated with recourse to the views of better-informed experts and published documents, including Internet resources. As such, numerical validity was not the core issue. Rather, the direction of causality related to vulnerability outcomes is emphasized. Nevertheless, this assessment is not a substitute for rigorous quantitative analysis, but rather should lead to more detailed assessments. Thus, this study should be treated as the first edition of a future comprehensive analysis.

Objectives

1. To examine water issues of selected river basins, and investigate the integrated impacts of potential environmental changes on water resources.
2. To evaluate the impacts of environmental change, in terms of water resources stresses and management challenges. (A water resource system is considered stressed if it is unable to deliver the necessary water for environmental, social, and economic purposes).
3. To complement the efforts and activities of governments, NGOs, and development agencies engaged in improving the status of water, by providing facts, figures and analyses related to water resources vulnerability.
4. To develop the knowledge and understanding necessary for forward-looking cooperation among riparian states in addressing competing water demands.

The general process adopted in the assessment is divided into two phases: (i) assessment of selected river basins, synthesized into sub-regional reports; and (ii) consultations with stakeholders and experts through review workshops, to ensure the correctness of data and the validity of the findings.

Methodologically, the vulnerability of water resources is assessed from two perspectives: (i) main threats to water resources, its development and utilization dynamics, including allowance for ecosystem maintenance; and (ii) the management challenges in coping with threats (UNEP-PKU 2009a). The threats are assessed in terms of: (i) resource stress; (ii) development and use conflicts; and (iii) ecological insecurity. Challenges in coping capacity are measured in terms of management capacity at the basin scale. Thus, this assessment marks a considerable departure from the preconceived notion of water vulnerability being synonymously linked to 'water crisis.' Evaluation of the different components of vulnerability are based on related indicators (Figure 1), considering a number of constraints related to data and information, including lack of access to some official data and wide seasonal and spatial variations in the basins' hydrology. A Composite Vulnerability Index (VI) is calculated based on four components of water vulnerability: (i) resource stresses; (ii) development pressures; (iii) ecological insecurity; and (iv) management challenges.

This summary highlights the key policy-relevant findings in Asia. It is based on the 3 sub-regional reports on water vulnerability, comprising North East, South and South East Asia (UNEP-PKU 2009).

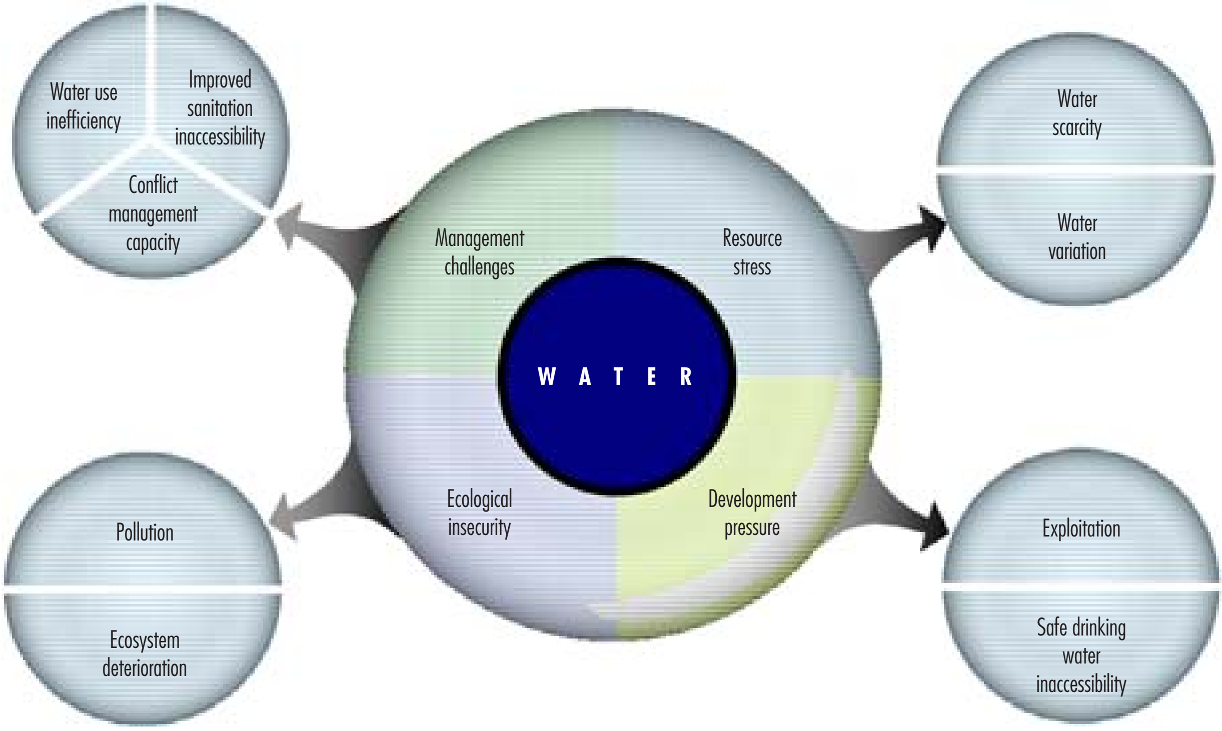


Figure 1: Freshwater vulnerability components and indicators

Source: UNEP-PKU 2009a

2. ASIAN SUB-REGIONS AND THEIR WATERS

Asia is the world's largest and most populous continent. It covers 8.6 per cent of the earth's total surface area (29.4 per cent of its land area) and, with almost 4 billion people, contains more than 60 per cent of the world's current human population. It also accounts for almost two-thirds of global population growth. Within the next 10 years, the Asian population is expected to grow by nearly 500 million, with virtually all this growth expected to be in urban areas (ADB 2007). Asia comprises 5 sub-regions, including (i) central Asia (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan); (ii) North East Asia (China, Japan, Mongolia, North and South Korea); (iii) South Asia (Afghanistan, Bangladesh, Bhutan, India, Iran, Maldives, Nepal, Pakistan, and Sri Lanka); (iv) South East Asia (Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor–Leste, and Vietnam); and (v) South West Asia (Armenia, Azerbaijan, Bahrain, Cyprus, Georgia, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Palestinian Territories, Qatar, Saudi Arabia, Syrian Arab Republic, Turkey, United Arab Emirates and Yemen).

Given its size and diversity, countries in Asia differ in climatic, physical, social, economic, environmental, and institutional conditions, thereby not being homogeneous in their social and economic development, or in the different factors likely to affect their development processes. Thus, a generalized picture of water-related trends in Asia that are equally applicable all over the region cannot be drawn. In this study, therefore, 3 sub-regions of Asia (North East, South and South East) are considered, and described briefly in this section (Figure 2).

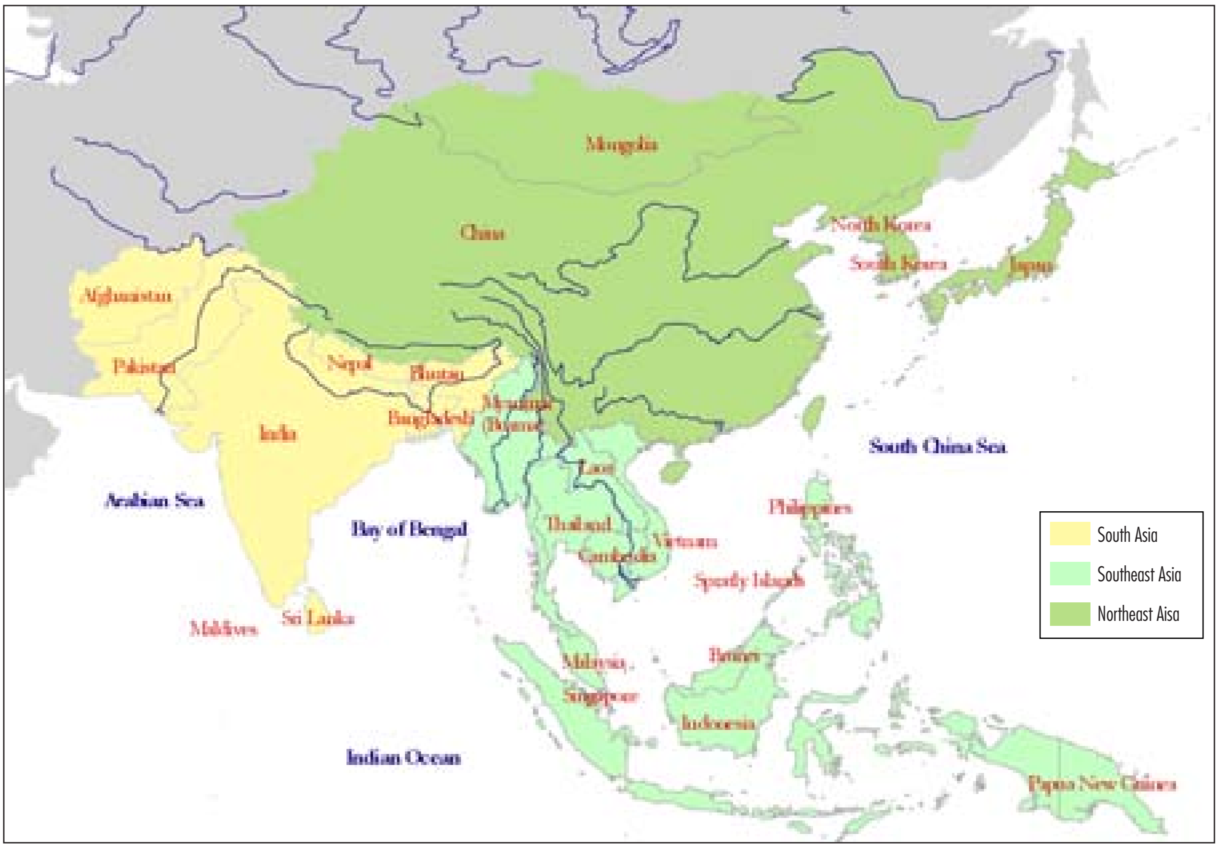


Figure 2: Three Asian sub-regions considered in this study

Source: UNEP-AIT 2008, 2009

North East Asia

North East Asia covers a vast area of 11,764,596 km^2 (4,542,336 mi^2), bordering the Pacific Ocean. It has a total coastline of 86,199 km (53,562 mi) and more than 22,000 islands. It is composed of 5 countries; namely, the People's Republic of China, Mongolia, Japan, Republic of Korea, and Democratic People's Republic of Korea, with over 1.5 billion inhabitants (2006) representing one-fourth of the world's total population. With a population density of about 128 person.km^{-2} (332 persons.mi^{-2}), it is considered to be one of the most densely-populated areas in the world. In 2002, there were about 335 million people with difficulties in accessing improved drinking water, and about 751 million people without access to improved sanitation, of which 78.3 per cent are distributed in the rural areas. The total GDP of North East Asia in 2006 was US$7,635 billion, with a per capita GDP of US$5,062. Although this figure is still only three-fifths of the global average per capita GDP, a progressive increase in GDP in recent years demonstrates the fast economic development characterizing this region.

North East Asia also is characterized by complex geographic and topographic features, with a rich combination of temperature-precipitation patterns forming its continental, oceanic and monsoon climates. Based on the annual accumulated temperature (with daily mean temperature higher than 10° C [50 °F]), North East Asia is divided into 5 temperature zones: (i) tropical; (ii) sub-tropical; (iii) warm temperate; (iv) middle temperate; and (v) cold temperate. The annual precipitation (about 1,100 mm [43 in]) decreases from the east to the west, and from the south to the north. Based on the iso-precipitation line, about 54 per cent of the sub-region belongs to the humid and semi-humid zones, and the other 46 per cent being in the semi-arid and arid zones.

