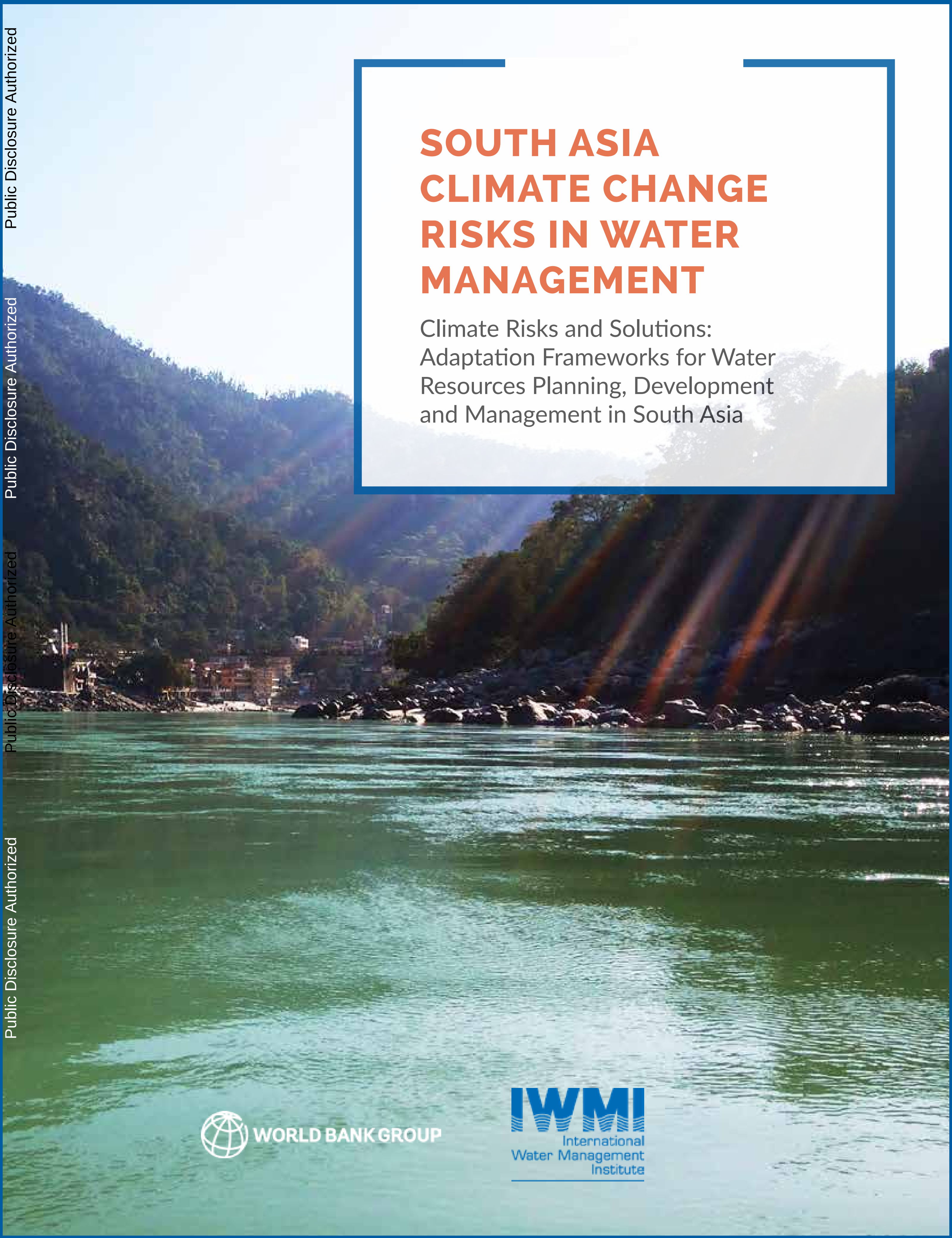
SOUTH ASIA CLIMATE CHANGE RISKS IN WATER MANAGEMENT

Climate Risks and Solutions: Adaptation Frameworks for Water Resources Planning, Development and Management in South Asia



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Cover photo caption: Ganga river in Uttarakhand.

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SOUTH ASIA CLIMATE CHANGE RISKS IN WATER MANAGEMENT

Climate Risks and Solutions: Adaptation Frameworks for Water Resources Planning, Development and Management in South Asia

Summary Report

Rafik Hirji, Alan Nicol, and Richard Davis

WORLD BANK GROUP

IWMI International Water Management Institute

"IT IS NOT THE STRONGEST OF THE SPECIES THAT SURVIVES, NOR THE MOST INTELLIGENT THAT SURVIVES. IT IS THE ONE THAT IS MOST ADAPTABLE TO CHANGE". CHARLES DARWIN.

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ACRONYMS AND ABBREVIATIONS

ADB	Asian Development Bank
BCAS	Bangladesh Centre for Advanced Studies
BIDS	Bangladesh Institute of Development Studies
CEGIS	Center for Environmental and Geographic Information Services
CGWB	Central Ground Water Board [India]
CSE	Centre for Science and Environment
DFID	Department for International Development
EIA	Environmental Impact Assessment
FAO	Food and Agriculture Organization
GBM	Ganges-Brahmaputra-Meghna river system
GDP	Gross Domestic Product
GHG	Green House Gases
GLOF	Glacial Lake Outburst Flood
GoN	Government of Nepal
GWP	Global Water Partnership
HKH	Hindu Kush Himalayas
IBKP	Indus Basin Knowledge Platform
ICIMOD	International Centre for Integrated Mountain Development
IDS	Integrated Development Society-Nepal
IGB	Indo Gangetic Basin
IPCC	Intergovernmental Panel on Climate Change
IRWR	internal renewable water resources
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
LAPA	Local Adaptation Plan of Action
MAR	Managed Aquifer Recharge
MCCICC	Multi-stakeholder Climate Change Initiatives Coordination Committee
MW	Mega-watt
NAPA	National Adaptation Program of Action
NAPCC	National Action Plan on Climate Change
NCCKMC	National Climate Change and Knowledge Management Centre
PMCCC	Prime Minister's Council on Climate Change

SAARC	South Asian Association for Regional Cooperation
SACEP	South Asia Co-operative Environment Programme
SAPCC	State Action Plan on Climate Change
SAWGP	South Asia Water Governance Programme
SAWI	South Asia Water Initiative
SWEC	Surface water entering the country
TRWR	Total Renewable Water Resources
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WEF	Water-Food-Energy
WEFE	Water-Food-Energy-Environment
WUA	Water User Association

FOREWORD

South Asia's rich human and physical geography are tightly bound to the rivers that radiate out and down from the great Himalayan massif and the extensive Indo-Gangetic basin aquifers. Driving some of the largest irrigation systems in human history and nourishing populations and ecosystems straddling rich alluvial floodplains, the annual flood pulses of these rivers — the Ganga, Indus, Brahmaputra and Meghna amongst them — has determined the development of human civilizations and provided livelihood security for several millennia. More recently, groundwater from alluvial and hard-rock aquifers has augmented less reliable surface supplies for irrigation and become the primary source of rural, urban and industrial water supplies.

These water resources are now rapidly changing, and this change brings heightened risk and uncertainty. Global warming is altering the behavior of the great ice mass — the cryosphere or 'third pole' — and is also affecting the pattern and behavior of monsoonal rains, river flow regimes, evaporation and demand patterns. Groundwater resources are under unprecedented pressure. The qualities of rivers and aquifers are deteriorating from contamination from communities, cities, industries and agriculture. Floods, droughts and cyclones cause devastation for millions. Climate extremes, together with changes in annual rainfall and sea-level rise, will affect the lives of over a billion people, increasing human insecurity and hindering the wider development efforts and economic growth directions of the region.

These series of South Asia Water Initiative reports were commissioned to help support greater understanding of these change including ways in which better water resources management can enable more effective climate adaptation policy, practice, design and implementation across the countries of South Asia. The summary report has drawn from three background papers and a range of expert inputs from IWMI, the World Bank and international and regional climate and water resource management experts.

By assessing available evidence and mapping the landscape of existing knowledge and policy approaches in South Asia, while keeping in mind key socio-economic and institutional contexts, this summary report and background papers inform public debate on climate change and water resources management in South Asia and provide valuable inputs to effective decision making.

The hope is that the guidance and recommendations offered by the wider project, of which these reports form a part, will enable South Asian governments and societies to enhance their capacities for building resilience to further climate change — which is now inevitable — and ensure a more sustainable and secure future for the whole region.

ACKNOWLEDGEMENTS

This summary report is part of the first phase of a two phased South Asia Water Initiative (SAWI) Technical Assistance (TA) project – Climate Risks and Solutions: Adaptation Frameworks for Water Resources Planning and Management in South Asia – to assess opportunities for adaptation to climate change in the water sector in Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka.

SAWI is a partnership between the governments of United Kingdom, Australia and Norway that supports a multi-donor trust fund that works to improve the management of the major Himalayan river systems of South Asia to achieve sustainable, fair and inclusive development, and climate resilience.

Phase 1 of this TA was implemented by the World Bank and International Water Management Institute. Rafik Hirji (Senior Water Resources Specialist, World Bank) was the Task Team Leader. Alan Nicol (Theme Leader, Governance, Gender and Poverty, IMWI) led the IWMI team. This Summary Report (prepared by Rafik Hirji, Alan Nicol and Richard Davis, consultant), synthesizes findings and recommendations of three commissioned papers prepared by IWMI and World Bank teams:

- Lacombe, G.; Chinnasamy, P.; Nicol, A. 2017. *Climate Change Science, Knowledge and Impacts on Water Resources in South Asia: A review*. Colombo, Sri Lanka: IWMI.
- Davis, R; Hirji R. 2017. *Water and Climate Change Policy Review*. Colombo, Sri Lanka: IWMI.
- Suhardiman, D.; de Silva, S.; Arulingam, I.; Rodrigo, S.; Nicol, A. 2017. *Review of Water and Climate Adaptation Financing and Institutional Frameworks*. Colombo, Sri Lanka: IWMI.

Draft background papers and summary of main findings and recommendations were presented and reviewed at a regional stakeholder workshop organized by IWMI in Colombo, Sri Lanka on July 12th- 13th 2016 attended by 65 national, regional and international climate change and water resources experts, including over 20 representatives of governments in the region. The workshop feedback and comments helped in shaping the revised drafts of the background papers and summary report. The many individuals who reviewed the background papers and workshop participants who provided comments are recognized in the respective acknowledgment sections of the three papers and the final workshop report.

This summary report has incorporated comments from the review meeting held in Washington, DC, on February 9, 2017 chaired by Martin Rama (Chief Economist, South Asia Region), including from peer reviewers - Richard Damania, Lead Economist, Omar Lyasse, Senior Economist, Nathan Le Engle, Senior Climate Change Specialist, and Professor Anil Markandya (Basque Centre for Climate Change), and other reviewers - including Pravin Karki, Senior Hydropower Specialist, Claudia Sadoff, Lead Economist, Bill Young, Lead Water Resources Specialist, Muthukamara S. Mani, Lead economist, and Masood Ahmad, Lead Hydropower Specialist. The comments from all reviewers and guidance from the meeting chair, SAWI Coordinators Bill Young and Halla Qaddumi, and SAWI Practice Managers Michael Haney (GWA09) and Meike Van Ginnekan (GWA06) is gratefully acknowledged.

A special thanks goes to Indika Arulingam of IWMI for helping with the additional research following the review meeting, Cherise Pereira for assisting with formatting.

EXECUTIVE SUMMARY

WATER MANAGEMENT IS A KEY DEVELOPMENT CHALLENGE IN SOUTH ASIA. THE REGION - ONE OF THE MOST DENSELY-POPULATED AND CLIMATE-VULNERABLE PARTS OF THE WORLD - HAS THE WORLD'S FASTEST GROWING REGIONAL ECONOMY AND THE LARGEST PROPORTION OF POOREST PEOPLE. WITH 23.7% OF THE GLOBAL POPULATION, BUT ONLY 4.6% OF THE WORLD'S RENEWABLE WATER RESOURCES, THE MANAGEMENT OF WATER IS A KEY DEVELOPMENT CHALLENGE FOR SUSTAINING GROWTH, LIVELIHOODS AND RESILIENCE. THE KEY FEATURES OF THIS CHALLENGE ARE ENSURING A RELIABLE SUPPLY OF WATER FOR FOOD, PEOPLE, ENERGY, AND INDUSTRY, AND MANAGING THE CONSEQUENCES OF EXTREME HYDROLOGICAL EVENTS. CLIMATE CHANGE WILL COMPOUND THIS CHALLENGE; IT WILL IMPACT, THOUGH UNEVENLY, WATER SUPPLY, DEMAND AND QUALITY, AND EXACERBATE EXTREME HYDROLOGICAL EVENTS.

The region is already facing severe water stress. With a highly variable monsoon, low water storage capacity, uncontrolled groundwater use, water supplies have become unreliable; water shortages are common; disputes, tensions and conflicts over water are growing; water levels are declining; wetlands are drying; and water pollution is widespread and becoming severe from sewage, industrial effluents, and agro-chemicals - and natural contaminants - arsenic, fluoride, and salinity. Urbanization is reducing groundwater recharge areas, rates and quality.

A hotspot for natural disasters, South Asia accounts for some 40% of globally-recorded events. It is often hit with damaging floods, droughts, storms, and landslides causing loss of lives, destroying livelihoods, damaging property and infrastructure. Accelerated sedimentation reduces river and canal conveyance capacities and dam storage, reducing their economic life.

Growing populations, economies, industries, urbanization and hydropower development is increasing the demand for water. By 2030, demand for water in the largest South Asian economies will be double the available supplies. Irrigation uses 91% of total use, municipal and industrial water uses are 7% and 2%. Although current regional water use is only 27% of the current supply, these region-wide and country-wide data mask considerable diversity. The two largest economies – India and Pakistan – are water scarce and many areas, including major cities, lack adequate water supplies.

Demand management offers considerable room to make better use of existing supplies through conservation, loss reduction, improved water use efficiencies, recycling and reuse. For example, lifting Pakistan's irrigation efficiency from the current 40% to 45% would save 5.8 BCM annually. Growing demand for municipal, industrial and environmental water will add pressure for improvements in irrigation water use efficiency and hydropower operations.

Groundwater comprises only 13% of the total renewable water resource but accounts for about 40% of total water use. It supports 60% to 80% of irrigation, rural and urban water supply. About 62% of the region's 555 BCM of annual renewable groundwater is pumped, making South Asia the world's largest abstractor of groundwater. Groundwater, key to the green revolution lifted millions out of poverty, is critical to the region's economy and is likely to become even more so as economies grow, populations increase, surface supplies become less reliable, and climate changes.

Groundwater, a common pool resource, provides greater drought and climate resilience than surface water, but remains highly undervalued. Aquifers have large natural storage, are protected from evaporation and better buffered against seasonal and annual climate variability. The Indo-Gangetic basin aquifers have immense natural storage capacity estimated to be 30,000km^3 – which is over a hundred times the total storage (about 280km^3) in all South Asian dams, reservoirs and tanks. **This immense natural storage volume is equivalent to over 20 times the total annual flows of the Indus, Ganges and Brahmaputra rivers combined**. Yet groundwater receives inadequate policy and management attention. Water policies are biased towards surface water, and allocate the bulk of the budget for surface water infrastructure with groundwater management receiving much smaller share of the funding.

Several other factors complicate water management in South Asia. First, water management cuts across many sectors – agriculture, energy, environment, health, industry, land, rural and urban – and is also impacted by policies and actions taken outside the water sector (e.g., agriculture, energy, land use, trade and foreign affairs). Addressing this requires a multi-sectoral approach, beyond the confines of the water sector, to equitably allocate water, and control and regulate use within sustainable limits. Second, the challenge encompasses working across numerous political and administrative jurisdictions – villages, cities, districts, states, provinces and nations – emphasizing the need for a collaborative approach. Third, all aspects of water resources - water quantity and water quality, surface and groundwater, water source areas and water use – are inadequately protected and managed, adding to the need for an integrative approach. Fourth, South Asia's diverse climate and topographic regimes from the Himalayan mountains with glaciers and snow fields to the arid regions of Afghanistan and Pakistan to the tropical coasts of India, Bangladesh and Sri Lanka, leads to diverse issues and management responses. Fifth, water related natural disasters - droughts and floods - continue to be addressed in a limited and incremental manner, instead of through systematic planning, management and development, including transboundary planning and management.

Each country faces a different risk profile from water-related climate change impacts. Table A.1 is a ranking of risks based on historical damage from water-related extreme events and priorities in climate change policy instruments. It does not take into account gradual changes that may occur as a result of climate change, such as diminishing mean river flows or increasing irrigation water demand because of increased evapotranspiration from rising temperatures.

Table A.1 - Ranking of climate-related risks

	Countries						
Risk level	Afghanistan	Bangladesh	Bhutan	India	Nepal	Pakistan	Sri Lanka
High risk level	Flash flood Landslide Riverine flood	Riverine flood Storm/ Cyclones Costal floods Siltation	Landslide Flash flood GLOF	Drought Riverine flood Flash flood Groundwater depletion	GLOF Flash flood Landslide	Drought Groundwater depletion Landslide	Storm/ Cyclone Riverine flood Coastal flood
Medium risk level	Drought Erosion/ siltation Groundwater depletion	Erosion Drought Groundwater Depletion Coastal aquifer salinization	Erosion/ Siltation Riverine flood Drought	Landslide Storm/ Cyclone Coastal aquifer salinization	Drought Erosion/ Siltation Groundwater depletion	Riverine flood GLOF Flash flood Erosion/ Siltation Groundwater salinization	Flash flood Landslide Erosion/ siltation Drought Coastal aquifer salinization
Low risk level	GLOF Storm/ Cyclone	Flash flood Landslide	Storm/ cyclone Groundwater depletion	GLOF Erosion/ Siltation	Riverine flood Storm/ cyclone	Coastal flood Storm/ Cyclones	Groundwater depletion

Climate change will add to and/or magnify the current water management challenge. Warmer temperatures will increase evaporation (water loss) and evapotranspiration rates (water demand), alter patterns of precipitation, river flows and aquifer recharge (water supply), affect water quality, as well as increase the frequencies and intensities of floods, droughts, sedimentation, and landslides (extreme events). Rising sea-levels and intense storms will salinize coastal aquifers (water quality). Hydrological non-stationarity will complicate river flow and groundwater modelling and infrastructure design and operations.