The total water resources in North East Asia (excluding DPR Korea) are 3,351 billion m^3 (BCM), and the per capita water resource is 2,221 m^3, one-fourth of the global mean level in 2006. There is a general trend of decreasing precipitation and increasing air temperature, however, that may affect its water balance (see Figures 3 and 4).

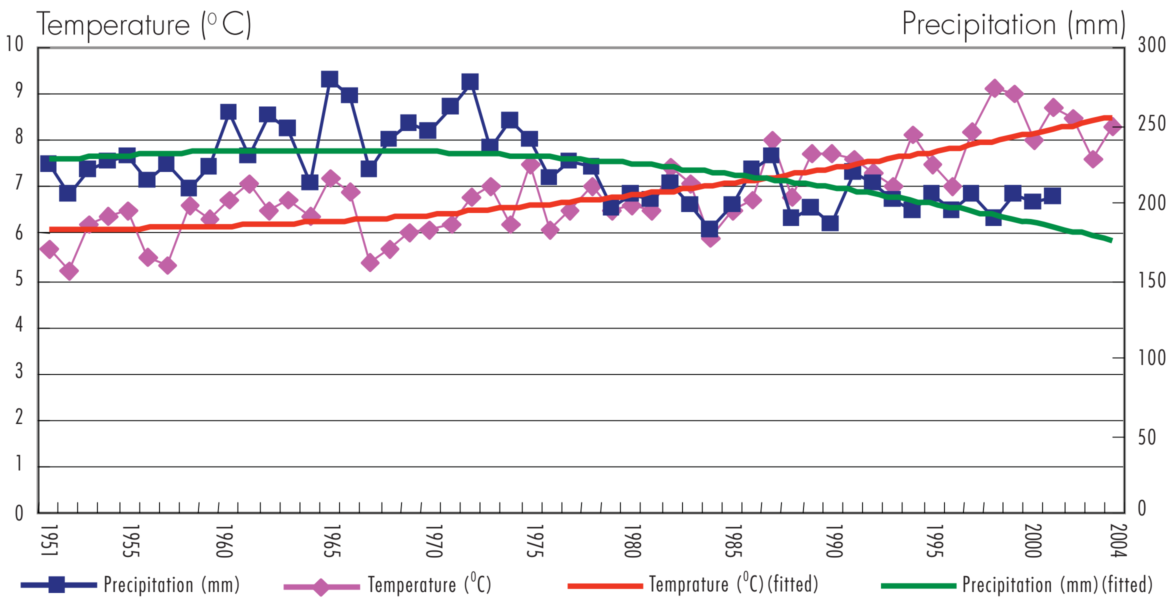


Figure 3: Changes in annual mean temperatures and precipitation over 50 years at Baotou City, in middle reach of Huanghe River Basin

Source: China Meteorological Data Sharing Service System CMDSSS; http://www.cma.gov.cn), redrawn by UNEP

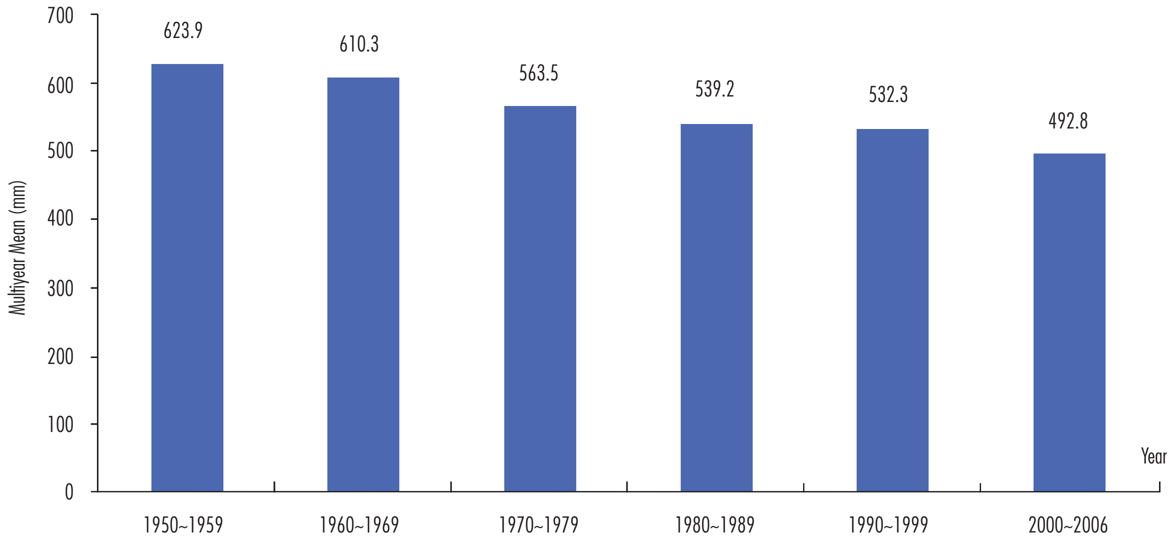


Figure 4: Multi-year mean precipitation in North East Asia sub-region

Source: UNEP-PKU (2009b), redrawn by UNEP

China presently has the largest proportion (83.6 per cent) of the total water resources in the North East Asia sub-region, while Mongolia has the smallest share (1.0 per cent). Japan and Korea have the remaining 15.4 per cent of the total water resource. In terms of per capita water resources, Mongolia, with the lowest population, ranks the highest at 138,400 m^3, followed by Japan at 3,125 m^3, R. Korea at 2,389 m^3, and China at 2,152 m^3. The water supply comes mainly from precipitation (70-80 per cent) during the rainy season, while groundwater, stored water and melting snows supply water needs in the region during the dry season.

The total water use in North East Asia (excluding DPR Korea) is 684.3 billion m^3. It accounts for about 29.7 per cent of the total global quantity, while the per capita water use is 454 $m^3.yr^1$, nearly 1.2 times the world average. Nearly 60 per cent of the total water use is for agricultural purposes. In the developing countries (China; Mongolia), more water is used for industrial purposes and for domestic use, contrary to the situation observed in developed countries (Japan; R. Korea) in the region.

North East Asia is home to about 28 of the world's river basins, including 10 international river basins (Figure 5). The rivers are characterized by long flowing distances, having a total length of 493,000 km (306,336 mi), with more than 80 per cent of the rivers being longer than 200 km (124 mi), and about 40 per cent being longer than 500 km (311 mi). The rivers are also large in areal terms, with nearly 2,000 rivers having land areas exceeding 1,000 km^2 (386 mi^2). Most rivers originate from high mountains, often 2,000 m (6,562 ft) above mean sea level, thereby providing a significant potential for hydropower development.

Figure 5: International river basins in North East Asia sub-region

Source: UNEP 2002a

The assessment of the vulnerability of water resources in North East Asia considers detailed analyses of 5 river basins, including the Changjiang (CRB), Huanghe (HRB), and Songliao (SLB) River Basins in China, and the Orkhon (ORB) and Tuul (TRB) River Basins in Mongolia.

The Changjiang River Basin (CRB) is one of the most water-rich regions in China, with a total area of 1,808,500 km^2 (698,266 mi^2). In 2005, its mean population density exceeded 265 persons.km^{-2} (686 persons.mi^{-2}). The basin's total water resources are 1,028.52 billion m^3, while the annual water uses total 171.891 billion m^3. About 57 per cent is used for agricultural purposes, 32 per cent for industry, and 11 per cent for domestic use.

In contrast to the CRB, the Huanghe River Basin (HRB) is one of the most water-scarce regions in China, with a total area of 795,000 km^2 (306,951 mi^2) (including 42,000 km^2 (16,216 mi^2) of endorheic basin). The mean population density in the HRB in 2005 exceeded 503 person.km^{-2} (1,303 persons.mi^{-2}). The basin's total water resources are 59.78 billion m^3, while mean annual water use is 38.8 billion m^3. About 77.2 per cent of water use is for agriculture, 14.4 per cent for industry, and 8.4 per cent for domestic purposes.

The Songliao basin (SLB), covering 1,249,000 km^2 (482,242 mi^2) is generally divided into 2 independent sub-basins; namely, the Songhuajiang (SHJRB) and Liaohe (LHRB) River Basins, and several important international rivers, including the Amur, Sujfu, Tumen and Yalu Rivers. Based on 2003 statistics, the mean population density in SLB was just 95 persons.km^{-2} (246 persons.mi^{-2}). The total water resources are 199 billion m^3, while mean annual water use is 57.98 billion m^3. About 70.6 per cent is used for agricultural purposes, 21.0 per cent for industry, and 8.4 per cent for domestic purposes.

The Orkhon River Basin (ORB) is one of the most important river basins in the central territory of Mongolia, covering an area of 83,012 km^2 (32,051 mi^2). Based on 2005 statistics, the mean population density was as low as about 4 persons.km^{-2} (10 persons.mi^{-2}). The total water resources of ORB are 5.06 billion m^3, with a mean annual water use of 20.43 million m^3. About 20 per cent is used for agriculture, 54 per cent for industry, and 23 per cent for domestic purposes.

The Tuul River Basin (TRB) is the other most important river basin in the central territory of Mongolia, covering an area of 49,841 km^2 (19,244 mi^2). Based on 2005 statistics, the basin's mean population density was as low as 18 persons.km^{-2} (47 persons.mi^{-2}). The total water resources of TRB are 1.28 billion m^3, with a mean annual water use of 53.43 million m^3. Of this total, 9.1 per cent is used for agriculture, 50 per cent for industry, and 40.9 per cent for domestic purposes.

South Asia

South Asia comprises the countries of Bangladesh, Bhutan, India, Nepal and Pakistan, as well as the island nations of Maldives and Sri Lanka, covering some 4.48 million km^2 (1,729,738 mi^2). In terms of its economy, South Asia, with a population of 1.4 billion, is one of the world's fastest-growing regions. Agriculture is crucial to South Asia's economy, contributing 25 per cent of its GDP (compared to the worldwide average of 4-5 per cent), and engaging 58 per cent of the workforce. Yet, the sub-region is a net importer of food. Major constraints on the agriculture sector include low agriculture productivity, and poor management of scarce water resources.

Although home to about one-quarter of the world's population, South Asia has about 9 per cent (3,900 billion m^3) of the world's annual renewable water resource (43,659 billion m^3). Except for Bhutan and Nepal, the per capita water availability in the region is less than the world average. The water use in the region is mainly limited to the agricultural sector, with almost 95 per cent of the withdrawn water being consumed in this sector, much higher than the global average of 70 per cent. The region's underdeveloped condition generally means that limited water resources are used in the industrial and domestic sectors. Thirty-nine percent of the population has better access to improved sanitation in South Asia, compared to the world average of 59 per cent. Water productivity, in terms of GDP.m^{-3} of water use, is low, being less than US$4.5, compared to the global average of US$8.6.

Among the south Asian countries, as the downstream and deltaic portion of the huge Ganges-Brahmaputra-Meghna basin, Bangladesh is naturally vulnerable because of the poor water quality and large water quantity flowing into it from upstream. Because all major rivers flowing through Bangladesh originate outside its borders, any interventions in the upper riparian countries can have a significant impact on Bangladesh. Water-related impacts of climate change and sea level rise are likely to be some of the most critical issues for Bangladesh. Climate change is predicted to increase both coastal (from sea and river water) and inland flooding (river/rain water) in Bangladesh.

Although Nepal is presently considered to be water rich, this situation may change with increasing water demands. Further, climate change-induced future higher temperatures, increased evapotranspiration, and decreased winter precipitation may result in more droughts in Nepal.

Bhutan receives a high quantity of precipitation, although it varies spatially within the country. Of the total precipitation received, the surface runoff constitutes 76 per cent, while 5 per cent is snow, and infiltration comprises 19 per cent. Any temperature increases caused by global warming will result in the retreat of glaciers, increasing the volume of glacial lakes and, ultimately, provoking glacial lake outburst floods (GLOFs), with potentially catastrophic consequences.

Maldives has achieved remarkable success in rainwater harvesting. About 25 per cent of the population currently depends on groundwater for drinking, while the remaining population uses rainwater and desalinated water for drinking purposes.

Water has been central to Sri Lanka's evolution as a nation. Evidently water-rich, the per capita water availability in Sri Lanka is 2,400 m^3, although it is estimated that it will decline to 1,900 m^3 by 2025.

The annual distribution of precipitation in Afghanistan illustrates an essentially arid country, with more than 50 per cent of its territory receiving less than 300 mm (12 in) of rain per year. Although located in a half-desert atmosphere, Afghanistan is still rich in water resources, due mainly to the series of high snowy mountains (e.g., Hindu Kush; Koh-I-Baba). Its internal annual renewable water resources are estimated to be 55 billion m^3.

India is by far the largest country in South Asia, in terms of population and land area, being home to one-sixth of the world's population, and endowed with one twenty-fifth of the world's available water. The basin per capita annual water availability in India varies considerably between 13,400 m^3 in the Brahmaputra–Barak basin, to about 300 m^3 in the Sabarmati basin in western India. Precipitation in Pakistan is markedly variable in magnitude, time of occurrence, and areal distribution. The Indus River is the primary source of water in Pakistan. In areas dependent on water from mountain sources, severe droughts may occur because of decreased winter snowfall on glaciers, with consequent decreased spring and summer runoff in the future.

South Asia is home to some of the world's largest river basins, in terms of catchment areas and flow volumes. This assessment of the vulnerability of water resources in South Asia considers detailed analysis of 3 south Asian river basins, including the Ganges-Brahmaputra-Meghna (GBM), Indus and Helmand basins (Figure 6).

Figure 6: South Asian sub-basins selected for analysis

Source: UNEP-AIT 2008

The GBM basin covers an area of 1.75 million km^2 (675,679 mi^2), stretching across Bangladesh (7.4 per cent), India (62.9 per cent), Nepal (8.0 per cent), Bhutan (2.6 per cent), and Tibet-China (19.1 per cent). The basin is second only to the Amazon in drainage area and discharge volume (UNEP 2006). The basin is characterized by a variety of climatic conditions, ranging from tropical to alpine. At a macro-scale, a monsoon precipitation pattern dominates, with maximum precipitation in the summer. The GBM river system originates partly in China, Nepal and Bhutan, subsequently flowing through India and Bangladesh. The Ganges stretches about 2,525 km (1,802 mi), and the Brahmaputra, the third great Himalayan River, to about 2,900 km (1,569 mi), flowing through Tibet, India and Bangladesh. The Meghna River, 930 km (578 mi) in length, flows southwest, draining eastern Bangladesh and the hills of Assam, Tripura and Meghalaya in India, to join the Ganges River at Chandpur, Bangladesh.

The Indus River Basin is one of the largest river basins in Asia, covering an area of approximately 1.2 million km^2 (463,323 mi^2) in five countries (Afghanistan; China; India; Nepal; Pakistan). The Indus supports a total population of around 215 million, providing needed water resource for extensive agricultural activities, and maintaining the health of ecosystems on which many people depend for the goods and services they provide. The climate of the Indus basin varies from subtropical arid in its lower parts (Singh), and semi-arid in the central basin (Punjab), to temperate sub-humid in the foothills of Upper Indus, and alpine in the mountainous highlands of the north. The rainfall magnitude in Indus is markedly variable, resulting in two distinct seasons, including Kharif (wet) from April to September, and Rabi (dry) from October to March. The basin's main river, the Indus, has a length of about 3,200 km (1,988 mi), making it one of the longest rivers in the Indian subcontinent, and the longest and most important river in Pakistan.

The Helmand River Basin, with a catchment area of 0.3 million km^2 (115,831 mi^2) is inhabited by around 7.1 million people, being shared by Afghanistan, Iran and Pakistan. The basin is confined by the southern Hindu Kush ranges on the north, by the East Iranian ranges on the west, and by the mountain ranges in the Baluchistan province of Pakistan on the south and east (Whitney, 2006). Most parts of Helmand basin are arid, except at its hyper-arid edges. The Helmand river, the main river of the basin with a length of 1,300 km (808 mi), drains from the Siam Koh Mountains to the eastern mountains and the Parowan Mountains, and finally to the unique Sistan depression between Iran and Afghanistan (Favre and Kamal 2004).

South East Asia

South East Asia, occupying 3.35 per cent of the world's total land area, consists of continental margins and offshore archipelagos lying geographically south of China and east of India. Continental South East Asia includes Myanmar, Thailand, Lao PDR, Cambodia and Vietnam, whereas archipelagic South East Asia consists of Malaysia, Brunei, Singapore, Indonesia, and the Philippines. The climate of South East Asia is mainly tropical-hot and humid throughout the year, being significantly influenced by the tropical monsoons originating in the South China Sea.

The sub-region is home to 8.6 per cent of the world's total population, with a population density nearly 2.6 times that of the global average. The urban population comprises 43 per cent of the total population. The yearly urban population growth (3.7 per cent) clearly indicates the problems associated with urbanization will become more evident in the coming years. It is forecast that the sub-region will have three mega-cities (Bangkok; Jakarta; Metro Manila) by 2015, each containing more than 10 million people (UNEP, 2004).

Despite population pressures, the annual per capita water resources availability exceeds 5,800 m^3 in all South East Asian countries, except Singapore. The average annual per capita water resources of 12,980 m^3 in the South East Asian region is almost double the world average. The total water withdrawal is 4.5 per cent of the available water resource, with variation among the countries, being 0.9 per cent in Cambodia, and Lao PDR, and 21.2 per cent in Thailand. The agricultural sector is the major water consumer, sharing 85.5 per cent of the total withdrawal, followed by the industrial sector (7.8 per cent) and domestic sector (6.6 per cent). The productivity of water use, measured as GDP produced per m^3 of water use, is in the range of 0.5 (Vietnam) to 10.5 (Malaysia). Rapidly industrializing and urbanizing countries (Malaysia; Philippines; Indonesia; Thailand) have relatively higher water productivity, reflecting the higher value of water in the industrial sector. Access to safe drinking water and improved sanitation in the South East Asian countries (except Cambodia and Lao PDR) are encouraging, compared to the world average.

The sub-region is home to more than 15 river basins of varying drainage areas and water resources. The major ones include the Chao Phraya, Mekong, Salween, Ca/Song-Koi, Red/Song-Hong, Ma, Tami, Sepik, Fly and Irrawady Rivers (Figure 7). The Mekong is the largest among the South East Asian basins, ranked twelfth among the world's great rivers on the basis of its mean annual flow at the mouth. The Mekong River stretches from the Tibetan Plateau to the South China Sea (MRC 2005), draining a total catchment area of 0.79 million km^2 (305,021 mi^2) (MRC 2007). Although the basin is not characterized by water shortages or open conflicts, its water issues have attracted considerable attention because of the possibility of future threats posed by development pressures on the one hand, and poverty on the other.

The Mekong River Basin can be functionally divided into two parts: Upper Mekong River Basin (UMRB) in China, which contributes 15-20 per cent of the water flowing into the Mekong River, and Lower Mekong River Basin (LMRB) from Yunnan downstream to the South China Sea. The LMRB, including Lao PDR, Thailand, Cambodia and Vietnam, covers about 75 per cent of the whole basin.

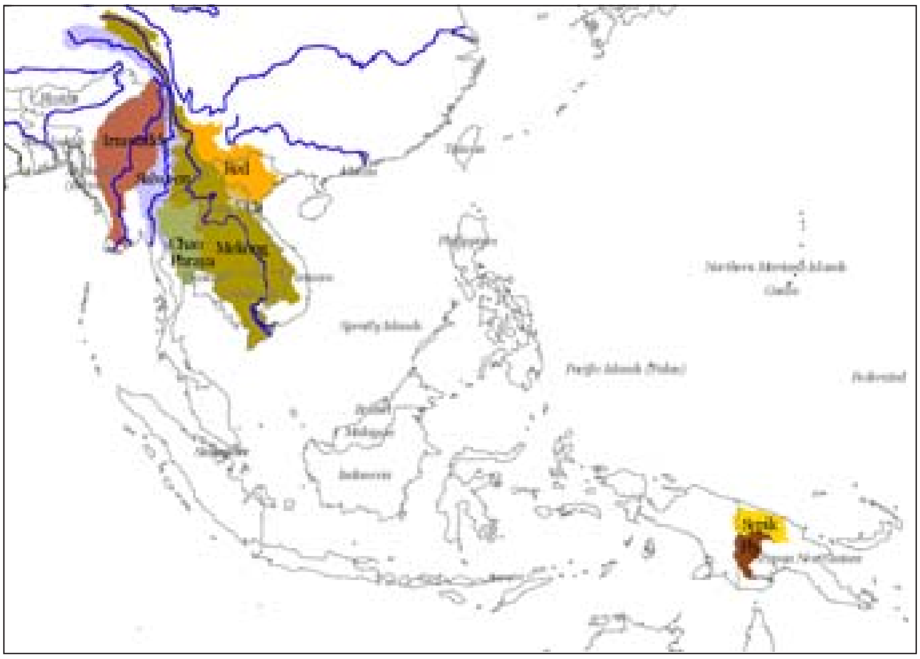


Figure 7: Major South East Asian river basins

Source: UNEP-AIT 2009b

From a physiographic viewpoint, the MRB comprises 6 distinctly different regions: (i) Lancang River Basin (parts of Qinghai province; Tibet autonomous region and Yunnan province in China); (ii) northern highlands (parts of Yunnan Province in China; Lao PDR; Myanmar; Thailand), where hydropower has the greatest development potential; (iii) Korat-Sakon plateau (parts of northern Thailand and southern Lao PDR); (iv) eastern highlands (parts of Lao PDR and Vietnam), the most heavily forested area of the entire MRB and rich in biodiversity; (v) southern uplands (parts of Cambodia); and (vi) lowlands (parts of Cambodia, Lao PDR and Vietnam) which comprise the lake Tonle Sap on the floodplain in Cambodia and the Mekong delta mainly in Vietnam, two important landforms in the basin.

From the perspective of economic livelihoods, the Tonle Sap, or 'Grand Lake' in Cambodia is one of the most important areas in the basin. It is the largest lake in South East Asia and one of the world's most productive freshwater ecosystems (Pantulu 1981), supporting 60–75 per cent of the inland fishing in Cambodia, with harvests that have historically reached 100,000 tonnes (224 million lbs) per year (Rothert, 1995). Further, as a natural reservoir, the Tonle Sap lessens the degree of flooding downstream of the MRB and, during the dry season, also augments downstream irrigation and drinking water supplies. The Tonle Sap provides critical spawning and other habitat to many important migratory fish species, including the giant catfish caught by subsistence and commercial fishermen far up the Mekong River (Pantulu 1986).