Considerable uncertainty exists about the magnitude and even the direction of these changes. Some effects are well established – rising temperatures, accelerating snow and glacier melt, rising sea-levels, and increasing frequency and intensity of extreme events (storms and droughts). Others, including changes in precipitation, river flow and groundwater recharge, and the dynamics of glacier melt are more uncertain as the processes are complex and not well understood. Even with these uncertainties, the IPCC categorizes South Asia as the region at greatest risk from climate change. Some changes will be gradual and long term (e.g. changes in annual flows and salinity), others will be more punctuated and severe (floods, droughts and landslides), and still others (e.g., salinity intrusion, sedimentation, and landslides) irreversible.

The overarching goal of this study was to use a collaborative process to build knowledge, tools and capacity that will assist governments in adapting to climate change challenges in the water sector. It draws from three commissioned papers and builds on the output of a regional meeting convened in 2016 which brought seven countries together to discuss climate-related water management for adaptation. It unpacks and addresses the nature of resulting policy, planning and operational challenges as regional governments and social systems attempt to adapt, mitigate and manage these challenges and ensure that sustainable water management remains a central pillar in economic development and social stability. It provides an evidence-base on which to build future capacity to improve water resources planning, development and management decision making under a changing climate. It places an emphasis on groundwater because it will become even more important than it is now as a source of water as climate changes, and it promotes planned conjunctive management of surface and groundwater.

Establishing effective adaptation frameworks is a necessary first step for responding to climate change across the very different social, geographical and environmental contexts across the region. At the heart of this work is the establishment of a risk framework – with primary and secondary risks - against which effective adaptation options in the water sector can be identified and developed, recognizing that the risk – and therefore adaption needs landscape – is highly variegated both spatially and dynamically over time.

*Effective adaptation framework must place emphasis on greater policy coherence and integration across multiple sectors as well as across different scales of managemen*t. The major water dependent sectors – agriculture, water supply, energy, transport, environment – need to develop (i) consistent policies for water sharing and water management and (ii) coordination mechanism for implementing these policies. Policy coherence is also needed with those sectors outside the water dependent family whose decisions and actions affect water demand and water management (e.g. food security, trade, land use, and energy).

Given the uncertainties surrounding the impacts of climate change, the adaptation framework must place emphasis on knowledge development and adaptive learning and management. This includes expanding water resources and climate monitoring and interpretation as well as better sharing of existing scientific knowledge including across countries within shared basins, enabling better co-decision making even if not under one transboundary institutional umbrella. The large uncertainties in hydrological projections under climate change imply that risk based methods, such as Decision Tree analysis, should be adopted for investment decisions. It is also important to understand which drivers of demand – socioeconomic (economic and population growth) or climate change – will be important in different circumstances in order to inform water allocation and development decisions. Current knowledge suggests that the Indus basin flows are likely to be impacted more by climate change over the medium term, whereas the Ganges and Brahmaputra are likely to be impacted more by socio economic drivers.

The framework should also incorporate improved water resources planning and management given the opportunities for making better use of the region's existing water resources. Improved water use efficiency, recycling and reuse, emphasis on demand management (through pricing reforms, removal of perverse subsidies, and user education and participation), and wider use of conjunctive management of surface and groundwater, would all provide better access to water in areas likely to experience water shortages and contribute towards more flexibility in responding to increased variability in water availability.

Considerable and highly cost-effective adaptation opportunities can be realized through systematically harnessing the benefits of the huge natural storage in South Asia's aquifers. This requires properly understanding the resource base and its use, and managing groundwater recharge, storage, and discharge; protecting groundwater quality; and managing groundwater demand. Comprehensive water resources planning with a focus on promoting wider and planned conjunctive use and management of surface and groundwater needs to be prioritized.

Improved water use efficiency will not obviate the need for new infrastructure for water storage to meet the rising demands for water because of population growth, growing economies and increasing prevalence of drought. Investments will be needed for building, maintaining and extending infrastructure (including single and multipurpose dams and inter-basin transfer schemes) to regulate river flows, provide water for irrigation, domestic and industrial water supply, generate hydropower and combat growing problems such as floods and sea level rise.

Strong participation, education and communication at all levels will be essential for tackling climate change. Some aspects of surface and groundwater resources development and management are best devolved to local stakeholders to promote collective action, take advantage of their local knowledge and incentive for action, while other aspects such as sectoral coordination and transboundary need to be tackled at higher levels.

Effective water management will not happen without adequate financing. One of the most important drivers of future financing will be the mainstreaming of climate adaptation into national development programs (OECD 2009). This also applies to water management for climate risk reduction and the development of key infrastructure.

This adaptation framework is consistent with the principles of Integrated Water Resource Management (IWRM). IWRM, one option in the adaptation toolbox, advocates integration across water dependent sectors, supports and establishes multi-stakeholder engagement as water users, proposes multiple levels of management from the individual users of the resource up to the basin scale, and embeds ideas of efficiency and equity in allocation including both demand and supply side management. This is no accident – a number of authors have pointed out that a major part of climate change adaptation in the water sector is simply better water resources management, and IWRM is a widely-accepted paradigm for improved water management. Nevertheless, IWRM has been criticized because there are multiple interpretations of its concepts and because it is difficult to put many concepts into practice.

Other options in the adaptation toolbox - the water-energy-food (WEF) and water-energy-food-environment (WEFE) nexus - also recognize the importance of cross-sector coordination, trade-offs between different uses and the need to remove policy distortions. These options are however ill suited for dealing with hydrological characteristics that are important for promoting adaptation (e.g. dealing with extremes in hydrological variability, non-stationarity, improving conjunctive management of groundwater and surface water) or with managing water at different levels, including transboundary waters.

IWRM's emphasis on coordination between water dependent sectors needs to be augmented with broader reforms to address policies and actions outside the water dependent sectors. Examples of such policies outside the water sector include energy policy (for electricity subsidies for farmers for food security), trade policies (promoting export of water intensive crops) and land use policies (that encourage development on groundwater recharge areas).

While IWRM is already enshrined as policy in nearly all South Asian countries, few of its principles are implemented. Sector interests do not easily share decision making power, institutions are notoriously segmented and cross-sectoral coordination arrangements are weak or non-existent. Decision making is seldom devolved to the river basin level, let alone lower levels. More efficient management of existing water resources is usually discarded in favor of augmenting water supply, and few funds are allocated to maintaining and improving water resources data collection, interpretation and dissemination, or to regulating, protecting and managing water resources and promoting collective action.

Main findings. The analysis of climate change impacts and management responses used the analytical framework for the water sector. Its main findings are reported below.

Knowledge. The information base for decisions needs to be comprehensive, consistent across sectors, up-to-date, and readily available. Hydrological and climate monitoring networks need to be better maintained and expanded, remote sensing can be used more widely, critical climate and hydrological processes need to be understood, and information needs to be made available to all levels, including transboundary where necessary. Groundwater monitoring and interpretation should be prioritized. For groundwater dependant coastal urban and community drinking supplies, systematic saltwater intrusion monitoring should be prioritized.

Policy and Institutions. The policy framework between the water sector and climate change needs to be fully harmonized. Water policies need to advocate incorporation of climate change in water resources development, planning and management decisions while climate change policies should recognize the need for improved water management within a cooperative and cross-sectoral institutional framework. Institutions implementing these policies need to be coordinated with the coordination mechanisms properly defined, authorized, trained and funded. South Asia with its many large and small transboundary rivers can benefit from taking a regional approach to climate change adaptation. Climate change adds to the hydrological uncertainty and will impact water resources management decision making. A risk-based decision framework needs to be adopted, using techniques, such as Decision Tree Analysis, for infrastructure investments and for decision making more broadly. Strong links need to be developed between scientists and decision makers at all levels. Management decisions should be subject to review (e.g. infrastructure operating rules) as new information becomes available.

Infrastructure. Existing storage and regulatory dams can be operated more efficiently to postpone expensive investments in new infrastructure. Both existing and new infrastructure including flood control structures need to be designed and operated to take account of the potential impact of climate change over the infrastructure's lifetime.

Planning and management. Demand management needs to be widely implemented to make better use of existing infrastructure and defer funding new infrastructure. Demand can be managed through economic instruments (e.g. realistic pricing, removal of subsidies) and community education and participation. Implementation of other methods to make better use of existing water sources, such as conjunctive use of surface and groundwater, recycling and reuse and improvements in irrigation water use efficiencies need to be emphasized.

Communications, education and participation. Communications programs are needed to build an understanding amongst government and private sector (e.g. irrigation industry) decision makers, as well as amongst the general public, about the potential impacts of climate change on water resources across the region. Institutional capacity building is essential for managing the technically and administratively complex process of better integrating climate and water management with other water dependent sectors at scales from transboundary to national, to state/province, to basin/aquifer, to local levels. Climate change policies promote centralized decision making, whereas water policies through IWRM have provisions for promoting decentralized decision making although in practice these are yet to be institutionalized. More should be done to involve local and community groups in water resources decisions.

Financing. Adaptation cost information is fragmented, incomplete and difficult to obtain. Climate change adaptation funding programs fail to reflect the water sector as a priority sector in funding allocation, although investments in improving water management are simultaneously contributing to climate change adaptation. With the exceptions of India and Bangladesh, adaptation activities are primarily funded through international adaptation funds.

Recommendations for building adaptation capacity in the water sector. The report presents six broad sets of recommendations for governments to strengthen their resilience to the impacts of climate change in the water sector. The first set is intended to deepen the knowledge base on which decisions are made at national and sub-national levels. The second set relate to strengthening the frameworks that govern water resources management and adaptation to climate change. The third set are intended to develop climate smart infrastructure, while the fourth set are aimed at improving water resources planning and management. The fifth set relate to improving the capacity of water managers at all levels and the engagement of water users, while the last set seek to improve financing of climate change adaptation activities. Not all recommendations are applicable to each country because each faces different climate-related risks (Table A.1) and each has determined its priority actions through water resources and climate change instruments.

- *Deepen knowledge and information*: Invest in strengthening and improving information and knowledge in basic surface and groundwater quantity and quality monitoring, analysis and dissemination, the use of remote sensing (RS), a flood early warning system, and transboundary data sharing initiative between interested countries.

- *Strengthen policies and institutions*: Review barriers to improved cross-sectoral coordination (together with impediments to State/Provincial/national cooperation) and develop operational guidelines for mainstreaming climate change adaptation into water dependent sectors. Review central/local linkages to improve ground-level adaptation actions. Develop a groundwater–climate change initiative that integrates aquifer protection, MAR and conjunctive management of surface and groundwater in adapting to climate change in policy, practice and in financing.

- *Develop climate smart infrastructure*: Develop water resources infrastructure planning and development guidelines for assessing climate change impacts and integrating them into planning and design decision making. Review infrastructure design standards and operating rules to ensure that they account for climate change.

- *Improve planning and management*: Introduce an initiative to develop basin-level water sharing plans that incorporate climate change. Develop operational guidelines for monitoring and managing saltwater intrusion in coastal water supplies. Conduct an integrated study to trial water management methods – demand management, regulation, water use efficiency improvements, recycling and reuse, and MAR – to improve drought resilience. Introduce climate adaptation into urban water planning and management.

- *Broaden participation, training and education*: Develop good practice case studies for improving community engagement in adaptation activities. A water-climate-poverty-gender initiative would help the poor and disadvantaged. Develop training for climate and water policy decision makers and for the public to improve their understanding of the climate change impacts in the water sector. Develop training for water managers in water management methods for improving climate change adaptability (e.g. Decision Tree analysis, and river basin planning methods). Develop an initiative to elevate understanding amongst policy makers about the importance of groundwater adaptation opportunities.

- *Financing*: The water sector in climate change financing needs to be given higher priority in the distribution of climate change adaptation funding. The end use of adaptation funds should be tagged to develop a more reliable picture of the extent to which the water sector adaptation capacity is built. Considerable funds will be required to implement adaptation plans and programs - Governments needs to contribute more and encourage contributions from the private sector through innovative programs[1].

[1] Estimating the cost of implementing adaptation programs is complex and could not be undertaken in this desk study but is recommended for the follow up phase of this work.

WATER MANAGEMENT AND CLIMATE CHANGE

WATER MANAGEMENT IS A KEY DEVELOPMENT CHALLENGE IN SOUTH ASIA. PROVIDING RELIABLE SUPPLY OF WATER FOR DEVELOPMENT AND MANAGING THE RISKS INVOLVED IN HYDROLOGICAL VARIABILITY ARE FUNDAMENTAL TASKS FACING THE REGION. CLIMATE CHANGE IS MAGNIFYING THIS CHALLENGE, THOUGH UNEVENLY, THROUGH WARMING TEMPERATURES, ALTERING SPATIAL AND TEMPORAL PATTERNS OF RAINFALL AND RISING SEA LEVELS IN COASTAL AREAS. IMPACTS WILL RANGE FROM GRADUAL AND LONG-TERM, SUCH AS INCREASES AND DECREASES IN MEAN ANNUAL RIVER FLOWS AND SALINIZATION OF COASTAL AQUIFERS, TO MORE IMMEDIATE AND PUNCTUATED, INCLUDING INTENSIFICATION OF FLOODS, DROUGHTS AND LANDSLIDES. SOME CHANGES (E.G., SALINITY INTRUSION, SEDIMENTATION, LANDSLIDES AND FLOODS) WILL BE IRREVERSIBLE.

This report unpacks and addresses the nature of resulting policy, planning and operational challenges as regional governments and social systems attempt to adapt, mitigate and manage these challenges and ensure that sustainable water management remains a central pillar in economic development and social stability. It provides an evidence-base on which to build future capacity to improve water resources planning, development and management decision making under a changing climate. This first chapter describes the rationale, objectives and methodology used in the study.

1.1. South Asia's Water Development and Management Challenge

Effective development and management of surface water and groundwater is a critical challenge for sustaining South Asia's growth and livelihoods. The first key component of the challenge is the availability of reliable supply of water for different purposes (e.g. domestic supplies, agriculture, energy generation, cooling thermal plants, industrial production, livestock, ecosystems, as well as grey or 'waste' waters that result from different uses). The second component is variability, including managing changes in volume, timing and frequency of supplies, from slower, longer-term shifts to the immediacy of extreme events such as floods, droughts and storms.

South Asia has the fastest growing economy in the world. These water management challenges are serious in a region with over 1.7 billion people and with an annual GDP growth at 7.1% in 2016 that is projected to increase further in the short to medium term (World Bank 2016). This, the world's fastest growing region, also exhibits a wide spectrum of economies and water environments, meaning that the management challenges are equally diverse. The seven countries of South Asia (Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan, Sri Lanka) are home to 23.7% of the global population, but contain only 4.6% of the global annual renewable water resources[2], unevenly distributed between countries and river basins. Table 1.1 shows rapid growth in India, Bhutan and Bangladesh in 2016; while Nepal and Afghanistan grew slowly. At the same time, India, South Asia's largest economy and most populous nation, has low per capita water

[2] These percentages are based on the South Asia's and world's population figures of 1.744 and 7.349 billion, respectively (UN, 2015), and the AQUASTAT database (FAO, 2016) providing the following figures: 1,982 km^3 of internal annual renewable water resources in South Asia; 42,810 km^3 of global annual renewable water resources. Internal annual renewable water resources in the only country-wide water resource figure that can be added up for regional assessment.

availability while Pakistan, with the second largest economy, is largely arid and semi-arid and has the lowest per capita availability of water in the region. Consequently, India and Pakistan are water stressed. This is evident from growing deficits between water supply and demand, excessive withdrawal of surface water, over-pumping of groundwater, contamination and pollution of surface and groundwater, inefficient use of water and growing tensions, disputes and conflicts over water. Afghanistan, upstream and embroiled in conflict has both a fragile economy and only a modest endowment of water. Both Bhutan and Nepal have abundant water resources, but small and fragile economies. Bangladesh is almost completely dependent on sources originating outside its borders. National averages are also misleading, however, given wide temporal and spatial ranges within countries, as even the relatively small island nation of Sri Lanka exhibits. A middle income nation with a modest endowment of water, the area of Sri Lanka's dry zone is larger than the area of its wet and intermediate zones combined, rendering large parts of the country drought prone.

Table 1.1 - South Asian GDP and Water Endowment

	Afghanistan	Bangladesh	Bhutan	India	Nepal	Pakistan	Sri Lanka
Population, 2015 (million)	32.5	161	0.8	1308.2	28.5	188.9	21
GDP, current (US $ billion)	19.6	195.2	2.0	2189.7	22.4	271.4	82.3
GDP per capita, current (US $)	601	1212	2532	1674	786	1437	3924
Real GDP Growth (2016)	0.5	7.1	7.3	7.6	0.6	5.7	4.8
Per capita water availability (m3)	2,008	7,622	100,645	1,458	7,372	1,306	2,549

Source: World Bank (2016) Investment Reality Check and FAO Aquastat

Water and growth in South Asian economies is therefore a complex set of relationships, demands and challenges. What is key is a common way of understanding and interpreting these challenges that will support delivery of the most appropriate response mechanisms in water management at local, national and transboundary levels.