3. VULNERABILITY ASSESSMENT

The vulnerability of freshwater resources was explored by isolating strategically-important issues related to different uses of a freshwater system in a basin. Thus, this analysis is based on the premise that a vulnerability assessment of a river basin must have a precise understanding of the 4 components of a water resources system, including their states and relationships. Thus, the approach recognizes that a sustainable freshwater system can only function within an integrative framework, combining the natural and management systems. The most fundamental part of a current vulnerability assessment is able to account for 3 different components related to the natural resource base, and how other factors (climate change; biophysical conditions; policy and management practices; etc.) influence the processes that make the natural system vulnerable. Considering a number of constraints related to data and information, as well as wide seasonal and spatial variations in the basins' hydrology, the evaluation of the different components is based on the related indicators (see Figure 1).

Resource Stress

The water resources of a river basin are stressed when the available freshwater fails to support socio-economic development, thereby failing to maintain a healthy ecosystem. Freshwater availability can be expressed as the per capita availability of water resources in a basin, and the variation of precipitation. The first parameter is related to the richness of water resources and dictates to what degree it can meet the demands of the population, while the second encapsulates the uncertainty associated with the availability of water. For benchmarking water availability, 1,700 $m^3.capita^{-1}.yr^{-1}$ is taken as the threshold value for a water-stressed condition (Falkenmark and Widstrand, 1992). For benchmarking the variation of precipitation from year-to-year, a coefficient of variation (CV) of 0.3 is taken as the critical level beyond which the water resources system is considered vulnerable.

Asian basins exhibit starkly contrasting pictures, in terms of annual per capita water availability. The CRB, GBM, Helmand and Mekong basins are endowed with abundant natural water and per capita water availability, ranging from 7,000 $m^3.capita^{-1}$ in the Mekong River Basin, to 2,300 $m^3.capita^{-1}$ in the CRB. The rivers in the CRB and GBM are supplied by monsoon rains and snowmelt. The Helmand River Basin, though located in the half desert atmosphere, is rich in water resources, due mainly to the presence of high snow-covered mountains, which feed the tributaries of the Helmand River. Although the available water resources in the ORG are low in volumetric terms, its low population density results in a high per capita water resources availability.

Nevertheless, although annual water is abundant at the basin scale, there are considerable spatial and temporal variations in water availability within any basin. About 30 per cent of the GBM basin area, for example, which is home to about 40 per cent of the population, is water stressed. On a temporal scale, the influence of intense monsoon is prominent in some basins. In the Mekong River Basin, for example, more than 80 per cent of the annual water is generated in the monsoon. Although Mekong River sub-basins are expected to provide an adequate level of annual per capita water resources, the Lower Mekong Delta region will be a hotspot for intervention, in terms of securing adequate water. Intense monsoon also is responsible for large floods in parts of some of the basins, especially the CRB, SLB, GMB, Indus and MRB. Floods inundate extensive areas of highly-productive floodplains, including those around the Great Lake (Tonle Sap) system in Cambodia, the single largest wetland area in the MRB and the deltaic regions of the GBM basin (see Box 1).

Box 1: Bangladesh: Young, flat and vulnerable

Situated at the head of the Bay of Bengal, most of Bangladesh is a delta formed by the convergence of three great rivers – Ganges, Brahmaputra and Meghna. Eighty percent of Bangladesh is less than 1.5 m (5 ft) above sea level. Every year during the monsoon season, the rivers flood half the country to a depth of 30 cm (12 in). The floods, which last for several months, have the environmental benefit of bringing fertile silt, but also cause great disruption. These annual floods, however, are insignificant compared to the really disastrous floods caused by tropical cyclones. In 1970, a tropical cyclone and tidal surge killed more than 450,000 people. A repeat of this disaster occurred in 1991, when 125,000 people were killed. More recently, in November, 2007, the cyclone that struck Bangladesh affected about 8.5 million people, destroying nearly 564,000 homes. The death toll reached 3,268 (VOA News, 2007). The cyclone also dealt a severe blow to the Sundarbans, destroying 1,528 km^2 (590 mi^2) of the forest, out of around 6,000 km^2 (2,317 mi^2), according to forest officials' primary assessment. Of the devastated areas, totaling about one- quarter of the forest, 1,200 km^2 (463 mi^2) are land, with the rest being waterbodies.

Source: Daily Star Newspaper, Nov. 30, 2007 and www.voanews.com/english /2007-12-04-voa25.cfm

It is expected that global warming will further affect the water balance, exacerbating the flooding situation in these basins, and putting communities, biodiversity and infrastructure at risk of being damaged (see Box 2).

Box 2: Climate Change Impacts Vulnerability

Basin	Population at risk (number of people)	Population at risk (per cent)	Area potentially lost (km^2)	Area potentially lost (per cent)
GBM	3,430,000	39.38	4,802	18.8
Mekong	1,910,000	21.93	2,858	11.2
Changjiang	484,000	5.56	1,081	4.2
Indus	7,200	0.08	185	0.7
Huanghe	3,760	0.04	58	0.2
World	8,710,000		25,487	

Box 2: Climate Change Impacts Vulnerability *(continued)*

Many parts of Asian basins are densely populated, often being impacted by climatic extremes (floods, droughts) and external marine influences (typhoons, cyclones, storm surges, coastal erosion). Projections of future climate change impacts on climatic extremes suggest a dire situation. Ericson et al. (2006) used a generalized modelling approach to approximate the effective rate of sea level rise under present conditions, basing estimates of sediment trapping and flow diversion on a global dam database, and modifying estimates of natural subsidence to incorporate accelerated human-induced subsidence. Based on a coarse digital terrain model and global population distribution data, they estimate that about 5.82 million people will be directly affected by 2050 in three Asian basins: Changjiang, GBM and Mekong. This will constitute about 67 per cent of the population affected by climate change and sea level rise around the world. Externally, the sediment supplies to many Asian deltas have been reduced by construction of dams, and there are plans for many more dams in the future. The reduced sediment supplies and expected sea level rise may inundate about 9,000 km^2 (3,475 mi^2) of coastal land in Asian basins, representing about 35 per cent of the area that can potentially be lost on a global scale by 2050 if no mitigation actions are taken now. Further, the impacts of climate change could be more pronounced in megacities located in some Asian basins, where natural ground subsidence is enhanced by human activity, examples being Shanghai in the Changjiang delta, and Tianjin in the Huanghe delta)

Source: IPCC 2007; Ericson et al. 2006

In the Indus River Basin, the annual available water resource is about 290 billion m^3, and the annual per capita water availability is about 1,330 m^3. Despite a general water scarcity on the basin scale, sufficient water availability in the lower portion of the Indus basin (including the delta) suggests spatial variability of water resources (Figure 8). The Pakistan portion of the Indus drains higher water resources in the basin, compared to other riparian countries. The large population in the Pakistan part of the basin, however, has reduced annual per capita water availability below the annual threshold of 1,700 m^3.

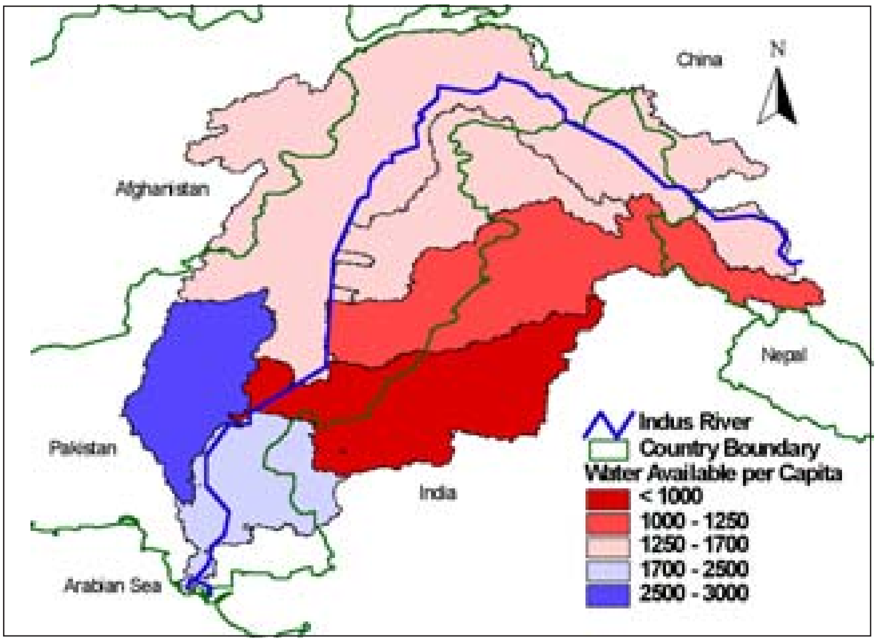
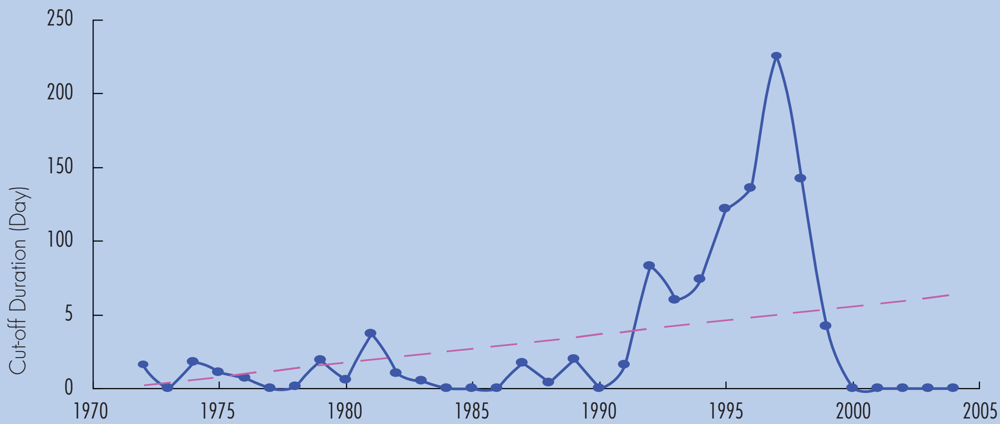


Figure 8: Annual water availability in Indus basin (m^3.capita^{-1})

Source: UNEP-AIT 2008

The water balance of the HRB water balance is not conducive to farming, with nearly 80 per cent of the precipitation received in the basin returning to the atmosphere via evapotranspiration. The per capita water availability is about 540 $m^3.capita^{-1}$, highlighting the most stressful situation among the Asian basins. In the semi-arid and arid zones of the HRB, decreasing trends of precipitation and runoff have been observed over the past 4 decades, being responsible for the partial river cut-off (or dry-up) in the lower reach of the Huanghe River. Because of the implementation of the South-North Water Transfer Project (SNWTP) since 2000, however, and strict control of water consumption in the upper and middle reaches of the Huanghe River, the duration of river cut-off in the lower reach was considerably reduced during 2000-2004 (see Box 3). In the SLB, although the basin represents one of the most water-rich basins in China, the per capita water availability (about 1,500 $m^3.capita^{-1}$) still represents a stressful condition.

Box 3: Cut-off (dry-up) of Huanghe River in HRB



River cut-off (i.e., the number of days the river is dry at a point) of the Huanghe River was a frequent annual event during the 20th century. During the 27 year period from 1972 to 1999, 22 annual river cutoffs – lasting a total of about 9 months – were observed at Lijin in the lower reach of the Huanghe River. Implementation of the South-North Water Transfer Project (SNWTP) in 2000, however, and strict control of water consumption in the upper and middle reaches, considerably reduced the duration of river cut-off in the lower reach during 2000-2004.

Source: Chen & Mu, 2000; Wang & Zhu, 2002; Li, 2005, redrawn by UNEP

Development Pressure

The development rate of water resources is used to demonstrate a basin's ability to support a healthy renewable process. It is evaluated as: (i) the percentage of water use to water availability; and (ii) the percentage of population having sustainable access to improved drinking water, reflecting the level of water infrastructure development. Water uses in 3 major sectors (agriculture, industry, domestic) are considered.

Waters in most of the river basins in North East and South Asia are extensively used, compared to the MRB in South East Asia. The irrigation sector comprises the major share of total water use in Asia, with most of the basins studied using more than 50 per cent of the available water for this purpose. The highest consumption occurs in the Helmand and Indus basins, with 97 per cent of total water use. Irrigation water use is also high in GBM in South Asia, as well as MRB in South East Asia

(88 per cent). Some of the river basins in North East Asia also have high percentages, especially HRB (77 per cent), SRB (70.6 per cent) and CRB (57 per cent) (see Figure 9). These values indicate the magnitude of agricultural activities in these basins, and highlight the importance of water for the basins' agrarian economy. Considering the fact that nearly all the available water in the Indus basin is used to meet agricultural water demands, and that the Mekong River Basin has a very high irrigation water requirement because of the growth of 2 crops per year, Muttiah and Wurbs (2005) showed that both basins might be 2 of the most affected major basins in the world, in terms of water shortages, due to changes in naturalized flows (runoff changes) in a future 2050 climate.

Mongolia is the only country in North East Asia dependent primarily on animal husbandry. Up to 2002, Mongolia had 23.68 million head of livestock. The secondary industry, mainly light industry, food processing, mining and energy, accounted for 23 per cent of the country's total GDP in 2002. Water consumption for irrigation in the 2 study basins, 20 per cent for the ORB and 9.1 per cent for the TRB, are lower than for other case study basins in Asia.

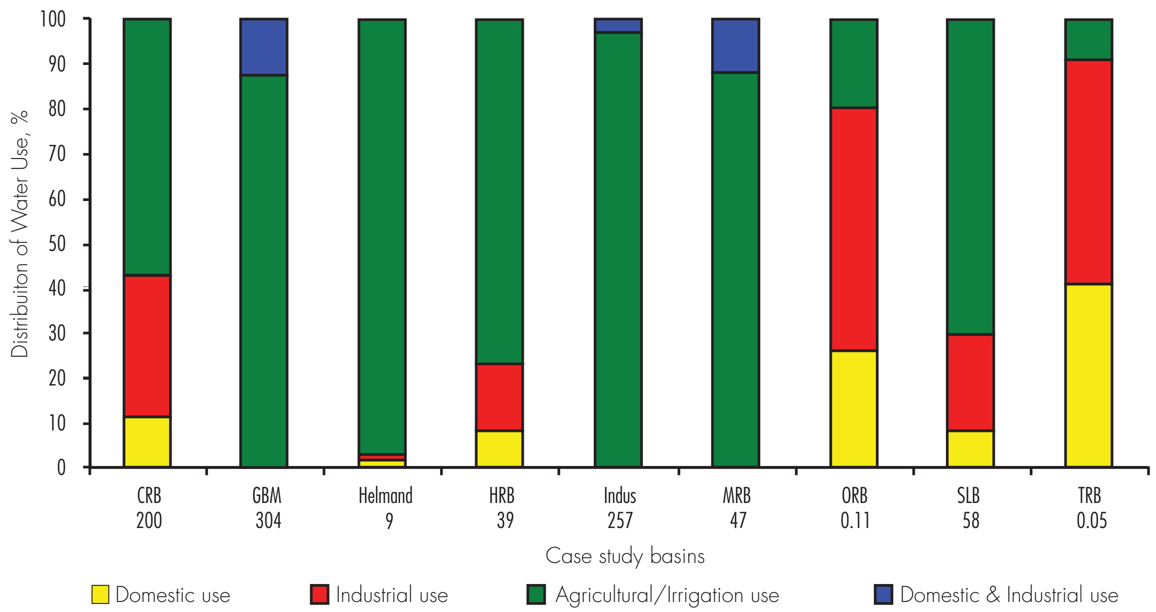


Figure 9: Sector-wise water use in Asian case study basins

Source: UNEP-AIT 2008, 2009; UNEP-PKU 2009b, redrawn by UNEP

Other than irrigation water use, new demands for freshwater resources are emerging from other sub-sectors (e.g., hydropower; recreation; navigation; other industries). The total water use for domestic purposes has increased rapidly because of the rapidly-changing lifestyles brought about by socio-economic development.

In South East Asia, the MRB countries are constructing scores of hydropower dams intended to support industrialization, and lift the population out of poverty. Lao PDR has begun construction on several of 23 projects planned for completion before 2010. China's Herculean project to build a massive cascade of 8 dams on the upper half of the Mekong River, as it tumbles through the high gorges of Yunnan Province, may pose considerable threat to the river. The reservoir behind the recently-completed third dam in the cascade, the 292 m (958 ft) high Xiaowan Dam, the world's tallest, can store more water than all the South East Asian dam reservoirs combined. Although hydropower development is inextricably linked to wider debates on dams and development, the impacts of the proposed hydropower development include changes in river flow volume and timing, water quality deterioration, and loss of biodiversity. Cambodia's Tonle Sap (Great Lake), the nursery of the lower Mekong's fish stocks, and Vietnam's Mekong Delta (its 'rice bowl'), are particularly at risk from alterations in the river's unique cycle of floods and drought (Cronin 2007). Further, (the Intergovernmental Panel on Climate Change (IPCC) (2007) reports that even a modest sea level rise of 20 cm (8 in) would cause contour lines of water levels in the Mekong delta to shift 25 km (15.5 mi) toward the sea during the flood season, and salt water to move further upstream (although confined within canals) during the dry season. Although this may not be detrimental for overall fishery yields, the inland movement of salt water would significantly alter the species composition of fisheries in the Mekong delta.

Another activity putting much stress on Asian waters is uncontrolled groundwater mining. In most study basins, groundwater levels have declined because of intense pumping, posing threats to soil and water quality. Some areas in the Indus basin, for example, suffer from a paradox of having areas with high water tables, and those where well development has been so intense that water tables are declining. Localized over-exploitation in fresh groundwater areas has already lowered groundwater tables from 2-4 m (7-13 ft) in some places, and there have been reports of deteriorating groundwater quality because of water intrusion from saline groundwater zones. In the Changjiang Delta Region of CRB in North East Asia, the economic loss of sinking land surface has reached as high as US$42.6 billion[1](350 billion RMB).

Other major concerns in Asia are lack of infrastructure to provide safe drinking water to the population, and proper discharge of wastes. A total of about 338 million inhabitants in 9 basins still lack access to safe drinking water (Figure 10), with HRB in North East Asia having the highest number of people (100 million) lacking access to safe drinking water.

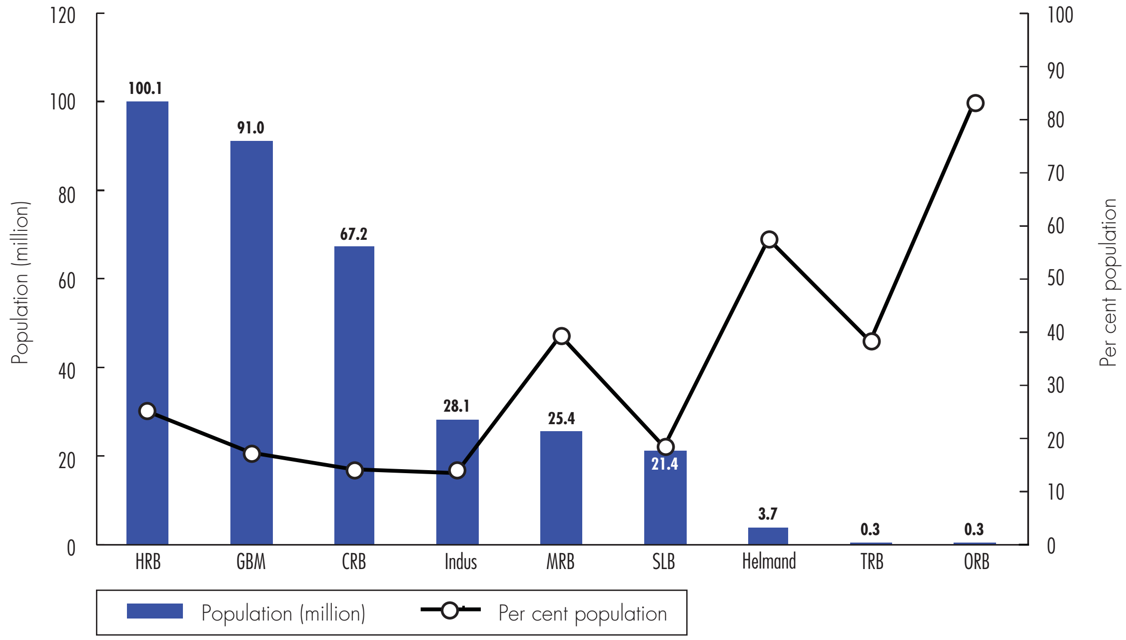


Figure 10: Population lacking access to safe drinking water in Asian case study basins

Source: UNEP-AIT 2008, 2009; UNEP-PKU 2009b, redrawn by UNEP

[1] 1US$ = 8.2 Rand

The GBM in South Asia comes second, with about 91 million inhabitants having no access to safe drinking water, although this represents only 17 per cent of the total population in the basin. In terms of percentage of population with no access to safe drinking water in North East Asia, ORB has the highest portion (83 per cent), although this is equivalent to only about 300,000 inhabitants. In South Asia, the Helmand basin has the highest percentage of the population (57 per cent) lacking access to safe drinking water, equivalent to about 3.7 million people. In Afghanistan in the Helmand basin, sustainable access to safe water is among the lowest in Asia, with more than half of all Afghans living in urban centres with no access to water from improved water sources. In the rural areas, an estimated four-fifths of the Afghan population may be drinking contaminated water (MDG 2005). According to the Asian Development Bank (ADB) (2007), the water accessibility situation in Asia generally is even worse in rural than urban areas. Moreover, access to safe drinking water in the rural areas is threatened by high concentrations (usually above normal standards) of iodine, fluorine, arsenic, etc., in the natural water, especially in groundwater, because of local geographical and geologic factors.

Ecological Insecurity

Land area without vegetation coverage (i.e., areas not covered with forests and wetlands) can cause severe problems, in terms of water conservation. Thus, the percentage of land without vegetation coverage was used as an indicator of ecosystem insecurity. At the same time, deterioration of water quality, as a consequence of water resources development and use (pollution), is an important indicator of existing ecological health. Thus, the wastewater volume discharged to the waters was compared to the available water, to evaluate the water quality situation in the basin.

This assessment of 9 river basins in Asia revealed that vegetation cover ranges widely, from 17-63 per cent of the basin area. The exception is the ORB, which exhibits a high vegetation coverage of 93 per cent, since the basin is largely covered by grasslands. These figures highlight the varying capacity of natural ecosystems to conserve freshwater resources.