The utilization of water resources has generated enormous socioeconomic benefits. Water systems in the region support a diversity of productive and service sectors through rural and urban water supply and sanitation, irrigation provision, hydropower generation, water for livestock, navigation and other local domestic uses. Hydropower drives the economies of Bhutan and Nepal, whilst across much of the region irrigation has lifted millions out of poverty – but at huge levels of water consumption in agriculture. The surface-to-groundwater relationship varies across countries with major groundwater withdrawal in India and Bangladesh and rapid growth in use elsewhere – including Sri Lanka, Pakistan and Afghanistan. The buffering capacity of groundwater during drought is becoming a central feature of the growing demand for the resource. While agricultural development continues to drive the region's food security, (and employment security, over half of all jobs are in the sectors), it is also a constant pressure on watersheds, wetlands, floodplains and estuaries, which support key ecosystem services including fishing and tourism.

1.2. South Asia's Water Management Strategy

Reliable supplies of water for domestic, industrial, agriculture, and energy uses are essential for sustaining growing economies, populations and urban areas, and rural livelihoods, and variable river flows for ecosystem services. A recent study estimates that South Asia could see its GDP growth rates decline by as much as 6% by 2050 as a result of water-related losses in agriculture, health, and income, and damaged human settlements and infrastructure (World Bank 2016). Growing economies, populations and urban areas are rapidly generating demand for food, energy and industrial outputs, in addition to rising drinking water and sanitation needs in burgeoning cities and rural communities. These factors are likely to be the major disruptor of demand in the near to medium term. By 2030, water demand in the largest South Asian economies is projected to be twice currently available supplies, leading to potential obstacles to growth. Investments in water supplies, including water storage to offset potential greater variability, and more effective conjunctive management of surface and groundwater will become essential. Inefficiencies will need addressing. Losses in municipal systems continue to grow and water use in irrigation, by far the largest user of water (91% of total water use) and greatest imprint on the environment, remains highly inefficient in most areas. Using both water supply side and demand side management is the first key element for water management strategies across the region.

Unsustainable uses and practices are degrading the quality of available water. Low availability combined with poor water allocation provision are contributing to inadequate environmental flows, reducing production services such as inland fisheries and regulating services such as waste assimilation, sediment transport and maintenance of estuarine, delta and near-shore marine ecosystems. Naturally occurring contaminants (e.g., arsenic, fluoride, salinity) and pollution from cities, industries, mines and agriculture are affecting urban and rural water supply quality, causing both immediate and longer-term public health crises and adding cost to the treatment of water supplies. Irrigation without adequate drainage is contributing to waterlogging and salinity buildup reducing agriculture productivity. Poor protection and management of watersheds, aquifers, lakes and wetlands are all adding pressure on the region's surface and groundwater resources. Promoting sustainable use through collective action by user groups and communities is the second key element for regional water management strategies.

The management of hydrological extremes – floods, sedimentation and droughts – is necessary to mitigate the consequences of water-related natural disasters. South Asia is a hotspot for natural disasters, accounting for some 40% of globally-recorded events. Over the past two decades, water related disasters – floods, droughts and cyclones – have affected half of South Asia's population causing tremendous loss of life, destroying livelihoods, damaging property and infrastructure, and generating extensive financial losses (Gupta et al 2011). Systematic planning, development and management to address the systemic risks emerging of water-related disasters brought about by hydrologic extremes needs to be a third element in the region's water management toolbox.

Many rivers and aquifers span across multiple administrative and political boundaries – villages, cities, districts, provinces and states, and nations. Rivers traversing political boundaries are the norm in the region. The Ganges-Brahmaputra-Meghna (GBM) and the Indus basins drain about half the region by area. The GBM is supplied mainly by monsoonal rains (of which about 20-40% of the water resources in the Ganges River Basin are used for irrigation), while the Brahmaputra and Meghna rivers remain largely unexploited in their Indian portion. The Indus basin includes the largest area of non-polar perennial ice cover in the world, the seasonal changes in which are a key driver of the river's flow. The Helmand river shared by Afghanistan and Pakistan also originates from the high mountains. In groundwater terms, the transboundary Indo-Gangetic Basin (IGB) alluvial aquifers underlie most of Pakistan, northern India, southern Nepal and Bangladesh and are among the most productive aquifers in the world. Optimal use or management of destructive floods on shared rivers is best facilitated through a collaborative approach implemented jointly by the administrative entities - districts, provinces, states or nations – sharing a resources. Given this essentially share challenge, a collective action approach is best suited for establishing regional ways of resolving regional problems. More collaborative management of shared waters therefore has to be a fourth element in the region's water management strategy toolbox.

Policies and actions outside the water sector are also profoundly impacting the water sector. Rapid urbanization and land use change in Lahore, Pakistan reducing groundwater recharge areas, rates of recharge and the overall quality of urban water supplies is one such example. Others include energy subsidies for agriculture in selected states in India (e.g. Punjab, Rajasthan and Karnataka) directly contribute to over-pumping of groundwater and declining water levels. And degradation of watersheds across many parts of the region accelerates downstream sedimentation and adds to potential flood risk through reducing conveyance capacity of rivers and channels as well as shortening the effective economic lifespan of dams. Habitation/ encroachment on riverine corridors and floodplains on the Indus and Ganges rivers continues to increase vulnerability of communities to flooding and flood damage. Current water policies inadequately address these extra-sectoral land use, energy and natural resource implications on future water resources availability and variability. Integrating policies and actions outside the water sector needs to be the fifth element of water management strategies across the region.

1.3. Climate Change: Management Risks and Future Costs

Underlying management risks are amplified by the anticipated impacts of climate change and variability across the region. Climate change, causing shifts in hydrological parameters and increasing variability, remains the key long-term, systemic disrupter of effective water management across South Asia. Changes in the hydrological cycle including impacts, such as floods, droughts, rainfall variation and salinity intrusion, will have severe direct and indirect, immediate and long-term, consequences for agriculture, the environment, health, energy, and urban and rural development across South Asia.

By mid-21st century South Asia could witness temperature increases of up to 3°C under a high-emissions scenario. Longer-term shifts in monsoons (with earlier onsets likely), higher evaporation and evapotranspiration rates, and altered patterns and timing of river flows and rising sea levels will affect the region's water supply, demand and quality. Less reliable surface supplies and frequent droughts will increase the need for storage and dependence on groundwater. Recurring floods may increase the need for flood control structures (dams, embankments) and nonstructural interventions (such as zoning and other measures). The region's high vulnerability is due in large part to the size of the population and high densities in some areas combined with high levels of poverty – including chronic poverty – and low adaptive capacity.

The estimated economic cost of climate change is high. The region's livelihoods and economic development are highly climate-sensitive. According to IPCC (2014a), climate change impacts are projected to slow down economic growth, make poverty reduction more difficult and further erode food security. Box 1.1 estimates the economic cost of climate change in South Asia. These exclude costs arising from the impacts of extreme events such as storms, floods and droughts, thereby underestimate overall economic costs.

Box 1.1 - Economic Cost of Climate Change in South Asia

Ahmed and Suphachalasai (2014) estimate that under a business as usual scenario, economic costs of climate change at a regional level could amount to an equivalent of 1.8% of South Asia's annual gross domestic product (GDP) by 2050, rising to 8.8% by 2100. The model employed to generate these estimates includes the effects of changes in temperatures and precipitation but not the impact of extreme events, such as storms, floods, and droughts, which could lead to even higher costs if included. Specific sectoral impacts would have disproportionately severe impacts on human security, not least because the poorest would be hit most acutely, particularly in countries that are highly dependent on agriculture. However, if global mean temperature rise is kept to within 2 Degrees Celsius, the region would only lose an average of 1.3% of GDP by 2050 and about 2.5% by 2100.

The authors estimate that Bangladesh, Bhutan, India, Nepal, and Sri Lanka would face respectively a 2.0%, 1.4%, 1.8%, 2.2%, and 1.2% loss in annual GDP by 2050, with average total annual economic losses projected to be 9.4% for Bangladesh, 6.6% for Bhutan, 8.7% for India, 9.9% for Nepal, and 6.5% for Sri Lanka by 2100. For India, the impacts would be felt through a decline in agricultural productivity, with implications for poverty alleviation (Garg et al. 2015). Chaturvedi (2015) estimates that major food crop losses could reach US$ 208 billion and US$366 billion in 2050 and 2100 respectively. In Nepal, a government led Economic Impact Assessment (EIA) found that agriculture and hydropower are the sectors most likely to be affected by climate change (IDS-Nepal, 2014). The EIA estimates climate change to have a direct cost to GDP of 1.5%-2% (US$ 270-360 million/year in 2013 prices) per year rising to a GDP cost of 5% per year in extreme years (IDS-Nepal, 2014). Bangladesh would experience these impacts through declines in agricultural production as well as through loss of land availability from sea-level rise.

Source: Suhardiman et al (2017).

1.4. Adaptation and Water Management

COP21 held in 2015 in Paris focused more specifically on water issues within the wider adaptation agenda. COP22 held in 2016 in Marrakesh elevated this discourse even higher and discussed integrated water resources management (IWRM) as part of the adaptation toolkit available. Although the need for building adaptive capacity in the water sector (and wider linked sectors) is widely recognized, how to move from understanding the challenge to building appropriate levels of capacity at both policy and operational levels is less clear. While some important technical studies – for example, the recent report "Confronting Climate Uncertainty in Water Resources Planning and Project Design: The Decision Tree Framework" (Ray and Brown 2015) – provide guidance on the integration of climate uncertainty in water planning and project design, there are no broader guidelines in place to support adaptive capacity development at sector level. This requires improved knowledge on climate impacts at regional (transboundary), national and local levels, joined together and able to inform improved water resources planning, development and management decision making. It also requires deeper understanding of the water resource base and the adaptation opportunities it provide.

This report - *Adaptation Frameworks for Water Resources Planning, Development and Management in South Asia* – helps fill this gap by identifying and supporting with evidence broader messages that can help link adaptation needs to water (and other) sector actions at a country level. It builds on the pioneering work conducted after the third IPCC assessment and published in the anthology "Climate Change and Water Resources in South Asia" (Mirza and Ahmad 2005).

In this report we place emphasis on groundwater management because groundwater will become more important as a source of water under changing climate conditions. Box 1.2 describes characteristics of groundwater that make it a more drought and climate resilient resource compared to surface water. Unlike surface water, groundwater is shielded from evaporative losses and provides a better buffer against increased climate variability. Surface and groundwater are closely linked and should systematically be managed conjunctively.

Box 1.2 - Groundwater and Drought and Climate Resilience

> Groundwater has some unique characteristics compared to surface water - large natural storage volumes, slow response times, and protection from evaporation – that are important for drought and climate resilience. Aquifers in general are naturally buffered against short- and medium-term climate (temperature and rainfall) variability compared to surface water. These characteristics provide a significant opportunity to store excess water during high rainfall period, to reduce evaporative losses and to protect water quality. Integrating these characteristics in water resources planning and management decision making can help to harness substantial opportunities for developing drought- and climate-resilient strategies.
>
> *Source*: Clifton et al 2010.

1.5. Objectives

This South Asia Water Initiative (SAWI) technical assistance project has the overarching objective of using a collaborative process to build knowledge, tools and capacity across the region that will assist governments in adapting to climate change challenges in the water sector. It is being implemented in two phases: Phase 1, reported here, is a desk study implemented by the World Bank and the International Water Management Institute (IWMI). It had four specific objectives:

1. Review the national water policies, water resources strategies and water resources plans or water masterplans and climate change policies, strategies, plans, NAPAs and NDCs in each South Asian country;

2. Review the current knowledge and information on climate change issues and impacts and modelling work to develop a comprehensive understanding of climate change impacts and risks on water resources, and their implications for current and future water resources planning, design and operations;

3. Review the economic impacts of climate change on water-related activities and assess the capacity of institutional and financial mechanisms for adapting to climate change; and,

4. Identify the types and range of short to long-term adaptation options and opportunities available to address climate change risks and to build resilience in South Asia.

1.6. Methodology

This report draws from a vast body of knowledge and literature and three commissioned papers. It summarizes the major climate change risks for managing South Asia's water resources and the emerging opportunities for the water sector to more effectively adapt to a warming world. It has synthesized existing knowledge available on government websites, from the academic literature, as well as from international organizations such as the IPCC, IWMI, the World Bank, FAO, and other UN agencies. It has also drawn on material from specialist international organizations including the Centre for Research on the Epidemiology of Disasters International, and the International Centre for Integrated Mountain Development (ICIMOD).

Three technical papers were produced:

- The first paper reviews South Asia's surface and groundwater resources, the hydrological cycle and the impacts of climate change on these water resources. It also reviews water flows and water quality and assesses the likely changes in both water availability and in water demand because of climate change;

- The second paper reviews the policies, legislation, strategies, and plans for managing water resources in each South Asian country and the extent to which these instruments help countries adapt to the likely impacts of climate change. The paper also reviews climate change policies, legislation, strategies and plans to determine whether they recognized opportunities for adaptation in the water sector (Appendix 1) lists the policy instruments reviewed);
- The third paper focuses on the economic implications of climate change in the water resources sector, current trends in financial structures and mechanisms for climate adaptation, and the effectiveness of institutional frameworks for climate adaptation, especially in the water resources sector in each country.

The drafts of the three papers were presented and reviewed at a regional stakeholder workshop held in Colombo, Sri Lanka in July 2016 attended by 65 national, regional and international climate change and water resources experts, including 20 representatives of governments across the region. Being a desk study, the analysis relied on published information and did not seek additional information from government officials or other experts apart from feedback received at the workshop. The revised background papers were also reviewed by World Bank staff in April 2017. A draft of this summary report was reviewed by World Bank and outside peer reviewers in February 2017.

1.7. Audience

The primary target audience for this report are South Asia's water resources and climate policy decision makers, managers and technical experts. Academics, researchers, development practitioners and planners will also benefit from the work, as will policy developers, decision makers and technical experts beyond the South Asia region.

1.8. Report Structure

This report is organized around three parts and twelve chapters.

Part 1 with four chapters discusses the risks and opportunities for adaptation to the water sector in South Asia. It includes discussion on known and emerging water resource issues, climate change information, and key risks and opportunities. This first chapter provides the background, context, objective and methodology used in this work and the target audience for the report. Chapter two describes South Asia's water resources, the main climate change risks, the primary climate drivers of hydrological changes and uncertainty in knowledge and information. Chapter three discusses the socioeconomic and climate drivers of water demand and chapter four extreme events under climate change.

Part 2 with seven chapters focuses on the opportunities for building adaptation capacity for the water sector. Chapter five describes the adaptation framework for the water sector drawing on reviews of the pros and cons of integrated water resources management. Chapters six to eleven present findings and recommendations from the review of the three background papers related, respectively, to addressing the water resources and climate knowledge gaps, strengthening water resources and climate governance (policies and institutions), enhancing water resources planning and management using a risk based approach to designing and operating water resources infrastructure, and improving communications, education and public consultations, as well as financing challenges.

Part 3 with the final chapter, Chapter twelve, presents the recommendations for building adaptive capacities for the water sector in South Asia.

Appendix 1 lists the government water and climate change instruments (policies, strategies, plans, legislation) reviewed in Background Paper 2.

WATER RESOURCES, CLIMATE RISKS AND UNCERTAINTY

THIS CHAPTER DESCRIBES THE WATER RESOURCES OF SOUTH ASIA AND DRAWS PARTICULAR ATTENTION TO THE GROWING IMPORTANCE OF GROUNDWATER AMID WIDER PRESSURES ON THE WATER RESOURCE BASE, INCLUDING DETERIORATING WATER QUALITY. GROUNDWATER IS A VITAL RESOURCE BUT REMAINS HIGHLY UNDERVALUED IN SOUTH ASIA, EVEN THOUGH IT CAN PROVIDE A CRITICAL BUFFER AGAINST INCREASING VARIABILITY, INCLUDING A RANGE OF IMPORTANT ADAPTATION OPPORTUNITIES. THE CHAPTER HIGHLIGHTS THE MAJOR CLIMATE CHANGE RISKS IN SOUTH ASIA, DESCRIBES THE MAIN CLIMATE DRIVERS OF HYDROLOGICAL CHANGE AND DISTINGUISHES BETWEEN THE TWO CONCEPTS, NATURAL CLIMATE VARIABILITY AND HUMAN-INDUCED CLIMATE CHANGE, THAT ARE SOMETIMES CONFUSED. FINALLY, THE UNCERTAINTY SURROUNDING CLIMATE CHANGE INFORMATION AND KNOWLEDGE IS DISCUSSED.

2.1. South Asian Water Resources: Key Challenges

The availability of water is affected by climate, topography, land-use, and socio-economic factors. Climate is influenced by topography (from the highest mountain ranges to large deltas), precipitation (from arid lands to extensive plains subject to unpredictable flooding) and environment (from glacial to tropical). In general, the eastern part of the region is wetter and the western part drier. Great seasonal, inter-annual and spatial differences in precipitation determines water availability – where, when and how much water is available. Spatial variations in mean annual rainfall can be very marked over relatively short distances, which also points to the need for locally-relevant adaptation options.

Water resources in rivers, lakes, reservoirs, snowpack, glaciers and aquifers that originate as rainfall and snow in each country are summarized in Table 2.1. Surface water and groundwater comprise 87% and 13% respectively of the Total Renewable Water Resources (TRWR). TRWR is water that originates within each country, and is a function of internal renewable water resources (IRWR), and water that flows from neighbouring countries as surface water entering the country (SWEC). Rainfall/runoff ratios range from 0.14 in Pakistan, where a significant part of rainfall evaporates, to more than 0.90 in Bhutan and Nepal, where evaporation rates are much lower and runoff rates are much higher due to mountainous and steep terrain (Singh and Karki 2004). Snowmelt contribution to TRWR varies from 92% in Afghanistan and 57% in Pakistan to nothing in Sri Lanka. In general, the higher the snowmelt contribution to the TRWR the greater is its vulnerability to warming temperatures.

Surface water entering the country represents the shared portion of the region's surface waters. The contribution of SWEC to TRWR varies from 0% (Bhutan) to > 90% (Bangladesh). The higher the SWEC the greater the dependence on inflows from other nations, making the receiving country more vulnerable to factors outside its control.