The TRB in North East Asia has the least vegetation cover (17 per cent), since the basin is highly urbanized, including Ulaanbaatar City, the capital of Mongolia. The GBM in South Asia also has low vegetation coverage, being 20 per cent of its basin area. The GBM basin supports nearly 40 per cent of the total population of South Asia, imposing great pressures on ecologically-sensitive areas, in terms of encroachment and unsustainable use. In fact, threats to the continued functioning of the Ganges River as a living system have reached a critical level, due ultimately to the exponential expansion of human populations and their economic activities.

Other basins with less than 50 per cent vegetation cover are the Indus (39 per cent) and Helmand (40 per cent), both in South Asia, and the HRB (48 per cent) in North East Asia. Aside from varying extents of vegetation cover among basins, the vegetation coverage also differs within basins. In the Indus basin, for example, the portions relatively less vulnerable because of denser vegetation cover are those covering the basin highlands and the North East portion of Pakistan's Baluchistan province. These parts of the basin, particularly the Indus highlands, must maintain good vegetation coverage, since further forest degradation would have major impacts on the downstream areas. On the other hand, the lower Indus has more than 65 per cent area without vegetation, correlating to the issue of the vulnerability of the Indus delta because of variable climatic conditions and other extreme conditions (e.g., flooding; drought). In fact, degradation of the Indus delta ecosystem and loss of biodiversity is already a visible phenomenon. Direct effects of climate change will occur because of changing patterns of precipitation, snow melt and rising sea levels, which will affect hydrology and water quality. Indirect effects will result from changing vegetation patterns that may alter the food chain and increase soil erosion.

The basins exhibiting better vegetation coverage are the Mekong (56 per cent) in South East Asia, and the CRB (61 per cent) and SLB (63 per cent) in North East Asia. Although these values suggest positive signs, there is a continuous declining trend threatening ecosystem health. Wetland areas in the Songhuajiang River Basin (SHJRB) of the SLB, for example have been reduced from 53,500 km^2 (20,656 mi^2) in the 1950s, to 26,100 km^2 (10,077 mi^2) in 2000 (Figure 11). Further, the forest cover in the Helmand basin in South Asia has been reduced because of continuing demands for fuel wood and illegal logging. In the Sistan region, in particular, a continuing decline in wetland vegetation cover has been observed since 1985, which does not exhibit a similar periodicity to the river flows to the Sistan lakes, suggesting other factors play a more important role in vegetation development than water supply (Vekerdy and Dost, 2006).

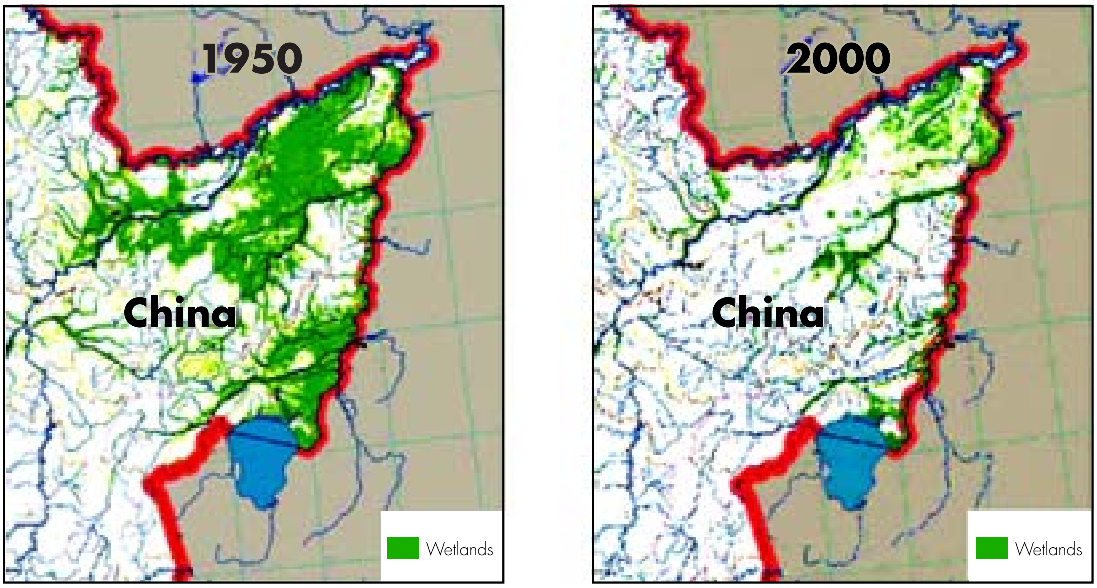


Figure 11: Shrinking wetlands in Songhuajiang River Basin of SLB

Source: Water Resources in North East China Project Group, 2006

There also is a very large variation among the study river basins in terms of wastewater discharges. The wastewater volume is lowest in the ORB (30 million m^3.yr^{-1}) in North East Asia because of a small population, whereas it is highest in GBM (92 billion m^3.yr^{-1}) in South Asia, due mainly to the large area coverage and large population.

The threat of wastewater discharges to water resources could be better indicated by the proportion of wastewater to total water resource. It was found that the Indus and Helmand basins, both in South Asia, exhibit the highest wastewater proportions of 19 and 16 per cent, respectively, of total water resources, whereas the proportion in the other basins range from 0.63 per cent in the ORB to 6.8 per cent in the HRB, both in North East Asia. The major factor for the high Indus and Helmand values is due to the large percentage of water use in the basins, being 90 and 50 per cent of the total available resource, respectively, with agriculture accounting for most water use. Eighty seven percent of wastewater discharges in the Indus River Basin originates from irrigation, and 92 per cent in Helmand. With agricultural water use accounting for most of the total water use in many of the basins in Asia, there is a need to examine management of wastewater from agriculture in order to decrease the vulnerability of the water resources.

In addition to agricultural water pollution sources, water quality deterioration is exacerbated by other pollutants from other sources. Examples include industry, municipal wastewater and urban runoff, which increase the need for proper wastewater treatment. These types of pollutants greatly contribute to localized and serious pollution of water resources in other basins, even though the basin-wide figures suggest a low proportion of wastewater to total water resources for these basins. In the SLB, for example, one of the problems bequeathed by old industrial plants is the discharge of 6.3 billion tons (14 trillion lbs) of sewage into the rivers. Further, in the CRB, a basin exhibiting rapid economic development, wastewater discharges increased rapidly from 11.39 billion tons (26 trillion lbs) in 1998, to 18.42 billion tons (41 trillion lbs) in 2005. This increased discharge might be responsible for increased rates of loss of endemic biodiversity, including fish, amphibians, waterfowl and aquatic mammals in the CRB. The great majority of well-studied species are declining in distribution, abundance, or both. A particular example is the population of the Changjiang River dolphin (*Lipotes vexillifer* Miller), which has rapidly declined in recent years, from less than 100 in 1995, to near extinction in 2006, attributed to deteriorating water quality.

Moreover, the increase in industrial activities in the GBM basin has resulted in accumulation of some 300-500 million tonnes (670-1,100 billion lbs) of hazardous and other industrial wastes each year, most of which get into the freshwater supply. In some developing countries in the basin, 70 per cent of industrial waste is dumped untreated into receiving waters. Spatial variation also reveals that, of the 31 sub-basins analyzed in this study, wastewater volume exceeds 15 per cent of the available water resources in 7 of them, with this higher percentage of wastewater discharge corresponding to higher agricultural water use. Other than wastewater discharges, one major cause of freshwater contamination is monsoon floods and tropical cyclones, predominantly observed in Bangladesh.

Animal husbandry is the key industry in Mongolia, with less industrial pollution having been observed. Thus, most water quality remains at Standard I (i.e., headwaters and national nature conservation zone) and II (i.e., source of drinking water, habitat of rare animals, and spawning areas). With the mushrooming mining sites, and corresponding increased water consumption during the last two decades, however, the water resources now appear to be severely polluted. In Songino at the lower reach of the TRB, the water quality has been degraded to Standard V (i.e., water for agriculture and landscape). According to the official statistics of 7 major water systems in China in 2006, only 41 per cent of the waterbodies are water quality Standard III (i.e., source of drinking water, swimming zone, aquaculture areas). However, 32 per cent are Standard IV-V (IV is water for industrial use and recreation without direct contact), and 27 per cent is worse than Standard V.

Water quality in the Mekong River Basin is generally good, although localized pollution exists near some major cities. Domestic wastewater is the major source of river pollution in North East Thailand, generally being discharged without treatment. Industrial pollution and agricultural runoff also are posing problems, particularly for the Mun River. The city of Phnom Penh mostly discharges its raw sewage into nearby rivers. Agro-pollutants have been found in fish, although dietary intake of PCBs and DDT from fish was lower in Cambodia than in other Asian countries (JSRC 1996; In et al. 1999). Accelerating hydropower-generating plants, industrialization, and expansion of agriculture in the future are all likely to affect Mekong River water use at many levels. This could change flood duration along the different reaches of the Mekong River, which would eventually result in decreasing oxygen concentrations during the rising flood, which may be harmful to fish, especially juveniles. This possibility, in addition to significantly decreased sedimentation in the lake and floodplain, may adversely affect productivity of the wetland and floodplain system.

The decreasing vegetation cover, and continuing degradation of water quality due to wastewater discharges, is generally expected to degrade ecosystem health across large parts of the Asian basins. The effect will be compounded in the delta regions of large basins, where saltwater may intrude a further 100 km (62 mi) inland in the case of the Changjiang and GBM basins, and 80 km (50 mi) and 60-70 km (37-43 mi) in the Indus and Mekong River Basins respectively (IPCC 2007).

Management Challenge
In addition to the availability of water resources and its uncertainty, management capacity also contributes to the vulnerability of water resources. An assessment of management capacity was done, utilizing 3 indicators, including: (i) efficiency of water use (measured as GDP produced from one unit of water use); (ii) human health condition (measured by access to sanitation facilities); and (iii) conflict management capacity (qualitatively evaluated through the existence and functioning of institutions, agreements and communication mechanisms).

Compared to the global average GDP production per unit of water use of about US$ 8.6.m^{-3}, most of the case study river basins in Asia exhibit a much lower water use efficiency, except for the Tuul River Basin (TRB) in North East Asia where the efficiency is as high as US$ 13.72.m^{-3} (Figure 12). This might be attributed to a greater water use for industrial purposes (about 50 per cent of total water use) in the TRB, compared to other river basins in Asia, where more than 50 per cent of the water resource is used for agriculture, and of which up to 75 per cent is wasted. Moreover, the TRB has a relatively high per capita GDP of US$ 1,217 for a small population of only 872,000 people, compared to other Asian case study basins. It must be noted that the price of water in the agriculture sector in a developing country generally is highly subsidized, which may be one reason for the lower GDP per unit of water use.

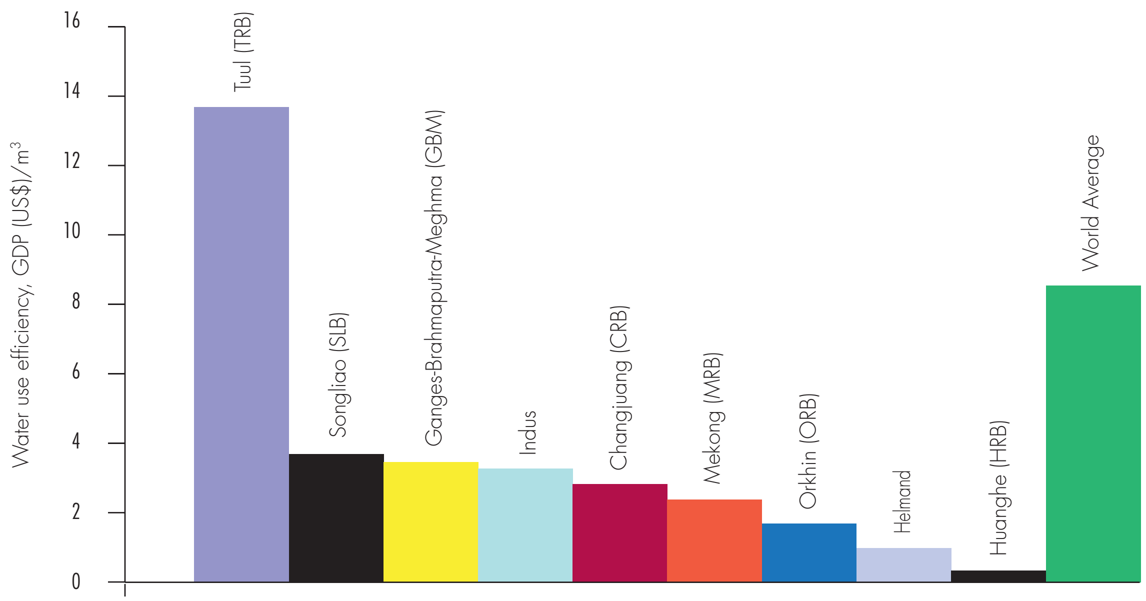


Figure 12: Water use efficiency in Asian case study basins

Source: UNEP-AIT 2008, 2009; UNEP-PKU 2009b, redrawn by UNEP

Poor water use efficiency, in terms of access to improved sanitation facilities, is evident in most case study basins in Asia, where about 652 million inhabitants lack access to sanitation facilities. In the GBM basin in South Asia alone, 321 million inhabitants (about 60 per cent of the total population) lack access to improved sanitation facilities (Figure 13). In terms of the percentages of the population, 95 per cent of the ORB population, and 61 per cent of the Helmand basin population, also lack access to improved sanitation.

On a sub-basin scale, about 28 per cent of the population in the Nam San sub-basin (Lao PDR) of the MRB has access to improved sanitation facilities. In North East Asia, most of the case study basins exhibit a relatively higher percentage of population with access to improved sanitation facilities, which might be due to increased coverage of the tap water system (TWSS), thereby leading to construction of more hygienic toilets. During 1995-2005, for example, the TWSS coverage in the rural areas of CRB increased steadily, from 46.3 to 65.3 per cent. In the ORB however, where water infrastructure is less developed, 95 per cent of the population still lacks access to improved sanitation facilities.

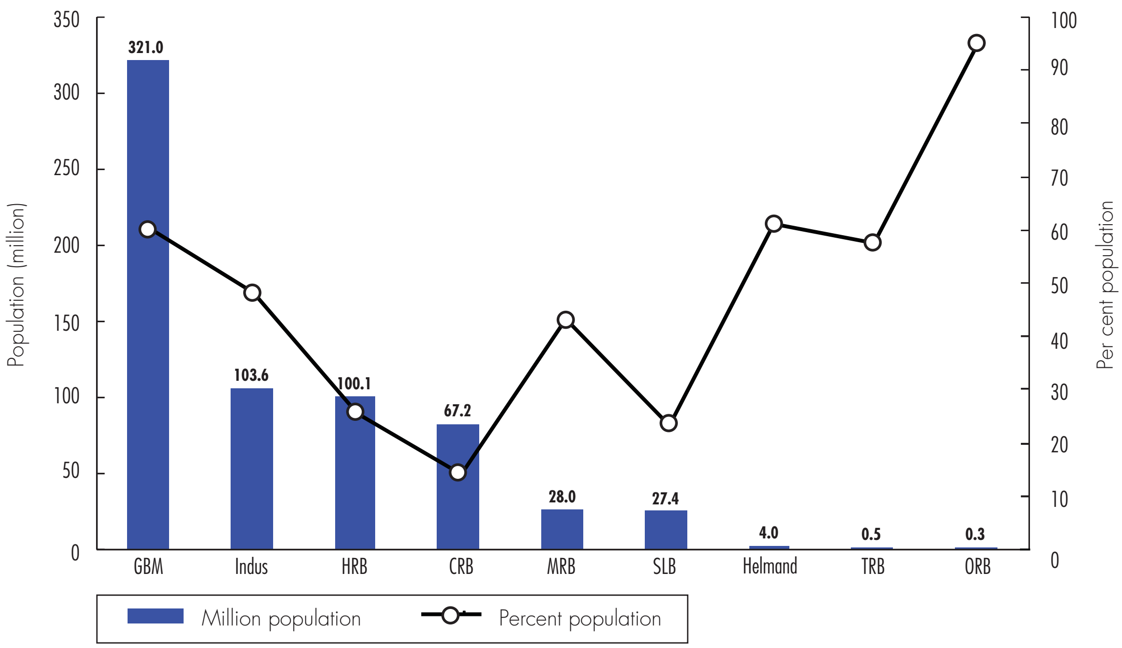


Figure 13: Population lacking access to improved sanitation in Asian case study basins

Source: UNEP-AIT 2008, 2009; UNEP-PKU 2009b, redrawn by UNEP

All the case study basins in South and South East Asia are international river basins. In South Asia, the waters of the Indus River are shared largely by Pakistan and India and, to a lesser extent, by Afghanistan. Five countries share the GBM basin waters, including Nepal, India, Bangladesh, Bhutan and China. The Helmand basin waters are shared by Afghanistan, Iran and Pakistan. Although some arrangements exist between respective co-riparian countries in the GBM and Indus basins, implementation of these arrangements pose considerable challenges, and may prove inadequate as the demands to harness more water increases over time. The Indus Water Treaty of 1960 between India and Pakistan, for example, focuses almost entirely on water allocation. It does not, however, cover issues pertaining to transboundary water pollution, or over-exploitation of groundwater aquifers. Thus, as the basin population increases, and per capita water availability declines, tensions over water allocation are likely to increase.

The Mekong River Basin (MRB) in South East Asia is one of the most hydro-politically unique transboundary water basins in the world, thereby presenting both opportunities and obstacles for cooperative management of basin resources. Since 1995, the basin has benefited from a comprehensive river basin management organization, the Mekong River Commission (MRC), based on the Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin. The MRC comprises the MRB countries, except China and Myanmar. In addition to the MRC, the region also is home to another influential cooperative organization, the Greater Mekong Sub-region (GMS). The GMS includes all 6 riparian Mekong countries (China, Myanmar, Thailand, Vietnam, Laos, Cambodia). Major GMS developments include the signing of a power trade agreement in November 2002, and promotion of regional tourism, trade and transport.

In North East Asia, the HRB is faced with inter-province transboundary management issues because of the large basin area, which stretches across 9 Chinese provinces. There is an imbalanced water use among the provinces because of their varying levels of economic development that are responsible for differential water demands. In order to address this issue, a water use quota policy (WUQP) - based on such indicators as per capita water use level, water use per unit of agricultural land, and general water use efficiency - was implemented in the HRB to improve its water resources management. Water resources conservation policies, and improved water use efficiency, also are currently in effect in North East Asia, emphasizing research and development (R&D). They are still lacking in implementation, however, especially in Mongolia. One specific five-year project on Modernized Agriculture Water-saving Technology System and New Products, which was launched in 2000 in China, greatly improved agricultural water use efficiency.

Despite many such achievements, however, concerns have been expressed in regard to mainstreaming climate change concerns into national and water sector development planning, through changes in policies and institutions, including technology deployment. Inadequate capacity to assess local impacts, and to identify appropriate adaptation technologies, has been blamed for the failure. This underscores the need for policy alignment to accelerate research on climate change impacts on water infrastructure and management practices.

Vulnerability Index

A composite basin water vulnerability index (VI) was calculated, on the basis of equally considering resource stresses, development pressures, ecological insecurity, and management challenges applied to the overall vulnerability situation. The value of VI ranges from 0 to 1, with the value of 1 representing the highest vulnerability (see Box 4).

In North East Asia, the vulnerability indexes of the 5 case study basins range from high to severe, indicating an urgent need for management intervention to reduce water resources vulnerability. Except for the CRB, which is located in humid and semi-humid areas, and the ORB, with a very low population density, all the other river basins located in dry areas generally have low per capita water resources, and suffer from unstable annual water resources availability. The SLB, for example, experiences high variations in annual precipitation, making it more difficult to implement sustainable water resources management in the basin. River basins suffering from water shortages usually exhibit a high water resource exploitation rate. Thus, in the HRB, which exhibits a high water resources exploitation rate of 65 per cent, the development pressure (DP) also is high (DP=0.453; see Figure 14).

Box 4: Interpretation of the Water Vulnerability Index (VI)

Vulnerability Index	Interpretation
Low (0.0-0.2)	Indicates a healthy basin, in terms of resource richness, development practices, ecological states, and management capacity. No serious policy change is needed. It is still possible, however, that moderate problems exist in the basin in regard to one or two aspects of the assessed components, and policy adjustment should be taken into account after examining the VI structure.
Moderate (0.2-0.4)	Indicates the river basin is generally in a good position in regard to realization of sustainable water resources management. It may still face big challenges, however, in regard to either technical support or management capacity building. Thus, policy design of the basin should focus on the main challenges identified after examining the VI structure, and strong policy interventions should be designed to overcome key constraints affecting the river basin.
High (0.4–0.7)	The river basin is under high stress, and significant efforts should be undertaken to design policy to provide technical support and policy back-up, in order to mitigate the stress. A longer-term strategic development plan should be created, with a focus on rebuilding management capacity to deal with the main threats.
Severe (0.7–1.0)	The river basin is highly degraded, in regard to its water resources system, and exhibits a poor management framework. Management for the restoration of the river basin's water resources will require strong commitments from both the government and general public. Restoration will be a long process, and an integrated basin-level plan should be created, involving agencies at the international, national and local levels.