Although groundwater is only 13% of South Asia's TRWR, it is a critical resource for all sectors. It supports 60% to 80% of the irrigation, rural and urban water supply across the region. Currently, 62% of the region's 555 BCM of renewable groundwater has been developed. South Asia is the largest abstractor of groundwater globally, pumping a third of all groundwater used globally and half of the world's groundwater for irrigation. India, Pakistan, and Bangladesh are the world's first, fourth and sixth largest abstractors of groundwater globally. Groundwater use in Afghanistan is moderate; in Nepal and Sri Lanka, low; and in Bhutan, minimal. Overall, the region's dependence on groundwater is expected to increase as economies grow, population increases, surface supplies become less reliable, and climate change requires a water source that is buffered against increasing variability.

Table 2.1 - Water Resources in South Asian countries

		Afghanistan	Bangladesh	Bhutan	India	Nepal	Pakistan	Sri Lanka	South Asia
IRWR	km^3.year^{-1}	47	105	78	1,446	198	55	53	1,982
	As % of rainfall	22	27	92	41	90	14	47	40
SWEC (km^3.year^{-1})		10	1,122	0	635	12	265	0	2,044
Groundwater as % of TRWR		16	2	9	19	9	19	13	13
Snowmelt as % of TRWR		92	0[3]	17	10	8	57	0	11
TRWR (km^3.year^{-1})		65	1,227	78	1,911	210	247	53	3,791
TRWR (m^3) per capita per year		2,008	7,622	100,645	1,458	7,372	1,306	2,549	2,175

Source: FAO (2016) AQUASTAT

South Asia has extensive alluvial and hard rock aquifers. The transboundary Indo-Gangetic Basin (IGB) floodplain and alluvial deposits that underlie most of Pakistan, Northern India, Nepal and Bangladesh have both high yield and recharge rates due to rainfall infiltration and/or stream water percolation. In contrast, hard rock aquifers that span peninsular India, parts of Bhutan and Nepal, and Sri Lanka, store groundwater in deep fissures which are generally less accessible and provide lower water yields because of lower recharge rates[4]. Each aquifer type requires different approaches to management given the differences in hydrogeological characteristics, resilience to change, and ease of abstraction and recharge.

Water storage. The monsoons result in nearly 80% of rain in much of South Asia falling from June to September. This makes seasonal storage of water critical (in dams, reservoirs, and tanks, as well as in aquifers, wetlands, and lakes) to provide reliable year round water supply and a supply buffer for lean periods. The total surface water storage capacity in all dams, reservoirs and tanks across South Asia is estimated to be 280 km^3. According to McDonald et al (2015), the natural storage capacity of the Indo-Gangetic basin aquifers alone is much larger; it is over two orders of magnitude larger than the total surface water storage (Box 2.1).

Degradation of surface and groundwater quality is a major problem that is widespread and growing. Natural and anthropogenic contaminants are affecting drinking and industrial water supplies in cities, major towns, and villages, causing an additional heavy burden on public health. In the Ganges River basin, risks of pathogenic contaminations increase with higher temperature and increased hydrologic extremes. Water quality is usually better in the upper parts of the large river basins, due to lower population densities generating less pollution than in the lower deltaic regions (e.g. plain of Dhaka). However, elevated concentrations of naturally occurring contaminants like arsenic and fluoride exist in many upstream areas. While water quality is high in the upstream Indus and its tributaries, effluents from agricultural drainage and wastewater from cities and industries seriously affect water quality downstream.

[3] In Bangladesh, which receives water from snowmelt rivers, the snowmelt flows are included in SWEC.
[4] It is important to note the limitation of this generalization because it is very context specific. They can provide both high rates of recharge and high yields under the right conditions, e.g. springs.

Box 2.1 - The IGB aquifer has immense natural storage

A recent regional study estimates that the storage volume in the first 200 depth of the IGB aquifer is almost 30,000 km^3. This is nearly100 times the total constructed surface water storage—dams, reservoirs, and tanks—in the region. This immense storage is more than 20 times the combined annual flow of the Indus, Brahmaputra, and Ganges rivers. However, this vast and vital IGB aquifer is left largely unprotected, insufficiently monitored, and inadequately managed, with huge long-term losses (opportunity costs) to the region's development if its essential qualities are lost.

Source: MacDonald et al 2015

2.2. Climate Change Risks

IPCC Fifth Assessment Report (IPCC 2013b) identifies key South Asian risks from climate change as: (a) increased riverine, coastal and urban flooding, leading to widespread damage to infrastructure, livelihoods and settlements; (b) heat-related mortality; (c) increased risk of drought-related water and food shortages causing malnutrition; (d) mudslides and sedimentation problems; (e) sea-level rise inducing saltwater intrusion of coastal aquifers; and (f) changes to the cryosphere of the Hindu-Kush Himalayas (the 'Third Pole') with downstream impacts in major river systems including the Ganges-Brahmaputra and the Indus. Under current variability in the region and under future climate change scenarios, inadequate development of water information systems, ineffective policies and institutions, and inadequate provision and management of key infrastructure will generate further risks for the region.

2.3. Climate Drivers of Hydrological Change

Changes in temperature and precipitation patterns (both average values and extremes) and rising sea-levels constitute the three primary drivers of hydrological change in South Asia. These, in turn, give rise to changes in a variety of water-related parameters such as river flows, groundwater recharge rates and changes in water quality. These secondary, hydrological impacts from climate change manifest themselves as changes in both the average values (such as mean annual flows) and extremes (such as floods). Crop water demand will also rise due to increased temperatures and evapotranspiration.

The warming of the Earth's atmosphere because of increasing concentrations of greenhouse gases has already brought about measureable changes in the global climate. The earth's surface has warmed by 0.85°C since the mid-19th century and sea levels have risen by about 1.7mm/year since the start of the 20th century. Natural climate variability and human induced climate change are sometimes confused. Box 2.2 distinguishes these two concepts and their implications for planning, designing and operating water resources infrastructure and for managing water resources.

Global warming will bring about changes in both average climate parameters and in extremes. For example, average temperatures will rise along with an increase in extreme cold and hot temperatures. This means that South Asian countries need to prepare and adapt for both more extreme events (such as floods, drought, cyclones and heatwaves) as well as shifts in long term average river flows, groundwater recharge levels, increasing water demands across sectors – and for different types of 'waters' – as well as the continuing retreat of glaciers and steadily-increasing sea levels.

Box 2.2 - Climate Variability and Climate Change

Climate variability describes variability of, for instance, precipitation in spatial and temporal scales beyond that of individual weather events. The familiar sequence of a monsoonal rainy season starting in April-May followed by a dry winter season starting between October and December is an example of natural seasonal variability across most of South Asia. There is also spatial variability in this climate pattern, with the southwestern parts of South Asia typically being the first to receive the monsoonal rains coming from the Arabian Sea and the Bay of Bengal. The climate also varies considerably between years. The conventional practice has been to use a reference period of about 30 – 40 years to characterize the variability of the climate in order to design water infrastructure. The assumption has been that the average climate and variability around that average remains constant over time. This stationarity assumption allows engineers to plan for infrastructure by assuming that future hydrology repeats itself and will be the same as that experienced in the past (Davis, 2011).

Climate change describes the change in climate variables caused by the warming of the earth's atmosphere as a result of human activities such as increasing GHG emissions, land-use change and emissions of aerosols. This warming will likely change both the average climate and its variability in a particular region or location across a wide range of temporal scales – sub-daily, daily, monthly, seasonal, inter-annual, and decadal. Thus, engineers cannot assume that infrastructure designed for past climates will be suitable and reliable for the future; in other words, the stationary assumption no longer holds.

Source: Davis and Hirji 2014

2.4. Uncertainty in Climate Change Information and Knowledge

South Asia is one of the regions where climate projections are least reliable. The most notable warming changes already apparent in South Asia are the retreat of HKH glaciers (with the exception of some Karakoram glaciers around the so-called 'Karakoram Anomaly'). Climate change will have widespread impacts on the hydrology of South Asia's surface and groundwater systems with consequent impacts on the region's natural environment, economy and society. Global Circulation Models (GCMs) provide projections of climate parameters, such as temperature and precipitation, although there are large errors in these projections because of the different formulations of different models and the assumptions and uncertainties about future greenhouse gas emissions. Hydrological models are used to translate these climate projections into river flows, groundwater recharge and estimates of crop water demand. Models can also predict the rate of sea-level rise from warming of the oceans and rapid ice melt.

Uncertainties in climate and hydrological projections arise from a range of factors. These include the reliability and availability of data used to calibrate the climate and hydrological models, the limited understanding of climatic and hydrologic processes and their inevitably inaccurate modelling, the uncertainty in future GHG emissions scenarios and the omission of other influential dynamics (e.g., changes in water uses and land uses). Background paper 1 (LaCombe et al 2017) discusses these factors in more detail.

The main hydrological modelling challenge in South Asia arises from the limited understanding of the physical processes regulating glacial melt in a complex orographic environment, and the hydrological processes involved in extreme events. The limited monitoring networks and data availability for both precipitation and river flows present further difficulties for validating models and estimates of water balances (Mathison et al. 2015).

2.5. Reliability of climate change projections

The reliability of climate change projections varies. There is high confidence that average temperatures and the frequency of hot days will increase, and sea-levels will rise across South Asia. However, the impacts of global warming on other climate parameters, such as precipitation, are less certain. These uncertainties are particularly high in South Asia because of the limited amount of climate monitoring data and the complexity of climatic influences in this region. Recent projections based on International Panel on Climate Change (IPCC) results (IPCC 2014b) show possible increases in annual precipitation across the Himalayan region, Nepal and Sri Lanka with smaller increases in Bhutan. There will possibly be a reduction in annual precipitation in lower parts of Afghanistan and across India, Bangladesh and Pakistan. There may be an increase in rainfall extremes. However, these projections are made with only low confidence. There is even greater uncertainty when these climate projections are translated into hydrological impacts – including mean annual river flows, groundwater recharge and peak flow events – because of the additional uncertainties that arise when changes in evapotranspiration and precipitation patterns, are coupled with changes in land use and vegetation cover as a result of climate change. This report uses the best available estimates of changes in climate and hydrological parameters from the IPCC5 reports (IPCC 2014a).

2.6. Variability of the monsoons

Trends in the variability in India's monsoons. The standard projections from climate change research have been that extreme wet and dry events will become more frequent, and that drier regions are likely to become drier and wet regions will become wetter under climate change scenarios. However, a recent study from India has found that, while the intensity and frequency of extreme monsoonal rainfall events are increasing as expected from climate change modelling, the mean monsoonal rainfall is decreasing over India's major water supply basins and increasing over drier areas (Ghosh et al. 2016). These latter findings, contrary to standard beliefs about climate change impacts, are important for reassessing the yield of existing river basins as well as for planning new infrastructure such as dams and inter-basin transfers. Above all they point to the complexity of managing decision making in imperfect knowledge environments, pointing to the need for continued adherence to no and low-regret solutions to future adaptation challenges.

SOCIO-ECONOMIC AND ENVIRONMENTAL DRIVERS OF WATER DEMAND AND SUPPLY

THIS CHAPTER DESCRIBES THE CURRENT PRESSURES ON WATER AVAILABILITY ACROSS THE WATER-DEPENDENT SECTORS OF SOUTH ASIAN ECONOMIES. IT ALSO DESCRIBES THE NEGLECT OF ENVIRONMENTAL WATER PROVISION IN MOST COUNTRIES – AN ESSENTIAL FACTOR IN MAINTAINING THE ECOSYSTEM SERVICES PROVIDED BY AQUATIC ECOSYSTEMS INCLUDING HABITATS FOR FISHERIES, AND RECHARGING SOIL WATER AND SHALLOW AQUIFERS BENEATH FLOODPLAINS. THE CHAPTER THEN EXAMINES THE POSSIBLE EFFECTS OF CLIMATE CHANGE ON BOTH THE AVAILABILITY OF WATER AND ON PATTERNS OF WATER DEMAND, KEEPING IN MIND THE CONSIDERABLE UNCERTAINTY ASSOCIATED WITH PROJECTIONS OF CLIMATE CHANGE IMPACTS. IT IS NOTED THAT CLIMATE RISKS DIFFER ACROSS THE REGION, WITH EACH COUNTRY HAVING A DIFFERENT RISK PROFILE, POINTING TO THE NEED FOR TAILORED- AND NUANCED-RESPONSES BASED ON COUNTRY- AND LOCALLY-SPECIFIC UNDERSTANDING OF RISKS AND IMPACTS, BUT IN THE CONTEXT OF WIDER 'SHARED TRANSBOUNDARY SYSTEMS'.

3.1. Water uses and demand

Total surface and groundwater withdrawals represent 27% of the total available renewable surface water and groundwater resources. Total surface water withdrawal is 61% of the total water resources withdrawal and total groundwater withdrawal is 39% of the total water resources withdrawal.

At the national level, total water use percentage varies from 5% or less in Bangladesh, Bhutan and Nepal to 74% in Pakistan of total renewable water. Afghanistan, India and Sri Lanka withdraw 31%, 40% and 25%, respectively, of their available renewable water resources. While water is mainly used for agricultural purposes, domestic and industrial water demand is increasing, driven by changing lifestyles, urbanization and demographics under changing socioeconomic conditions. At the same time, agricultural water use continues to increase due to intensification, in large part a response to rapidly-growing demand for food. Hydropower is a key water use, especially in mountainous regions in Bhutan, India, Pakistan and Nepal. The gross hydropower potential of India is estimated at 148,700 MW installed capacity. Further, small, mini and micro hydropower schemes (with a capacity of less than 3 MW) have been assessed as providing a potential 6,782 MW of installed capacity. Water for cooling thermal power plants is also a key growing demand.

Irrigation water use. A third of agricultural land is irrigated across the region. Bangladesh and Pakistan irrigate 55% of their agricultural land while Afghanistan irrigates only 8%. Overall, the region is home to some of the world's largest contiguous irrigation schemes. On average, irrigation uses more than 90% of the volume of water used in South Asia with variations ranging from 87% in Sri Lanka to 98% in Afghanistan and Nepal. However, the patterns of water use and the relative reliance on surface and groundwater vary significantly across the region (Box 3.1).

Box 3.1 - Seasonal Estimates of Irrigation Water Demand in South Asia

Agriculture in South Asia and the nature of the supporting demand for water have certain unique characteristics when compared to other food-producing regions of the world. Multiple cropping is practiced extensively. In many countries this takes the form of a monsoonal cultivation (kharif) followed by a second cultivation during the dry winter season (rabi). The lack of moisture during the drier season is usually compensated for by more intensive surface and groundwater irrigation.

A study by Biemans et al. (2016) in four South Asian countries (Bangladesh, Nepal, Pakistan and India) found that the rainfall pattern determines the timing and extent of irrigation water demand. Of the four countries, India and Pakistan have the highest demand for water. In Bangladesh and Nepal, irrigation is mostly required only for the rabi season. Irrigation water is required in equal proportions for the two seasons in Pakistan while, in India, almost three-quarters of net demand is during the dry season. However, when the total water withdrawn is considered, the differences between the four countries become less obvious because of the higher efficiency of groundwater irrigation, which meets the greater proportion of the dry season demand. In general, groundwater meets most of the dry season irrigation needs in all four countries. Further, the study finds that improvements in land use and cropping periods have resulted in lower demands on irrigation water, compared to previous studies.

The second major factor that determines seasonal water demand is the type of crop cultivated. Rice has peak water requirements during both the *rabi* and *kharif* season, while wheat has a highly pronounced demand during the dry season. Rice has a reputation as a highly water-intensive crop. However, because it is grown mainly during the *kharif* season in most areas, it is other crops such as wheat and sugarcane that account for a greater proportion of the irrigation water demand during the dry seasons.

The nature of the water demand in the Indus, Ganges and Brahmaputra basins is depicted in Figure 3.1. The water demand in the Indus does not show a great degree of fluctuation during the year, with the irrigation water demand being met by melt runoff during the *kharif* and groundwater during the *rabi*. In both the Ganges and Brahmaputra, water demand during the summer is lower, with large parts of the basin being rain-fed.

Total regional crop production (of the five most important crops - wheat, rice, maize, tropical cereals and pulses) is almost equal in both the seasons. Some 50% of this production requires irrigation in the *kharif*, and 95% requires irrigation during the *rabi*. In the Indus, the greater proportion of the food is produced during the *rabi*. Rainfed production becomes more pronounced in the Ganges, whereas in the Brahmaputra, the *kharif* is the most important food-producing season. Thus, the relative importance of irrigation decreases when moving from the west to east across the region.

These findings illustrate the need for governments across the region to strengthen their groundwater policies and to better integrate surface and groundwater management if dry-season production is to be maintained under reduced water availability. Climate change is likely to bring not only changes to annual average rainfall and stream-flow but also to rainfall patterns and to groundwater recharge, affecting cropping mixes across South Asia. At the same time, the current variability in cropping across South Asia to take advantage of different water availabilities illustrates the adaptability of agriculture and the potential for farmers to learn how to adapt to changing rainfall patterns. Both improvements in scientific knowledge and sharing and learning from current experience are important aspects of climate change adaptation.

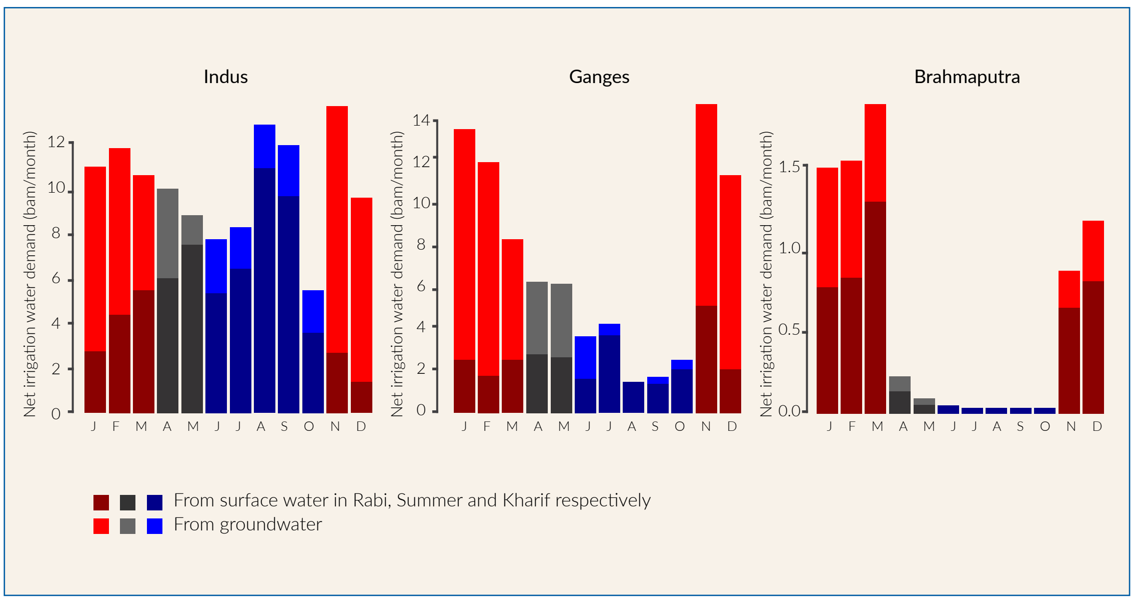
Source: Biemans et al. (2016).

Table 3.1 - Water uses in South Asian countries

	Afghanistan	Bangladesh	Bhutan	India	Nepal	Pakistan	Sri Lanka	South Asia
Total water use as % of total renewable water resources	31%	3%	0%	40%	5%	74%	25%	27%
Total water use (km^3/year)	20.4	35.9	0.3	761.0	9.5	183.5	12.9	1023.5
Agriculture water use (km^3/year)	20.0	31.5	0.3	688.0	9.3	172.4	11.3	932.8
Industrial water use (km^3/year)	0.2	0.8	0.0	17.0	0.0	1.4	0.8	20.2
Municipal water use (km^3/year)	0.2	3.6	0.0	56.0	0.1	9.7	0.8	70.4
Surface water use (km^3/year)	16.7	7.4	0.3	531*	7.6	121.9	5.1	550.4
Ground water use (km^3/year)	3.7	28.5	0.0	230**	1.9	61.6	7.8	325.7
Groundwater use as % of total water use	18%	79%	0%	36%	21%	34%	60%	39%
Groundwater use as % of total renewable ground water resources	34%	2%	0%	53%	10%	24.8%	15%	63%

Other sources: (National Statistics Bureau, 2009) for Bhutan. *: this volume includes the direct use of agricultural drainage water that represents 14.9% of total water withdrawal (FAO, 2016). **: highest in the world (Shah, 2010).
Sources: FAO. 2016. AQUASTAT Main Database – FAO of the United Nations (http://data.worldbank.org/). Website accessed on 18/02/2016.

Figure 3.1 - Monthly irrigation demand for Indus, Ganges and Brahmaputra river basins



Source: Biemans et al. (2016)

Groundwater is a vital source for irrigation. About a third of irrigation water is pumped from aquifers and the remainder is pumped or diverted from rivers and reservoirs. In India, the agriculture sector accounts for 60% of total groundwater abstraction (Hoekstra 2013). Water for agriculture, including major groundwater abstraction, helped to drive the green revolution increases in yields in previous decades. Groundwater-fed irrigation has become the mainstay of irrigated agriculture over much of India and Bangladesh, Punjab and Sindh provinces of Pakistan, and the Terai Plains of Nepal. In Bangladesh, groundwater accounts for about 80% of total water use. This dramatic growth in groundwater use in India, Pakistan and Bangladesh has surpassed natural recharge in some areas, causing aquifers to decline rapidly. Box 3.2 shows that South Asia is the largest groundwater exporting region of the world through its export of grains. Ensuring future sustainability of this resource will be a key plank in any future adaptation strategy across the region, but especially where dependence is already high.

Box 3.2 - South Asia is the world's top exporter of groundwater

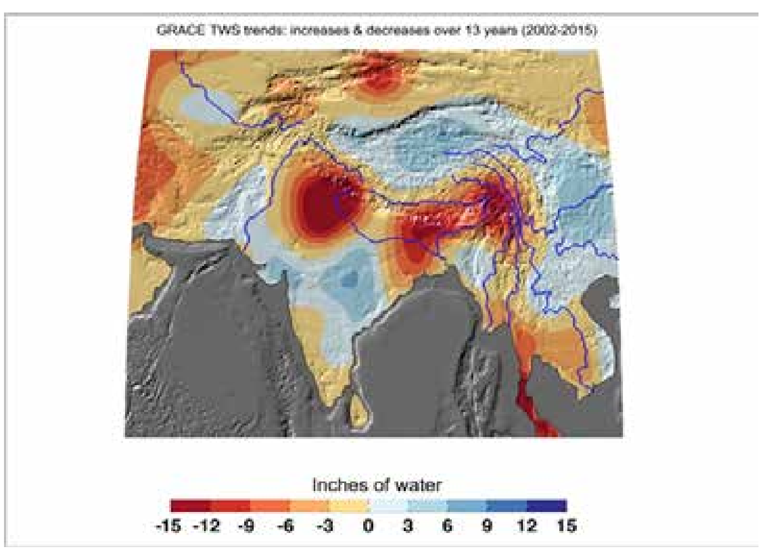
Pakistan and India are the world's largest and third largest exporters of groundwater through their grains export. In 2010, Pakistan exported grains that had required 7.3 km^3 of groundwater to grow. India exported grains that required 3 km^3 to grow.

The trifecta of groundwater depletion for water intensive crops, grain exports and the use of electricity for mining groundwater add up to a perfect recipe for causing water and food shortages. Climate change impacts are likely to worsen the situation.

Source: Raghu Murtugudde, May 3, 2017 (https://www.thethirdpole.net/2017/03/03)

South Asian aquifers are now highly stressed. Groundwater levels have dropped significantly in recent decades in the large alluvial aquifers of the major rivers because of over-use for irrigation and domestic use. Figure 3.2 shows long-term drawdown of regional aquifers from GRACE satellite data from 2002 to 2015. Groundwater quality is highly variable across South Asia, affected by anthropogenic pollution from cities, industries and agriculture. The Indus Basin aquifer is classified as the second most stressed aquifer in the world, with 60% of the aquifer being brackish.

Figure 3.2 - Cumulative groundwater storage losses in the Indo-Gangetic basin aquifers (NASA Jet Propulsion Laboratory)



Water Quality. Most shallow freshwater is polluted with pesticides and fertilizers from agricultural runoff and biological contaminants from sewage. Some aquifers are also compromised by high concentrations of arsenic and fluoride from naturally occurring sources in Bangladesh (Ahmed et al 2004), the Ganges plain (CGWB 2015, Mukherjee et al. 2008), crystalline aquifers in 19 States of India (Maheshwari 2006), southern Nepal (Thakur et al. 2010), and Punjab and Sindh regions of Pakistan (Smedley 2005). Arsenic contamination is exacerbated by over-pumping of groundwater (Harvey et al 2002).

Seawater contamination of coastal aquifers is reported in India during droughts when aquifers are heavily drawn down, during storm surges in Bangladesh and the lower Indus delta, and in some Sri Lankan shallow sand aquifers that are subject to heavy use. In some cases, brackish water contaminates inland aquifers (e.g. in the Indus Basin), enhancing mineral dissolution and/or agricultural pollution (CGWB 2015). Intensive groundwater use exacerbates these problems (e.g. Sri Lankan coastal areas) (Rajasooriyar et al. 2002).

Domestic water. *Access to sufficient and good-quality domestic water is highly varied – and a continuing challenge*. Access is affected by increasing groundwater depletion and pollution (Shamsudduha 2013), droughts and destructive floods, unreliable infrastructure, and competition with agricultural water use. Countries most affected by limited access include Afghanistan (due to low availability and problems of access caused by poverty and years of damage to infrastructure), and Bangladesh and Pakistan, the last two being exposed to recurrent floods and high water demand. More than half of Afghanistan's urban population has no access to improved water resources and 80% of the population in rural areas drink contaminated water (MDG 2005).

In Pakistan, only 53% of the total rural population has access to safe drinking water supply. The rest use untreated surface water resources (e.g., streams, canals, ponds or springs) (Mirza and Ahmad 2005). In 1995, around 12.4 km^3/year of untreated water was discharged into water bodies (Ahmad 2008), including 0.5 and 0.3 km3/year of sewage from Karachi and Lahore, respectively; this was often reused without treatment for drinking, causing numerous waterborne diseases. In Nepal, about 40% of the population still does not have access to safe drinking water (MoE 2005). On the other hand, in Bhutan, about 97% of the population has access to improved drinking water sources.

Industry. *In Bangladesh and India, industries use 2% of the total water withdrawals*. In India, more than 70% of industrial water use is for energy generation (Aggarwal and Kumar 2011), the remainder is used for engineering industries (CSE 2004). Water for energy is mainly used to cool thermal power stations. Typically, about 5-10% of these withdrawals are consumed through evaporation. This is not only the dominant industrial demand but the fastest-growing (in relative terms) demand in India, and constraints on availability (e.g., during drought) have significant downstream economic consequences. In recent years, groundwater has also been used along with surface water for industrial purposes. The total industrial water demand is expected to increase to 80 km^3 and 143 km^3 in India by 2025 and 2050 respectively, which represent around 8.5 and 10% of the expected total withdrawals for these two years, respectively (CSE 2004; Aggarwal and Kumar 2011). In Bangladesh, if business as usual continues in the development of the textile sector, an additional water demand of over 3.4 km^3 by 2030 is expected, equivalent to the annual water needs of a population of approximately 75 million. Current groundwater abstraction rates are close to their limit and further growth of the textile sector will require the development of new sustainable water supplies and effluent treatment facilities for this highly-polluting sector.

Hydropower. *The larger the storage capacity of hydropower dams the greater the capacity to absorb higher seasonal variations between high flows and low flows so that turbine discharge remains stable throughout the year*. If properly operated, by buffering seasonal variations in river flow regimes, hydropower dams may enhance downstream dry-season flow (providing potential additional water resources to downstream users but, at the same time, threatening ecosystems that rely on flow variability) as well as reducing flood risks by storing excess floodwater during the high-flow season. Areas with potential for hydropower development are characterized by high annual rainfall, river flow with limited sediment content (to minimize reservoir siltation and wear on turbines), and availability of land and steep terrain to generate sufficient head for power production.

There is high hydropower development potential in Bhutan and Nepal. Almost all hydropower dams in Bhutan and Nepal are run-of-the-river with generating capacity limited during dry season low-flow. Selling of electricity to India is a potential driver of hydropower development in these two countries. Nevertheless, the fragile mountain environments in which dams may be constructed require careful planning in the selection of sites, and effective system sustainability built into the development of all hydropower projects.

Environmental water. *The importance of providing water for the environment is not well understood.* This is in spite of the reliance of many communities across the region on services provided by water-dependent ecosystems (the rivers themselves, lakes, floodplains, marshes, estuaries). Livelihoods in downstream areas, such as the Indus and GBM deltas, are dependent on the continued productivity of fisheries and floodplains. Aquatic ecosystems are progressively being degraded as water is abstracted from rivers and groundwater systems for irrigation, industry, power generation and municipal water supplies. Abstractions and impoundments not only diminish the quantity of water available for ecosystem purposes but also alter timings and patterns of river flows. The lack of environmental flows can affect urban water users and industries too – some valuable free benefits (such as natural removal of excess nutrients and the breakdown of organic contaminants) are compromised when flow patterns are severely degraded. Consequently, the neglect of environmental flows is not just an issue of equity between poorer communities perhaps more reliant than others on ecosystem services, but is an issue of unnecessary environmental and other costs and future economic efficiency in industries and urban communities.

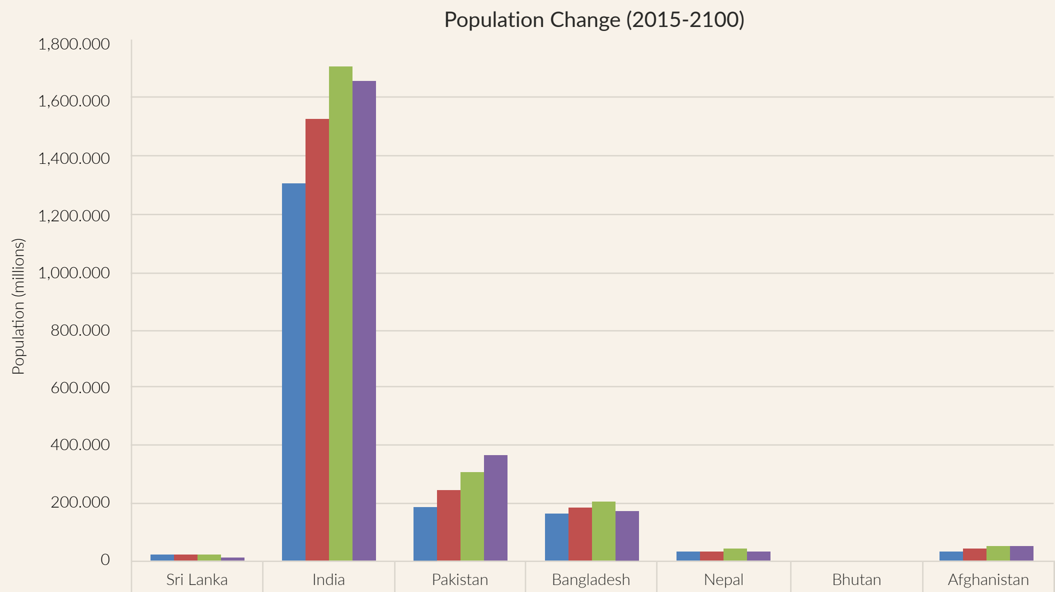
3.2. Socio-economic drivers of water demand

While climate change is expected to increase water stress in South Asia, it is only one of a number of factors. Population growth, increasing urbanization and expanding economies are already increasing demand for water. As a result of these factors, water use in Asia has more than tripled over the last 50 years and is expected to grow in future (Mishra 2002).

The conceptual link between population growth and water demand is clear. Increasing population will require increasing access to water for livelihood and economic purposes, all other factors being equal. Figure 3.3 shows the projected population growth for the seven South Asian countries. Only Afghanistan and Pakistan have continuing population growth to 2100. The others are projected to reach peak population around 2050.

Irrigation water supply will come under pressure in several river basins. Growing population will intensify the competition for water. If water supply is not expanded, more water will be claimed for municipal, industrial and environmental flows, and pose a serious threat to water for food (Strzepek and Boehlert 2010). Liu et al 2013 estimate the expected deficits in the resulting irrigation water supply from 2011 to 2050 in South Asian river basins in different countries without factoring climate change (see Table 3.2). In Bangladesh, deficits of between 18% and 21% are expected in the Brahmaputra and Ganges basins. In India, the deficits will range from a low of 1% (Mahi Tapi) to a high of 90% (Luni). In Nepal, the Ganges river basin will have a decline of 1%. In Pakistan, the Indus is projected to decline by 43%. Unless there is government intervention, these deficits will increase the value of water, lead to a decline in food production, an increase in food imports, an increase in food prices, a shift from irrigated to rain fed crops and a decline in GDP. In all cases the largest impacts will be in Pakistan.

Figure 3.3 - Change in population in the South Asian countries from 2015-2100



	Sri Lanka	India	Pakistan	Bangladesh	Nepal	Bhutan	Afghanistan
2015	20.72	1,311.05	188.93	161	28.51	0.78	32.53
2030	21.54	1,527.66	244.92	186.46	33.1	0.89	43.85
2050	20.84	1,705.33	309.64	202.21	36.16	0.95	55.96
2100	14.86	1,659.79	364.28	169.54	29.68	0.79	57.64

Data source: United Nations, Department of Economic and Social Affairs, Population Division. United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Prospects: The 2015 Revision, Key Findings and Advance Tables. Working Paper No. ESA/P/WP.241

Table 3.2 - Expected changes in water supply for irrigation by country and river basin (% change in 2011-2050)

Country	River Basin	Reduction in irrigation water (%)	Country	River Basin	Reduction in irrigation water (%)
Bangladesh	Brahmaputra	-17.9	India	Indus	-7.1
Bangladesh	Ganges	-21.3	India	Krishna	-42.6
India	Cauvery	-49.6	India	Luni	-89.5
India	Chotanagpur	-23.8	India	Mahi Tapti	-1.2
India	Eastern Ghats	-34.5	India	Sahyada	-5.7
India	Ganges	-15.7	Nepal	Ganges	-0.8
India	Godavari	-19.7	Pakistan	Indus	-42.7
India	East Coast	-42.1	R. of S. Asia	Indus	-43.8

Note: River basins with no or small change in water scarcity are not included in this table
Source: Liu et al. (2013) reported in Markandya et al (2017)

South Asian countries have relatively low urbanization rates compared to other developing regions (Ellis and Roberts 2016). Nevertheless, the urban share of each country's population, with the exception of Sri Lanka, has increased between 2000 and 2010 with Bhutan having the highest annual urban growth share of 3%. This increasing level of urbanization is believed to lead to dietary changes with a general trend towards more water-intensive diets (Katz 2015), although this may be the result of increased income rather than urbanization. The evidence for links between increased urbanization and water use are not well established.

The link between economic development and water use is complex. The relationship has been assumed to be an inverted U-shaped curve (a Kuznets Curve) where water use initially increases with rising national income and then declines as the major water using industries (especially irrigated agriculture) decline in importance and water use efficiencies improve across all sectors – including greater so-called 'allocative efficiency' as more water goes to higher value uses and away from primary agricultural production. However multi-country and multi-sectoral studies of water use and economic growth have produced conflicting results[5].