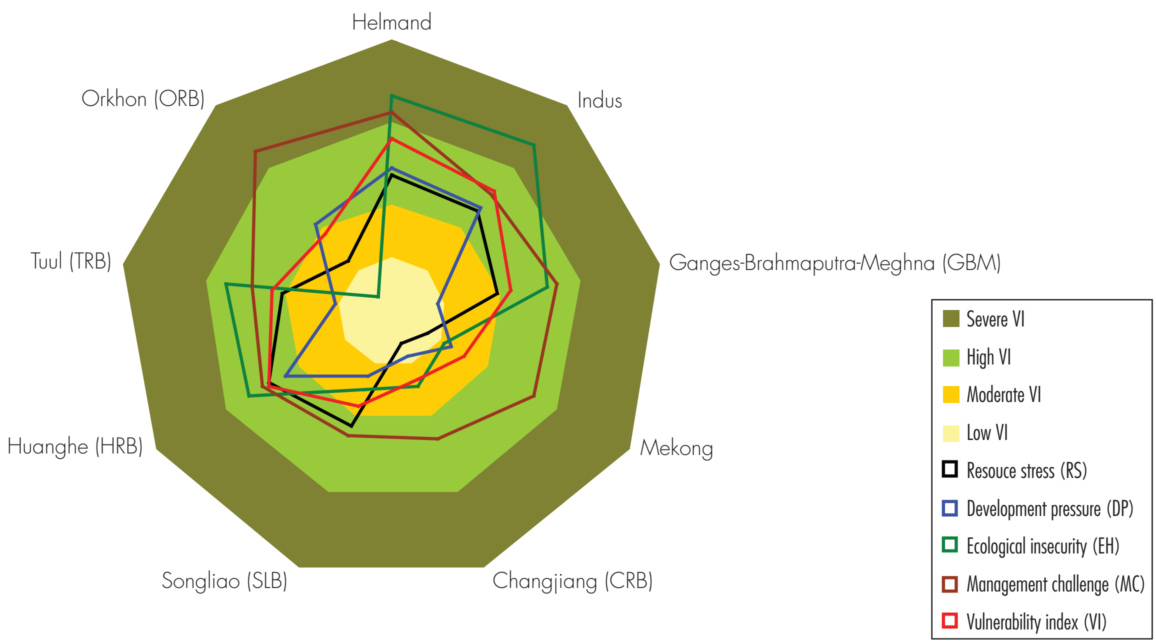


Figure 14: Sources of vulnerability in Asian case study basins

Source: UNEP-AIT 2008, 2009; UNEP-PKU 2009b, redrawn by UNEP

Although water exploitation remains low in the other river basins of North East Asia, continuous urbanization and increased population growth will pose a big challenge for future water development and use. Further, over-exploitation of water resources (both surface and groundwater) will adversely affect hydrological processes, and place some of the North East Asian river basins at ecological risk. Even those with low ecological insecurity have already exhibited signs of deterioration, especially in terms of declining water quality. This also can be observed on the basis of the low vegetation coverage (including wetlands) of the North East Asian case study basins. There is a high disparity among the 5 North East Asian river basins, in regard to management capacity, although the common problem is low water use efficiency, except for the TRB (MC=0.524). In terms of transboundary issues, the North East Asian case study basins, although not all being international basins, experience a certain level of transboundary management issues related to their large catchment areas. Although similar in institutional arrangement, the CRB, HRB and SLB exhibit minor variations, in terms of management capacity. A similar institutional arrangement also is being implemented in the ORB and TRB, the two Mongolian river basins.

Water resource systems in the Helmand and Indus basins in South Asia were found to be highly vulnerable, with the Helmand basin being the more vulnerable of the two (VI=0.64, see Figure 14). The water resources in the GBM basin also are highly stressed. Parts of the GBM basin (upper Ganges sub-basins in India, including Gomti, Ghagara Confluence to Gomti Confluence, and upstream of Gomti Confluence) exhibit severe (VI>0.7) overall vulnerability situations (Figure 15).

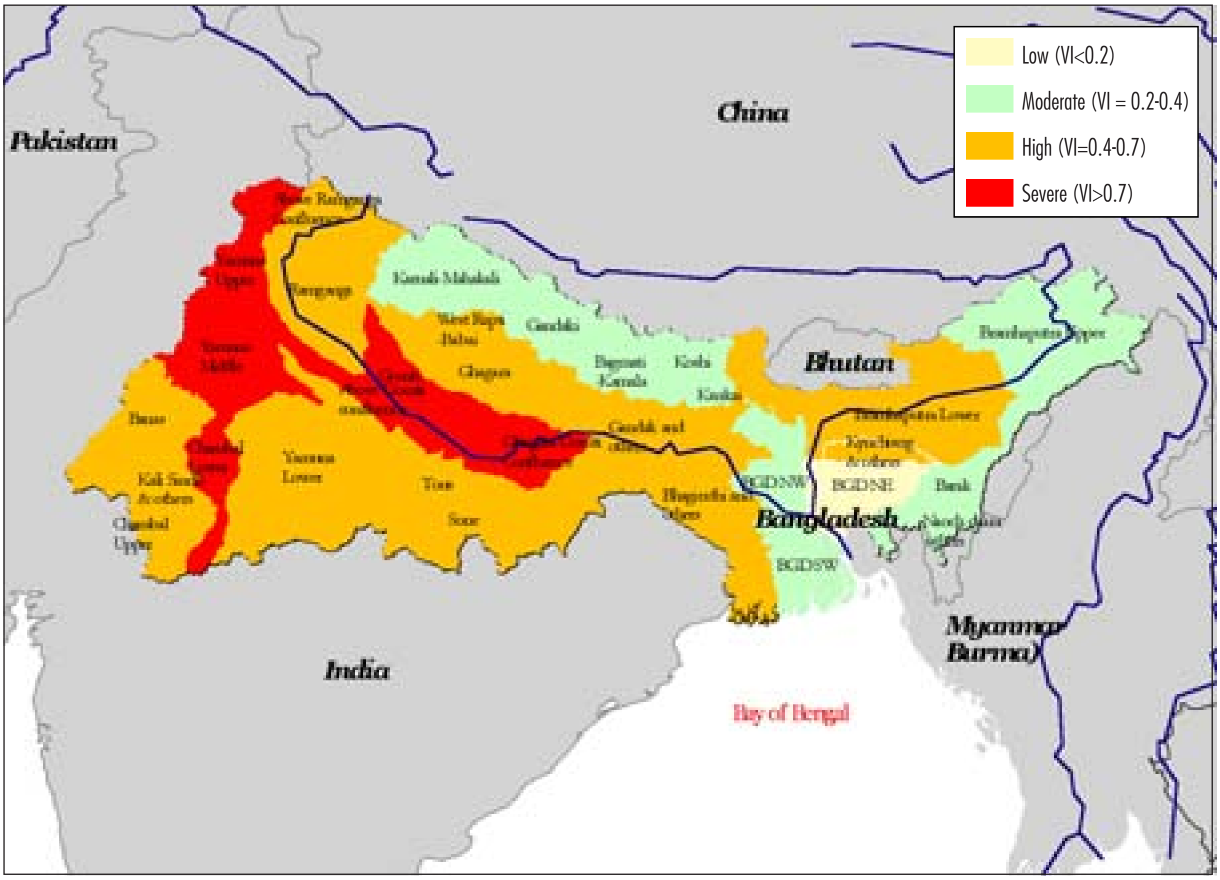


Figure 15: Water Vulnerability Index (VI) for the GBM basin

Source: UNEP-AIT 2008

Ecological insecurity (EH=0.8) contributes most to the water resource vulnerability in both the Helmand and Indus basins, while management challenges post the greatest threat in the GBM basin (MC=0.62). Management challenges in the Helmand basin (MC=0.74), however, also are high. Key issues leading to water resources vulnerability in the GBM basin include seasonal variation of water resources (flooding and drought); climate change implications (increased glacier melt, increased precipitation, loss of ecosystem); degradation of water quality; and transboundary water management issues. Similarly, issues in the Indus basin include salinization and sodification of agricultural lands; degradation of the Indus delta ecosystem; low irrigation water use efficiency; lack of integrated water resource management in the upper Indus; and declining groundwater level related to groundwater mining. Finally, key issues leading to water resources vulnerability in the Helmand River Basin include lack of a dense hydro-meteorological network; lack of an information system; variability of available water resources; limited access to water supply and sanitation facilities; low efficiency of the irrigation infrastructure; and lack of management capacity, and coordination among water related national agencies and riparian countries.

The overall vulnerability index of the MRB in South East Asia is moderate (0.31; see Figure 14), implying the MRB is generally in a more favourable position in regard to achieving sustainable water resource management. Moreover, it is observed that the vulnerability index for the Mekong sub-basins is most related to management capacity (MC=0.6), followed by development pressure (DP=0.25). The sub-basins are faced with moderate management challenges attributed to the gap between water use efficiency in the sub-basins and the global average; lack of improved sanitation facilities (especially in Lao PDR, Cambodia and Vietnam); and the capacity of the MRC to resolve transboundary conflicts. Moderate development pressures in the sub-basins is due partly to some degree of exploitation of water resources during the dry season, as well as lack of access to safe drinking water by more than 50 per cent in the less-populated sub-basins.

4. OPPORTUNITIES FOR ACTION

The 9 river basins considered in the present study is different in regard to their hydrological nature, vulnerability situations, and geopolitical settings. Given the diversity of these river basins, and the complexities and dimensions of current and future water issues, there are no viable generic solutions to the water vulnerability problems facing the case study basins. For each case study basin, therefore, the options available for reducing water vulnerability rely on a unique combination of policy interventions and a preferred pathway for development. This approach can be summarized as follows:

- **Promote water-centered and water-based basin development**
  High resource stresses and development pressures in most case study basins (especially the Helmand and Indus basins), and large spatial and temporal variation of resources within most of the case study basins, require a paradigm shift in the way water resources are managed in the Asian river basins.

- **Improve water management efficiency**
  Agriculture is by far the largest water user in most of the case study basins. Nevertheless, management efficiency in the agriculture water sector remains much less than desired, implying that the current management and distribution systems for water resources are inadequate, and there is a need to adopt a policy to use the existing water resources more efficiently. This may include refining the agricultural production structure, providing economic incentives for water pricing, and water resources allocation. In addition, improving technical input by research and development (R&D) in water-saving technologies used in agriculture and allied industries must be a priority of the national key technological development agenda.

- **Increase investments in water development and use**
  Lack of management capacity, and a low level of water exploitation in most case study basins, implies the existence of the scope for water resources development. However the underdeveloped socio-economic conditions on the one hand, and low water exploitation on the other, create a vicious cycle. Investments must prioritize sustainable development of water resources in most of the case study basins.

- **Balance between resource exploitation and maintenance of ecological health should be emphasized in all water infrastructure developments**
  Given the contrasting scenario of rich water availability in volumetric terms, and lack of water service provision in some basins, the challenges facing future policy creation for reducing water-related vulnerability, is to establish a balance between resource exploitation and the maintenance of ecological health. Stringent implementation of an environmental impact assessment before construction of large-scale water infrastructure, for example, that consider the impacts on the natural flow of the river, the policy options to manage hydropower reservoirs, and encouragement of development of alternative energy sources, may reduce potential risks in the GBM and Mekong basins.

- **Full provision for non-consumptive water use**
  The findings of poor ecological health in the case study basins call for full provision for non-consumptive use of water.

- **Pursue long-term basin-wide cooperative development and management of water resources**
  Most of the case study basins are transboundary in nature. Opportunities for a consensus-based approach to sustainable water resources development and management exist for all the basins, as evidenced through a number of earlier developments in the GBM and Indus basins. Special emphasis should be given to establishing long-term governing principles for transboundary water sharing, and institution building, including a regional data collection and monitoring network, a river basin organization, and tribunals for dispute settlement. There is a need to reach consensus on equitable utilization between upstream and downstream co-riparian countries in the MRB, for example, including an environmental flow requirement. Considering the very high economic growth rates in parts of the MRB, and the consequent need to harness its water resources, the ongoing cooperation between the 6 co-riparian countries should be further strengthened and consolidated.

- **Coordinate river basin management through decentralization and commitment at the most senior level**
  It is evident that more involvement of local government in river basin management should be encouraged. This is particularly relevant for North East Asia. The management strategy should focus on basin-scale management among the different reaches of the river, as well as encouraging participation of all basin stakeholders.

- **Expand and strengthen the climate change knowledge base, promote education and raise awareness**
  Lack of awareness of climate change within the development community, limitations on resources for implementation, and inadequate available climate information for development-related decisions, might increase vulnerability in some of the Asian case study basins. This aspect highlights the need to promote scientific research and make data accessible through improved monitoring, assessments, and advancement in the knowledge base.

- **Put greater emphasis on economic instruments to protect freshwater resources**
  Instruments, such as green taxes, can raise revenues that could be used to improve the state of freshwater resources, or reduce income taxes for the poor.

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