Bhattarai (2004) examined the relationship between irrigation water use and income for 13 Asian countries, including Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka, and found evidence for a Kuznets relationship. However, other factors, such as macro-economic policy, agricultural productivity, types of structural change in the economy (and wider global economy), electricity use, and underlying public institutions and governance structures also affect irrigation development and water use. This severely limits the use of the Kuznets curve as a predictive model for specific countries. Bhattarai (2004) uses Taiwan and Japan (per capita GNI $42,000) as examples of Asian countries that show a decline in irrigation area as a function of income, implying that the South Asian countries studied here with per capita GNIs from $680-$3440 will remain on the rising arc of the curve for some decades. That is, irrigation water use will continue to increase with rising incomes until such time as the demands from and impacts on other sectors are detrimental to wider economic development, including the trade-offs between agricultural demand and demand from growing urban areas.

Overall, South Asian countries are likely to face an increasing demand for water, without factoring in the effects of climate change, from on-going population growth, growing needs to feed and provide energy to a growing population, economic development and possibly slowly-increasing rates of urbanization. This rapidly rising demand needs to be met through improved water management (including water use efficiency, demand-side management, recycling and reuse of water, conjunctive use of surface and groundwater, and better monitoring and information gathering) because the opportunities for new water storage infrastructure are becoming costly and diminishing. The costs of new storage infrastructure are likely to exceed the benefit of making better use of existing water resources.

3.3. Environmental Drivers of Water Demand and Supply

Climate change adds a further layer to these existing water challenges. However, the relative impacts of growth and the changing climate are not uniform across South Asia. In some regions, the increasing demand for water from socio-economic growth will outweigh the projected impacts of climate change for many decades; in other regions, climate change will potentially place greater pressures on water resources than the interrelated complex between population and economic growth. Fant et al (2016) have separated out the potential impacts of climate

[5] Some studies identify Kuznet-type relationships between sectoral water use and income (e.g. Jia et al 2006, Bhattarai 2004), while others (e.g. Gleick 2003) found no relationship between capita national water use and income. Katz (2015) has re-examined these earlier studies and has concluded that, while there was some evidence of a Kuznets-type relationship, the results were highly dependent on the statistical techniques used and the data sets. He also concluded that, even when relationships were detected, these multi-country studies provided little guidance on the relationships between rising income levels and water use for individual countries.

change from those arising from socio-economic growth (both population and economic growth) on water stress by 2050 in densely populated watersheds in selected Asian countries including China, three South Asian nations - Afghanistan, India and Pakistan – and other nations.

The study found that most of China, particularly the North of the country, as well as Pakistan and Afghanistan are primarily vulnerable to the impacts of climate change, while India, China and Mainland Southeast Asia are expected to be more vulnerable to increased demands due to socioeconomic developments. By 2050, if adaptive responses are not developed, a large proportion of people currently living in moderately water-stressed regions will be living in areas that are heavily stressed. In the median case, this number is expected to be as much as 1 billion people which is 50% higher than the baseline case of current climate and growth rate for the year 2000.

When a basin-specific perspective is taken, the Indus Basin already experiences a significant level of water stress in the baseline case, with both climate change and growth expecting to exacerbate this about equally into the future. This pattern is also expected to be seen in the Ganges Basin. In the Brahmaputra Basin, the impact of growth is expected to be more substantial in determining water stress, while the impact of climate change is expected to be about neutral.

Overall, socioeconomic changes and climate change impacts are expected to have differing sectoral impacts on water stress. Industrial and municipal water are expected to increase considerably faster than irrigation water demand. Parts of India are expected to experience 2-5 times the baseline growth in domestic water demand. Pressure for maintaining adequate environmental flows will also grow. By 2050, the impacts of changes to climate, while important under present conditions, will be overshadowed by changes in socioeconomic growth and water requirements. Thus, socioeconomic changes in these regions can be expected to be more important in determining in how future water resources are to be managed. This illustrates the need for any future adaptation frameworks and actions at the level of policy and practice to keep a balanced view of relative drivers between population and economic growth and the impacts of climate change and variability. It is the intersections between all three and the risks and sensitivities that will arise that should form specific areas of attention.

EXTREME EVENTS UNDER CLIMATE CHANGE

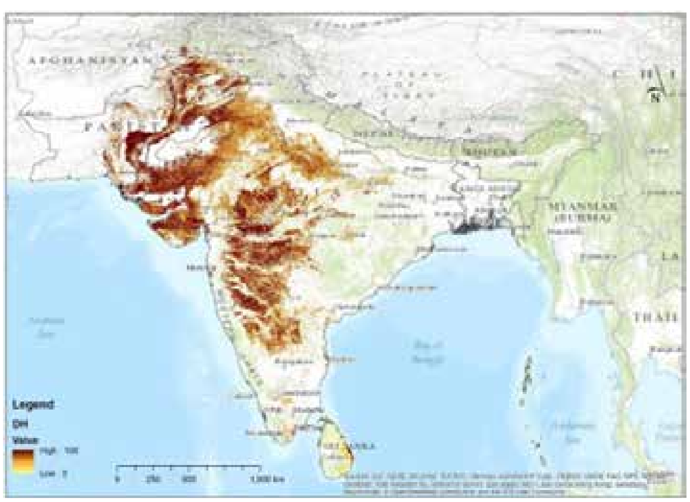
AS CHAPTER 2 MAKES CLEAR, CLIMATE CHANGE WILL BRING ABOUT NOT ONLY CHANGES IN AVERAGE METEOROLOGICAL AND HYDROLOGICAL PARAMETERS (SUCH AS INCREASES IN AVERAGE TEMPERATURES AND RISING SEA-LEVELS) BUT ALSO MORE VARIABILITY IN THESE PARAMETERS. THE INCREASED VARIABILITY WILL MANIFEST ITSELF AS AN INCREASE IN THE FREQUENCY AND MAGNITUDE OF EXTREME EVENTS. IPCC (2014A) STATES THAT "CLIMATE-CHANGE-RELATED RISKS FROM EXTREME EVENTS, SUCH AS HEAT WAVES, EXTREME PRECIPITATION, AND COASTAL FLOODING, ARE ALREADY MODERATE (HIGH CONFIDENCE) AND HIGH WITH 1°C ADDITIONAL WARMING (MEDIUM CONFIDENCE). RISKS ASSOCIATED WITH SOME TYPES OF EXTREME EVENTS (E.G., EXTREME HEAT) INCREASE FURTHER AT HIGHER TEMPERATURES (HIGH CONFIDENCE)." ALREADY SOUTH ASIA HAS EXPERIENCED AN INCREASE IN WARM DAYS AND NIGHTS AND A DECREASE IN COLD DAYS AND NIGHTS SINCE THE 1950S, THE FREQUENCY OF HEATWAVES HAS INCREASED SINCE THE MIDDLE OF THE 20TH CENTURY, AND THERE HAVE BEEN MORE EXTREME RAINFALL EVENTS IN CENTRAL INDIA (IPCC 2014B).

South Asia is highly vulnerable to water-related extreme events: droughts, floods of different types, landslides and siltation are major threats. This chapter summarizes these climate risks, and includes fine resolution maps of drought and flood hazard developed using MODIS time series satellite imagery at a scale of 500 m, and ranks climate related risks in each country.

4.1. Droughts

Consecutive years of El Nino monsoon failure in 2014-2016 affected 330 million people in India alone. Among all types of natural disasters, drought affects large areas and by far the largest number of people through water shortage, food shortage and energy shortage and sometimes associated heat waves. Lack of precipitation can significantly impact agricultural output since approximately 60% of cultivated areas in South Asia are rainfed. Figure 4.1 shows drought hazard areas of South Asia determined from MODIS satellite imagery based on time series images from 2000 to 2013 using a resolution of 500m.

Figure 4.1 - Drought hazard area mapped using MODIS images 2003-2013 (Giriraj et al 2016)



Droughts have been found to be more frequent during the years following ENSO events (Dai 2012) and the warming of the Eastern Equatorial Pacific Ocean. At least half of the severe failures of monsoons since 1871 have occurred during El Niño years (Webster et al. 1998). Countries mostly affected by droughts are located in semiarid and arid areas like Afghanistan, Pakistan and some parts of India or where river flows become very low during the dry season (Bangladesh), partly due to upstream flow diversion. In Bhutan, Nepal and Sri Lanka, droughts have minor effects compared to those in other climate-related disasters.

The 1978-79 drought in Bangladesh affected half of the cultivated land and population, destroying over 2 million tons of rice. Most drought problems in India are related to the availability of food, safe drinking water and shelter. Droughts not only affect surface water availability but also the recharge of aquifers which are currently depleted by unsustainable pumping rates. Alongside Afghanistan, Pakistan is the most water-scarce country in South Asia due to its semi-arid climate. With growing population and food demand, large irrigation areas can become rapidly water-stressed. Because of repeated droughts and rising water demand, aquifers of Baluchistan province are dropping by 3.5 m annually, and are estimated to run out in a couple of decades with massive internal displacements expected. Sri Lanka is also subject to droughts with most occurring during the inter-monsoonal months from January to March and August to September. The 2015/16 drought in Sri Lanka resulted in severe water, food and energy shortages and severe impacts on livelihoods in the dry zone.

4.2. Floods

South Asia experiences both large scale riverine floods and coastal floods as well as more localized floods such as flash floods and glacial lake outburst floods (GLOFs). Due to their size and sediment loads, the largest rivers of South Asia are difficult to manage and regularly cause flooding. Riverine floods lead to significant indirect losses including the degradation of agricultural land which subsequently diminishes agricultural productivity, impacting rural development and income opportunities, as well as the contamination of surface and groundwater, either with salt intrusion or pollutant dissemination. Riverine floods also damage water infrastructure including hydropower dams and irrigation schemes. This last decade saw the highest number of reported flood disasters with the greatest spatial coverage on record. These included the devastating 2010 floods in Pakistan and the 2013 Uttarakhand floods in India (Box 4.1).

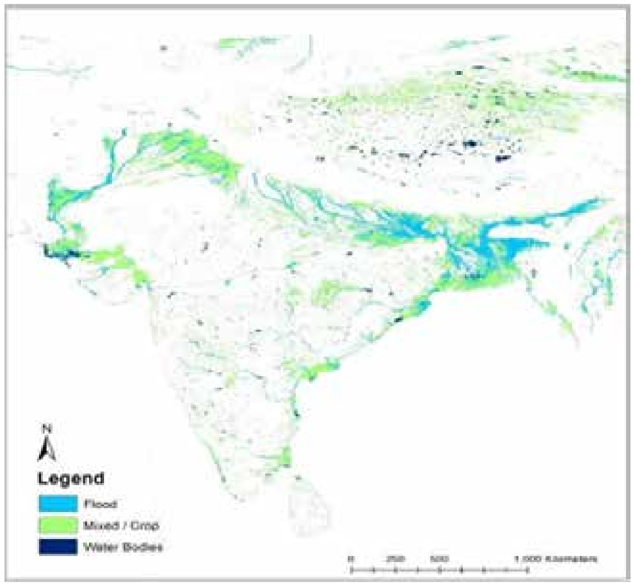
Box 4.1 - Seasonal Estimates of Irrigation Water Demand in South Asia

Both India and Pakistan suffer severe flooding. About two-thirds of Pakistan lies in the Indus Basin. Floods can cover up to a fifth of the country, posing high risks to riverine populations. Luo et al. (2015) indicate that 710,000 people in Pakistan are exposed to risks of annual river floods, while in some years, the number of affected people reaches up to 21 million (Syvitski and Brakenridge 2013). Over the last 6 years, Pakistan has witnessed three major floods. The 2009 floods were caused by a major embankment breach that changed the course of the floodwater entirely (Winsemius et al. 2013). The lack of plans to handle large sediment loads transported during floods is one major reason that has led to severe flood impacts in Pakistan (Syvitski and Brakenridge 2013; Winsemius et al. 2013). The catastrophic 2010 flood along the Indus River was caused by exceptional rainfall in conjunction with a reduction in conveyance capacity of water and sediment, and dam and barrage-related backwater effects (Syvitski and Brakenridge 2013). On average, annual floods in Pakistan result in a loss of 1% of total GDP, which is equivalent to USD1.7 billion. The 2010 floods cost the country USD10 billion in damage. In June 2013, India suffered severe flooding in Uttarakhand caused by exceptionally heavy rainfall. Over a thousand people were killed and many thousands more displaced, as well as destruction to key infrastructure (ReliefWeb).

Source: Lacombe et al (2017)

Figure 4.2 shows the extent of riverine flood hazard based on data from 200 to 2012 using a spatial resolution of 500m. Areas of high flood hazard occur along the lower reaches of the Ganges and Brahmaputra floodplains and along the length of the Indus river.

Figure 4.2 - Recurrent flood inundation extent mapped using MODIS time-series imagery for South Asia. (Giriraj et al 2016)



Densely populated lowland areas of Bangladesh are exposed to coastal floods worsened by sea level rise and cyclones (Box 4.2). According to the International Disaster database coastal floods have caused far fewer casualties, affected fewer people and led to less damage than have other water-related disasters in the region (http://www.emdat.be/database). Those that have occurred have mainly been in India and Bangladesh.

Localized flash floods commonly occur in the foothills of the HKH mountains. High flow velocity can cause extensive damage to crops, property and infrastructure. Populations along river banks and foothills, on steep slopes, and in low-lying slums and squatter settlements are particularly vulnerable to flash floods. Afghanistan, particularly the mountainous north-east of the country, is especially vulnerable to flash floods because of the lack of infrastructure, inadequate disaster preparedness, and poor socio-economic conditions. Eastern and Northern areas of Bangladesh adjacent to the border with India are also vulnerable to flash floods resulting from heavy rainfall occurring over hilly and mountainous regions.

GLOFs arise from a potentially catastrophic discharge of water from glacier lakes due to failure or breach of unstable end moraines or ice dams. About 8,880 glacial lakes were recorded in Bhutan, India, Pakistan, Nepal and the Ganges basin in China in the late 1990s and early 2000. Of these, 204 were listed as potentially dangerous. Some 56 GLOFs have been reported in the HKH since the 1970s. These GLOFs resulted in significant damage to crops, and hydraulic infrastructure, including hydropower plants, as well as injury and death to local people. In 1984, a GLOF of Lake Dig Tsho caused about 1 million m^3 of water to be released, creating an initial peak discharge of 2,000 m^3/s. This spectacular natural event eliminated all the bridges for 42 km downstream with loss of life and property. However, the actual scale of GLOF disasters in terms of casualties is relatively low, compared to other climate-related risks.

Box 4.2 - Bangladesh flooding

Bangladesh is the world's most densely populated country and consists largely of a low, flat floodplain of the GBM (60% of the country lies between 0 and 6 meters above mean sea level). Due to its downstream location in the GBM, Bangladesh drains an area 12 times its size. On average, 22% of the country is flooded each year. The continued development of upstream parts of the basin, deforestation in the Himalayas, dyking along channels, land degradation and erosion have aggravated the flood situation. From 1987 to 2007, Bangladesh experienced five large floods (Mirza 2011). In 1988 and 1998, the peak flows of the Brahmaputra and the Ganges coincided, resulting in inundation of about 60% of the country (Khan 1999). The spatial extent of flooding is usually aggravated by heavy monsoonal rainfall and cyclonic surges.

Cyclones and storms are the major cause of coastal floods in low-lying and coastal parts of Bangladesh. Sea level rise by just a meter, in response to strong winds for example, frequently causes disasters. Over the last 40 years, 520,000 deaths have been recorded, of which approximately 300,000 and 140,000 were caused by two cyclone events that occurred in 1970 and in 1991, respectively (World Bank 2012).

Eastern and northern areas of Bangladesh adjacent to the border with India are vulnerable to flash floods resulting from heavy rainfall occurring over hilly and mountainous regions. The normal period of flash flooding is late April to early May and from September to November (Mirza and Ahmad 2005).

Source: Lacombe et al (2017)

4.3. Landslides/Mudslides

Landslides/mudslides have increased over recent years due to more intense anthropogenic activities, especially deforestation, particularly in the HKH (e.g. in Nepal). Landslides are costly, having caused an estimated US $ 37 billion in damage[6]. India, Bangladesh, Pakistan, Afghanistan and Nepal are the most affected countries but other nations are also impacted. Recent floods and mudslides in Sri Lanka, for example, claimed nearly 150 lives, left 77,000 people homeless and destroyed 1500 homes.

4.4. High Erosion Rates/ Sedimentation

In the Indus River Basin, perennial runoff, partly sustained by ice- and snowmelt, is responsible for high erosion rates on hillslopes where vegetation is sparse and the soil is fragile due to semi-arid climate and agriculture intensification. The Indus River and its tributaries carry about 0.44 km^3 of sediment annually of which nearly 60% is deposited in natural depressions, reservoirs, canals and irrigation schemes. In the Tarbela catchments, 167 m^3 of silt are eroded per square kilometre per year. The Mangla and Tarbela Dams/Reservoirs play an important role in the economy of the country yet, due to sedimentation, these reservoirs are losing about 0.031 and 0.14 km^3/year in live storage capacity, respectively. About 794×10^6 tons of sediments are transported by the Ganges Rivers each year, with 80 ± 10% coming from the High Himalaya, and 20 ± 10% from the Lesser Himalaya. About 8% of the river sediment is deposited on floodplains and delta plains in Bangladesh. The remaining ~ 45%, is deposited in the subaqueous delta and the Bengal Fan (Wasson, 2003). High sediment deposition rates in the delta of the GBM partly compensates for land subsidence (Brown and Nicholls, 2015) and therefore slows down the detrimental effects of sea level rise.

4.5. Climate change will aggravate all water-related extreme events

More intense and concentrated rainfall is expected to generate sharper and more destructive flash floods. This will be the case especially in mountainous areas (Afghanistan, Bhutan, Nepal, Northern India, Northern Bangladesh, Northern Pakistan), and more erosion and downstream siltation (especially in semi-arid areas like Afghanistan, Northern India and

[6] http:\www.emdat.be

Pakistan), with loss of water storage capacity, and reduced groundwater recharge (due both to altered rainfall patterns and siltation of water bodies).

Temperature rise is also inducing snow and ice melt increasing the risk of GLOFs (Bhutan, Nepal, India, Pakistan), and earlier flood peaks in the year (springtime) in snow/ice fed rivers (e.g. Indus). This will not match irrigation peak demand in summer time and will impact food security and hydropower production, increase crop water demand and increase evaporation losses from surface reservoirs.

Sea level rise combined with more intense and frequent cyclones will induce destructive coastal flooding. The most vulnerable areas to coastal flooding will be the low-lying and densely populated areas, (e.g. Bangladesh) and those areas where costal aquifers are at risk (e.g. in Sri Lanka).

Prolonged droughts will affect all countries during the dry season, especially with rising food demand related to overall population growth and economic development. Semi-arid and arid zones (e.g. Afghanistan, Pakistan, North-west India) will be the most vulnerable to droughts, worsened by glacier melting, reduced groundwater recharge and reservoir siltation, affecting not only agriculture but also industrial and domestic water uses. Water-dependent ecosystems will also be affected by climate change, although these impacts have not been properly assessed. For example, increasing crop water demand because of rising temperatures is likely to further reduce river flows and groundwater levels.

4.6. Climate Change Risks

Each country faces a different risk profile from water-related climate change impacts. Table 4.1 is a ranking of risks each country faces based on historical damage from water-related extreme events (drawing from data available at http://www.emdat.be/ and Giriraj et al 2016) and priorities identified in country climate change policy instruments (Davis and Hirji 2017). This ranking integrates damage costs, casualties and numbers of affected people, under the recent climate regime and has a subjective element - priorities defined in the respective climate change instruments. Damage acts as a surrogate for risk in this table, although the table does not include some risks arising from gradual changes in climate and hydrological parameters, such as diminishing mean annual flows in rivers, steadily increasing rates of evapotranspiration because of rising mean temperatures leading to increasing irrigation water demand, or changing patterns of groundwater recharge. In the future (as climate continues to change), coastal flood and storm/cyclone risk levels will rise, especially in Bangladesh but this will not necessarily change the risk categories (high, medium, low) as all other risks may also increase concurrently.

Table 4.1 - Ranking of climate-related risks

	Countries						
Risk level	Afghanistan	Bangladesh	Bhutan	India	Nepal	Pakistan	Sri Lanka
High risk level	Flash flood Landslide Riverine flood	Riverine flood Storm/Cyclones Costal floods Siltation	Landslide Flash flood G:LOF	Drought Riverine flood Flash flood Groundwater depletion	GLOF Flash flood Landslide	Drought Groundwater depletion Landslide	Storm/Cyclone Riverine flood Coastal flood
Medium risk level	Drought Erosion/siltation Groundwater depletion	Erosion Drought Groundwater Depletion Coastal aquifer salinization	Erosion/siltation Riverine flood Drought	Landslide Storm/Cyclone Coastal aquifer salinization	Drought Erosion/siltation Groundwater depletion	Riverine flood GLOF Flash flood Erosion/siltation Groundwater salinization	Flash flood Landslide Erosion/siltation Drought Coastal aquifer salinization
Low risk level	GLOF Storm/Cyclone	Flash flood Landslide	Storm/cyclone Groundwater depletion	GLOF Erosion/siltation	Riverine flood Storm/cyclone	Coastal flood Storm/Cyclones	Groundwater depletion

Not all risks are not all relevant to all countries and, to prioritize, countries could focus on the high level risk followed by medium level risk.

ADAPTATION FRAMEWORK FOR WATER RESOURCES PLANNING, DEVELOPMENT AND MANAGEMENT

PART 1 DISCUSSED WATER RESOURCES MANAGEMENT AS A KEY DEVELOPMENT CHALLENGE. BOX 5.1 LISTS THE MAIN ELEMENTS OF SOUTH ASIA'S WATER RESOURCES MANAGEMENT STRATEGY DISCUSSED IN CHAPTER 1. WATER FOR ALL USES, PARTICULARLY IRRIGATION, IS PROJECTED TO BECOME INCREASINGLY SCARCE AS A RESULT OF POPULATION GROWTH AND ECONOMIC DEVELOPMENT. CLIMATE CHANGE IS PROJECTED TO EXACERBATE WATER SCARCITY BECAUSE OF INCREASED WATER DEMAND AS A RESULT OF RISING TEMPERATURES AND (IN SOME AREAS) REDUCED ANNUAL AVERAGE PRECIPITATION AND/OR ALTERED PATTERNS OF PRECIPITATION AND DIMINISHED GROUNDWATER QUALITY IN COASTAL AQUIFERS FROM RISING SEA LEVELS. IT IS ALSO EXPECTED TO IMPACT EXTREME HYDROLOGICAL EVENTS.

Addressing this important development challenge will require greater policy coherence and integration across many economic sectors and administrative jurisdictions. They will also require investments in water supply and demand side management options, investments in flood management and drought resilience, and capacity to manage the region's water resources challenges.

Box 5.1 - The main elements of South Asia's water resources management strategy

- Developing reliable supplies for meeting growing domestic, industrial, and agriculture water demand, and energy uses;
- Promoting sustainable use, protecting water quality, and managing watersheds, aquifers, lakes and wetlands;
- Systematic planning, development and management to address the systemic risks emerging of water-related disasters-droughts, floods, sedimentation;
- Promoting collaborative management of shared waters across districts, river basins and aquifers, states and provinces, and nations;
- Integrating water policies and actions with those outside the water sector (environment, land use, energy).

Integrated Water Resources Management (IWRM)[7] *is an approach that seeks to improve the efficiency, equity and sustainability with which a country's water resources are managed.* It is a key part of the adaptation toolkit available for promoting greater integration across water and water-impacting sectors in South Asia. Other approaches in the toolkit are the water-food-energy (WEF) nexus and its variant the water-food-energy-environment (WEFE) nexus. The latter two are useful approaches to address inter-sectoral allocation issues and policy distortions, but are ill-suited for dealing with risks of extreme hydrological variability, non-stationarity, conjunctive management of surface and groundwater or managing water at inter-state, inter-province or transboundary levels. When addressing climate variability, IWRM emphasizes the need for stronger data collection (water availability, use and quality), more effective management – assessment, allocation, regulation, reuse, improved efficiency of water use, conservation and protection of water resources, appropriate infrastructure development, better planning processes and institutional coordination.

Moving from statement in policy to IWRM institutional implementation is a complex process. It is necessarily incremental in pace with reforms taking decades to implement. Although our analysis shows that IWRM is embedded in water and climate policy instruments in nearly all South Asian nations, earlier chapters also highlight the fragmented and in some cases almost disintegrated state of water resources management practice. Building effective adaptation capacity through IWRM as one key tool will require greater policy coherence, integration, coordination and collaboration in combination with effective implementation across many sectors of the economy.

This chapter introduces key features of IWRM, but also highlights its limitations. It discusses IWRM in the context of climate change adaptation, highlighting the pros and cons of using it as an adaptive approach to water planning, development and management. Finally, the adaptation framework that is used to guide the reviews under chapters 6-10 is presented.

5.1. Integrated Water Resources Management

IWRM is defined as "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (Global Water Partnership 2000 p 22). This definition makes clear that IWRM aspires to incorporate both development as well as management of water resources. It also states that IWRM is a process to achieve an end rather than an end in itself, and in which should be embedded cycles of learning that support continuous improvement in management practice.

The term 'integration' in IWRM carries a number of meanings. Most importantly, it refers to integration of multi-sectoral and multi-jurisdictional dimensions of water. This means the integration of water-dependent sectors (including irrigation, hydropower, industry, domestic water supply and environment) in decisions about water allocation and use, but also integration of decisions by water-using or affecting individuals or administrative units upstream on a river with those affected downstream. This includes different political boundaries – villages, cities, district, states, provinces and nations – as well as integration of the management of water quantity (water utilization) and quality (protection of water quality and control of pollution from point and nonpoint sources of water), integrated management

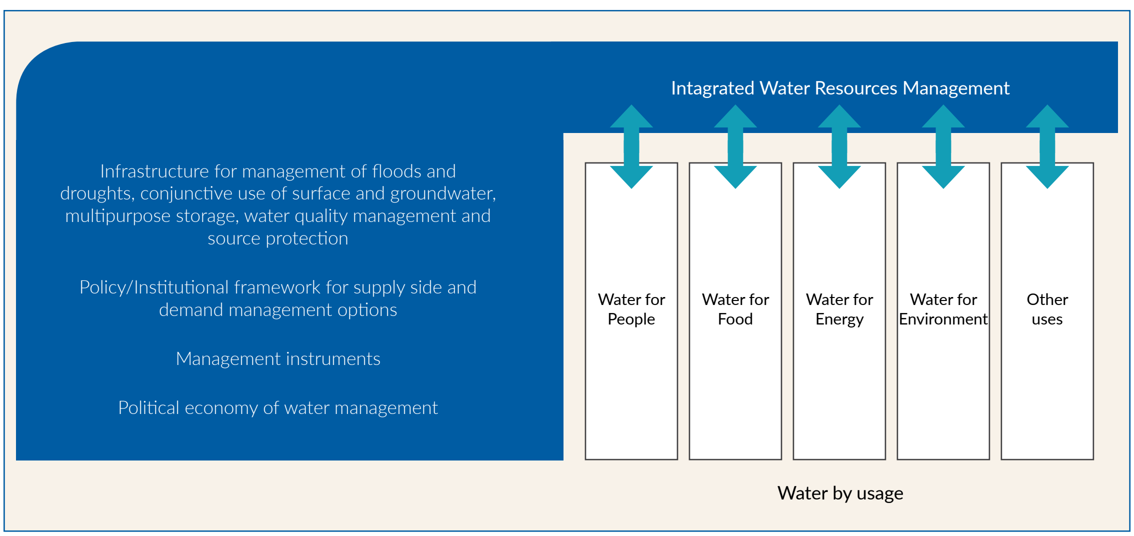
[7] The four Dublin Principles (from the International Conference on Water and Environment held in January 1992 in Dublin) and endorsed at the UN Conference on Environment and Development in June 1992 in Rio de Janeiro for developing new approaches for the assessment, development, and management of freshwater resources are: (1) Effective management of water resources demands a holistic approach linking social and economic development with protection of natural ecosystems, including land and water linkages across catchment areas or groundwater aquifers; (2) Water development and management should be based on a participatory approach involving users, planners, and policy makers at all levels; (3) Women play a central part in providing, managing, and safeguarding water; and (4) Water has an economic value in all its competing uses and should be recognized as an economic good.

of connected surface and groundwater systems, integrated management of water bodies (rivers, lakes, aquifers) and connected catchments, and the integration of freshwater and connected estuarine and marine systems.

Essentially, IWRM advocates the management of the complete water cycle at a watershed scale, with inputs from water-users themselves. The emphasis on coordination is just a means to allow the cycle to be managed as a whole. IWRM also recognizes that some tasks can only be undertaken at the State or National scale such as managing transboundary water and establishing the rules by which water management is to occur. Box 5.2 list the key elements of IWRM. The challenges here include both assuming that water users want to be water managers, and that they are capable as managers in their own right, including having the necessary management tools and levels of knowledge at their disposal.

IWRM means using different management instruments in a coherent and collective manner under systems of resource governance that engage stakeholders (as users) alongside planners in resource allocation and management decision-making. Water resources are commonly depicted in the IWRM framework as constituting the handle – the blue part – of a comb (Figure 5.1) where the teeth – the white parts – of the comb are the various sectors that use or depend on these water resources. The environment is included as a water-using sector along with irrigation, energy and water supply in recognition of its provision of ecosystem services such as mangroves that provide storm surge protection and trap sediment, floodplains that attenuate peak flood events and allow the recharge of alluvial aquifers, and removal of nutrients and other contaminants to make water more potable for downstream domestic consumption. In this report, the combination of the water resources sector and the water-using sectors (i.e., the whole comb) are referred to as the water sector. IWRM can be used to protect water quantity and quality in the natural environment (surface and groundwater) and to plan and manage access of the various water-using sectors to the resource. It can also be used to manage hydrological variability, including extremes, through drought planning, preparedness and management as well as flood forecasting, planning and management. The provision of infrastructure is an essential element of IWRM, along with the policy/institutional framework needed to implement integrated management, the use of a range of management instruments (described below), and attention to the political economy of water management including the norms and issues under each jurisdiction within which IWRM is to be applied. In general, IWRM provides a framework for a structured review of supply driven and demand management options.

Figure 5.1 - Conceptual framework of integrated water resources management. (Global Water Partnership 2000)



Box 5.2 - Some of the key features of IWRM

- *Takes an inter-sectoral approach to water resources management and development.* Coordination across sectors is essential because links between activities within a watershed need to be understood within sectoral ministries. It is not uncommon to find substantial barriers between ministries, and with technically competent professionals who pursue narrow sectoral objectives. Establishing a genuinely inter-sectoral approach is probably the most challenging feature of IWRM as it often upsets established power relationships.
- *Decentralizes management to the basin level.* This is the natural area within which many (not all) water-related decisions take place, are interdependent and need to be managed. Decentralization has proven difficult partly because it challenges the authority of centralized water management agencies, and partly because river basins do not match existing institutional boundaries.
- *Manages water efficiently and cost-effectively.* This includes assessing surface and groundwater resources, allocating use through transparent processes, regulating use to ensure equitable access and environmental flows, conjunctive use and management of surface and groundwater, recycling of water, reuse of wastewater, desalinization of seawater, and integration of environmental and social impacts of water use decisions.
- *Protects and manages water quality.* This includes monitoring and assessment of surface and groundwater quality, regulating and controlling wastewater discharges from cities, villages, industries, and mines and runoff from agricultural fields and urban areas.
- *Strengthens demand management.* This establishes prices for surface and groundwater use that reflect its full value, introduces water efficient technologies and a sense of responsibility among water using groups, and builds decentralized water management authorities.
- *Ensures equitable access to water.* Establishes water user associations (WUAs) to provide a voice for individual and community water users, including marginalized groups. It is also important to integrate equity considerations within policies, strategies and plans for infrastructure investments and management activities by, for example, extending water supply to poor communities. Equity also implies that groups that contribute to water resources issues take responsibility for their impacts. This includes the private sector that can seriously affect both the quantity and quality of surface and groundwater.
- *Establishes policies so that government intentions are clear.* This is important to establish over-arching principles such as State ownership of water, ensuring polluters pay, establishing water quality standards, and introducing market-based regulatory mechanisms. Policies should be backed by legislation that provides institutions with the authority to implement these policies.

Source: Global Water Partnership (2000)

There is no universal model for implementing IWRM, however. Different features will be needed, depending on specific issues facing each country from water management norms and priorities to the state of knowledge on existing water resources and future trends in demand and use. Twenty years of experience shows that implementing IWRM is almost always challenging and, as a result, frequently incremental, long-term and slow. It is worth agreeing on an implementation strategy with agreed milestones and timetables, but at the same time these should be open for review and modification as experience is gained of what works/does not work.

5.2. Limitations of IWRM

A number of commentators have criticized IWRM on both conceptual and practical grounds (e.g., Gain et al. 2013). The principal conceptual objection is that there are so many different interpretations of IWRM that it is not possible to know what the concept means in practice (Biswas 2008). While the description of IWRM is clear, in practice is interpreted in many different ways by different stakeholders. In this report we use the above widely-accepted GWP definition to help anchor our conceptual understanding. The practical objections are concerned with the difficulty of bringing about the major changes proposed in

IWRM. For example, a mechanism for coordinating decisions about water development and management will always be challenging when sectoral ministries act independently. Similarly, agencies responsible for managing water quantity and water quality do not always work together efficiently. However, it is difficult to see how progress can be made in sharing scarce and uncertain water resources without challenging some traditional social and institutional relationships and assumptions. In order to have genuinely robust, resilient and sustainable development (included within which is strong adaptation capacity), integration of water resources management is a necessary, but not sufficient, condition. Snellen and Schrevel (2004), in their comprehensive review of IWRM, conclude that, in spite of the difficulties of implementation, "It is generally accepted that to manage water resources there is no alternative to IWRM" (p 14).

Consequently, we have structured this paper around IWRM concepts because they remain the best blueprint for improving water management and are widely-accepted among South Asian governments. We also recognize that the conceptual terrain is complex and changing and IWRM is one of a suite of approaches that can help strengthen adaption responses in water management in the region.

5.3. IWRM and Climate Change

Climate change affects many water dependent sectors (irrigation, water supply and sanitation, hydropower generation, industry, environment, and tourism) through changes to water availability, changes in water demand and increases in the risk of extreme events. Consequently, a number of reports conclude that water is the medium through which most early climate change impacts will be felt (Alavian et al. 2009, World Water Council 2009; Sadoff and Muller 2009a; Global Water Partnership 2007). Water also multiplies some of the impacts of climate change. For example, a 1% change in annual average precipitation often translates into a 4-5% change in runoff and stream-flow. Thus, adapting to the effects of climate change means adapting to changes in water availability, water demand and water-related risk.

An important point is that adaptation to climate change is about improving existing water management rather than undertaking a fundamentally new approach. Shah and Lele (2011), in their report from an International Water Management Institute (IWMI) and Global Water Partnership (GWP) workshop on adapting to climate change in the water sector in South Asia, concluded that "climate change adaptation does not call for a different way of managing water resources; we need to simply do a far better job of planning and managing our water resources than we have done so far" (p14). Having said this, there are two additional topics that need to be added to the suite of existing water management activities – the effects of non-stationarity of climate parameters (see Paper 1) now need to be accounted for (for example, in monitoring, modeling and establishing infrastructure design standards and operating procedures), and the impacts of sea-level rise on coastal surface and groundwater systems need to be added to existing coastal water quality concerns, especially for rural and urban water supplies.

Adoption of IWRM principles means that water users and water managers can adapt to climate change by using water more efficiently and equitably where there is increasing pressure on water availability, and managers can respond more flexibly in the face of increasing variability. Consequently, IWRM is well placed to be a foundation on which to build adaptation to the effects of climate change for a number of reasons:

- If countries follow a strictly sectoral approach to adaptation then they risk exacerbating competition for water resources. For example, pursuit of a national food security strategy through irrigation to respond to increased food import prices may cause shortages in water for hydropower generation and competition in water availability for domestic water supply. Also some mitigation strategies (such as a shift to hydropower generation or increased reliance on biofuels) can have water resources implications. In reality, trade-offs will be needed between competing water demands. IWRM, with an emphasis on collaboration and consultation, provides tools for dealing with these conflicts (Sadoff and Muller 2009a, b).

- The emphasis on water use efficiency and demand management under IWRM is also important, especially where water shortages are likely to increase because of shifts in demand or reductions in water availability. Similarly, coping with existing climate variability through IWRM helps adapt to increases in water variability from climate change (Cap-Net 2009). IWRM includes infrastructure and institutional responses, demand management and supply augmentation, as well as structural and nonstructural approaches to efficiency (Box 3).

- IWRM works best when it builds in reflexive learning to allow for modifications according to circumstance. As Slootweg (2009) points out, changes in society such as population growth and/or economic development are already strong drivers of change in water demand. Climate change adds yet another layer of complexity. IWRM – as a systematized way of thinking – copes with this, by providing robustness and flexibility in solutions, as long as there is real *integration* of different sectors and management elements, from knowledge production through design to strategy and implementation of actions (both in terms of hard and soft infrastructure). Overseeing all of this should be guidance by user-communities and according to stakeholder needs and understandings.

- Adaptation will require better information and more responsive institutions together with both infrastructure investments and structural and nonstructural responses at all levels. IWRM offers a coherent way to implement these responses (Global Water Partnership 2007).

- IWRM provides the tools to promote adaptation at all levels in a coherent way (Sadoff and Muller 2009a, p16). "The impacts of variability, aggravated by climate change, will have to be addressed at different levels. Individual farmers, commercial organizations, urban residents and national governments will all have to engage with the issues and take difficult decisions. Because decisions at all levels can affect the holistic resource, they will have to be coherent with one another if they are to be effective."

Box 5.3 - Possible IWRM Activities to Respond to Climate Change

In areas of water stress: Adaptation interventions could consist of:

- Seasonal water rationing during times of shortage;
- Adapt industrial and agricultural production to reduce water wastage;
- Increase capture and storage of surface run-off;
- Reuse or recycle wastewater after treatment;
- Desalination of salty or brackish water;
- Better recharge systems, monitoring and use of groundwater resources; and
- Rainwater harvesting to augment availability and increase groundwater recharge capacity.

In areas where water quality is affected, possible measures are:

- Improvements to drainage systems to reduce different waters 'mixing' (blue, green, grey);
- Upgrading or standardizing of water treatment at different levels and scales (from households through to urban areas and the wider landscapes in which they are situated)
- Better monitoring of changes in quality; and
- Special measures during high precipitation seasons to manage impacts on quality

Source: adapted from CAPNET 2009

There are also shortcomings in using an IWRM approach to climate change adaptation. The World Water Council (2009) cautions that, even though IWRM advocates a multi-sectoral approach amongst water dependent sectors, its implementation is inevitably limited when water decisions are affected by sectors outside of the water family. "Sectors outside the water sector may be totally ignorant of the principles of IWRM. For example, energy supply, tourism, or agriculture all have to adapt to potential water stress or water-related hazards as a result of climate change. Yet, there are few mechanisms to get a foothold for IWRM in these sectors." Also, IWRM has been developed primarily for national water management and there are few examples of the principles being successfully applied to transboundary water management which is an important requirement in South Asia where all major river systems are transboundary in nature. Gain et al. (2013) assessed six principles of IWRM against four desirable characteristics of adaptive approaches. While they conclude that, overall, IWRM does enhance adaptive responses to climate change, they see a need for IWRM to be more flexible if it is to be used to respond to the effects of climate change.

5.4. Adaptation Framework

Figure 5.1 presents the five components (knowledge, governance, infrastructure, planning and management and communications / education /participation) of IWRM that comprise the framework for reviewing the primary and secondary climate risks. Each of these components plus adaptation financing are reviewed and elaborated in Chapters 6-11.

Table 5.1 - Climate related risks to water resources and potential adaptation actions

Climate Risks	Knowledge	Governance (policies and institutions)	Infrastructure	Planning/ management	Communications / Education / Participation
1. Primary risks					
a) Changes in precipitation (especially monsoon)	Research; weather monitoring	Coordination between meteorological, water and agriculture agencies	Dams; inter-basin transfers; groundwater recharge (including artificial options)	Flexible irrigation management systems; inter-sector responses to assist adaptation	Water User Associations (WUAs) and farmer organizations (FOs) involvement; capacity development; communication to farmers and other stakeholders
b) Sea-level rise	Monitoring; research	Coordination between water agencies, agriculture and other water using sectors, and coastal authorities	Embankments; sub-surface groundwater barriers, maintaining and restoring natural shorelines	Groundwater use plans; controls over groundwater use;	Involvement of coastal communities; capacity development
c) Temperature extremes	Research; monitoring	Coordination between water, energy and productive sectors	Soil and water conservation; improved water supply infrastructure	Mapping trends and designing for peak demands	Prevention of risk through public information and information sharing

Table 5.1 - Climate related risks to water resources and potential adaptation actions (continuation)

Climate Risks	Knowledge	Governance (policies and institutions)	Infrastructure	Planning/ management	Communications / Education / Participation
2. Secondary risks					
a) Floods	Monitoring and early warning systems	Coordination (interagency, government-public)	Embankments; Dams; flood refuges	Flood management plans; restrict development on floodplains; flood mapping; flood insurance	Public awareness of flood risk areas; capacity strengthening
b) Droughts	Weather prediction and early warning communications; research; monitoring	Allocation priorities and planning mechanisms; coordination between agriculture / power / water resources / water supply; local institutional capacities to manage scarce water resources and improvise	Dams; interbasin transfers; groundwater development	Water allocation plans; conjunctive use; demand management including pricing; water efficiency technologies; irrigation and urban water management; recycling and reuse	Involvement and sharing local solutions; capacity development
c) Reduction in groundwater recharge	Monitoring and characterization of aquifers; research into groundwater; database on groundwater-related information,	Coordination between agriculture, domestic water supply, industrial water use, water resources; public ownership of groundwater	Check dams, recharge ponds, managed aquifer recharge development	Groundwater use plans; controls over groundwater use including indirect regulation; artificial recharge; conjunctive use	Awareness of groundwater limitations; capacity development
d) Increased erosion, landslides and sedimentation	Research into soil management and protection; monitoring and early warning system	Coordination between land, water, energy and other agencies	Sedimentation dams	Land management; riparian management; soil conservation	Awareness of soil loss; participation and local solutions; capacity development
e) Reduced water quality (surface and groundwater)	Monitoring; research into water quality treatment	Coordination between water resource and industry / water supply and sanitation agencies	Wastewater treatment and pollution treatment plants	Water quality standards and enforcement; wastewater and pollution treatment including through incentives and disincentives; recycling and reuse	Awareness on pollution risks and prevention measures, polluter pays principle

WATER RESOURCES AND CLIMATE KNOWLEDGE

SOUND WATER RESOURCES MANAGEMENT AND ADAPTATION IN THE FACE OF CLIMATE RISKS REQUIRES ACCURATE INFORMATION AND UNDERSTANDING OF HOW THE QUANTITY AND QUALITY OF WATER VARY SPATIO-TEMPORALLY, WHICH DRIVERS AFFECT THESE VARIATIONS AT DIFFERENT SCALES, AND HOW CLIMATE CHANGE IMPACTS WILL MODIFY THESE RELATIONSHIPS. IMPROVED KNOWLEDGE CAN ASSIST DECISION MAKERS IN RESPONDING TO THE POTENTIAL IMPACTS OF CLIMATE CHANGE ON SURFACE AND GROUNDWATER AVAILABILITY, WATER QUALITY (CONTAMINANTS, SALINITY, SEDIMENTATION, ETC.), SEA-LEVEL RISE, AND EXTREME EVENTS SUCH AS FLOODS, GLOFS AND DROUGHTS. HOWEVER, THE INFORMATION GAINED FROM WATER RESOURCES AND CLIMATE INVESTIGATIONS NEEDS TO BE PROVIDED TO DECISION MAKERS AT ALL LEVELS – REGIONAL, NATIONAL, STATE/ PROVINCE AND LOCAL –IN AN ACCESSIBLE FORM SO THAT THEY CAN UNDERSTAND AND UTILIZE IT APPROPRIATELY.

This chapter discusses the main findings about climate and water resources knowledge and the recommendations for improving the knowledge base for making more informed decisions.

6.1. Main Findings

Addressing climate knowledge gaps. Knowledge about some important climate processes that still needs to be improved across South Asia, include:

- the changes in glacier and snow mass balances that influence flash flood risks and dry season water resources (e.g. in the Indus Basin);
- the role of the atmospheric brown cloud in climate change in South Asia where there are high concentrations of atmospheric pollutants; and
- the dynamics and causes of land-subsidence in major river deltas related to sea-level rises.

Modelling the effects of greenhouse gases on the climate and hydrology of South Asia is subject to considerable uncertainty. Apart from the challenges associated with projections from Global Circulation Models (GCMs), there are additional uncertainties in the South Asia region because of the difficulty in modelling regional precipitation distribution where the atmospheric dynamics controlling the monsoon are difficult to model (Turner and Annamalai 2012). A key source of uncertainty is the poor representation of precipitation processes at high altitudes and across strong elevation gradients and the paucity of high-altitude data for calibration. Chapter 2 discussed the uncertainty in climate and hydrological projections and the contributing factors. In lieu of uncertainty in climate and hydrological knowledge, Box YY in chapter 8 discusses a risk-based approach developed to inform the planning and design of hydraulic infrastructure under climate uncertainty.

Coping with droughts requires a better understanding of hydro-meteorological processes that control the spatio-temporal variability of water resources and stronger models to predict droughts. The drivers for spatio-temporal variability of precipitation in the South Asia region, and the effects of global warming on this variability, are poorly understood. For example, recent analysis has shown that, contrary to the accepted norm, the water yield is decreasing in surplus river basins but is increasing in deficit basins (Ghosh et al 2016).

For coastal cities, towns and communities dependant on groundwater for drinking supply, systematic monitoring of saltwater intrusion will need to be a priority investment. In addition to installing monitoring stations, this will require development and implementation of clear protocols for regularly measuring chloride, TDS or EC (as measures of salinity) in defined monitoring wells. Saltwater intrusion in groundwater is generally very hard and very expensive to reverse, and often, the damage is irreversible. Clear management objectives have to be set because measures to slow down, halt or reverse saltwater intrusion vary. Options to address saltwater intrusion typically include reducing or stopping groundwater pumping, injecting freshwater or treated wastewater to create a barrier to slow down salinity movement or the use of other supply options such as surface water, reuse of treated wastewater or treated seawater (desalination).

Gaps in water resources knowledge. The main data limitations concern the distribution of groundwater contaminants, especially in deep aquifers, and the connectivity between groundwater and surface water in the Indo-Gangetic Basin. The main hydrological modelling challenges in South Asia stem from limited understanding of the processes regulating glacial melt in a complex orographic environment, and the hydrological processes involved in extreme events (Mathison et al. 2015).

Lack of consistent, longitudinal, available monitoring data hinders the ability to assess the hydrological impacts of climate change. In general, there are too few flow-monitoring stations established across South Asian countries to provide the information needed for reliable flow modelling. Similarly, there is little systematic information on groundwater levels, use and quality across South Asian aquifers, because of inadequate monitoring, especially of deep aquifers. The maintenance of hydro-meteorological stations tends to be neglected especially in remote and high-altitude areas or regions prone to political conflicts. Support for quality control and quality assessment in data collection and analysis is rarely a priority and systematic data sharing between institutions is uncommon. Consequently, hydrological and climatic data are often of unknown quality with gaps in the long-term record, and difficult to access because data recording is not computerized or because of access restrictions. There is also limited capacity for data analysis and forecasting within scientific institutions and little appreciation amongst officials and local groups about how to use scientific information.

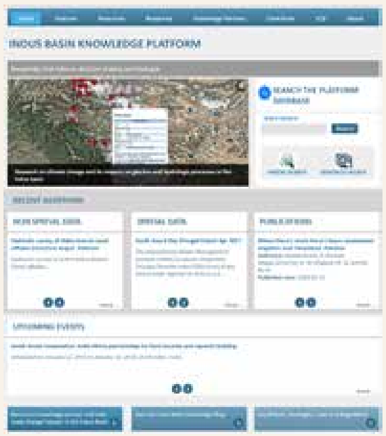
Saline contamination of coastal aquifers during storm surges is the major climate-related cause of groundwater contamination currently observed in South Asia. The nearly 10,000 km-South Asian coastline (7,000 km in India, 1,340 km in Sri Lanka, 1,046 km in Pakistan and 580 km in Bangladesh) including some of the largest cities – Karachi, Mumbai, Kolkata and Dhaka – and thousands of rural and urban communities are prone to groundwater contamination by saltwater intrusion, especially during droughts and when groundwater levels are depleted. The presence of tidal rivers and estuaries above an aquifer can also lead to salinization of the aquifer as water infiltrates downward. Monitoring data are scarce, as are effective regulation and planning environments.

There needs to be a better understanding of the linkages between surface and groundwater in the Indo-Gangetic plain, if planned conjunctive use is to be effective. In Pakistan's Punjab, it is necessary to increase the number of monitoring wells and the frequency of monitoring to better understand the temporal and spatial variations in groundwater levels and their connections with surface water bodies. Hydrological and groundwater modeling would help forecast variations in groundwater and surface water availability under different aquifer conditions and climatic scenarios.

Modern remote sensing methods for hydrological data collection can augment, but not replace, in situ data collection. Remote sensing from aircraft and satellites can provide rapid and comprehensive data on surface water distribution and, to a limited extent, on water quality at large regional scale, in a relatively short period of time and in a cost effective manner. The GRACE satellites, for example, now allow the total mass of water over regional areas (including surface and groundwater, and soil moisture) and their change over time to be monitored and estimated. These data sources can be combined with ground observations to provide a more comprehensive picture of water distribution, and changes in storage and quality. However, analytical and interpretation capacities are often lacking in the poorest countries of the South Asia region to take advantage of these remote sensing opportunities. Technical skills need to be improved and expanded.

Existing data is not readily available and shared across the region. Work under the Informing Change in the Indus Basin is an example of data sharing that helps make information more widely available (see Box 6.1). ICIMOD's Regional program on Adaptation to Change is another example of a program that is systematically generating and sharing knowledge across the Hindu-Kush-Himalayan region (see Box 6.2). There is growing need for improving collaboration in monitoring and collecting hydrological, hydrogeological and water quality information across shared surface and groundwater systems to study regional problems and to develop regional solutions.

Box 6.1 - Informing Change in the Indus Basin



Informing Change in the Indus Basin is a two-year component of the DFID South Asia Water Governance Programme (SAWGP) implemented by IWMI. Its mandate is to deliver over an 18-month period:

Knowledge consolidation and provision under an Indus Basin Knowledge Platform (IBKP) hosted and managed at IWMI HQ in Colombo (see www.indusbasin.org); **Stronger decision making** through mapping patterns of influence within irrigation schemes using tools of social network analysis and supporting upstream decision making through use of a decision support tool; and **Facilitating dialogue**, at an inter-provincial level on water management and use in Pakistan, at a basin scale through working closely with the Indus Forum under SAWI; and with public information through a media dialogue within and across all four countries sharing the basin.

Source: IWMI (http://www.indusbasin.org)

Box 6.2 - ICIMOD and Climate Change

The International Centre for Integrated Mountain Development (ICIMOD) is a regional intergovernmental learning and knowledge-sharing center serving the eight regional member countries of the Hindu-Kush-Himalayas – namely Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. Based in Kathmandu, Nepal, ICIMOD aims to assist mountain people to understand changes including climate change and globalization, adapt to these changes and make the most of new opportunities, while addressing upstream-downstream issues. ICIMOD works by supporting regional transboundary programs through partnership with regional partner institutions, facilitating the exchange of experience, and serving as a regional knowledge hub.

ICIMOD runs a Regional Progrm on Adaptation to Change the purpose of which is to enhance resilience and to support adaptation. The program develops adaptation mechanisms and works with partners to promote them, including seeking to capture indigenous knowledge on autonomous adaptation and to contribute to planned adaptation by providing scientific support. In particular, this seeks to promote innovative livelihood improvement and sustainable natural resource management strategies that can ensure continued ecosystem services and promote adaptation. Particular attention is given to the challenges and role of women in adaptation. ICIMOD's work on the HIMALA project is developing a prototype integrated hydrological model to assess water availability and improve understanding of the contribution of snow and glaciers to the flows of the rivers in the HKH, a critical factor in understanding the parameters for establishing effective water management adaptation strategies.

Source: www.icimod.org

6.2. Recommendations

- Significant investment is needed in the rehabilitation, expansion and upgrading of in-situ climate and hydrological monitoring surface and groundwater networks as well as expanded use of remote sensing platforms for data collection and analysis. In particular, monitoring needs to be expanded in data poor areas such as coastal aquifers and high altitude areas.

- Data and hydrological information, including projections based on climate change modeling, need to be shared between institutions, both within a country and between countries. Where necessary, policies, legislation and practice need to be amended to encourage information sharing.

- Research is needed into important climatic and hydrological processes such as the spatial and temporal variability in precipitation across river basins under climate change, and connectivity between surface and groundwater in the Indo-Gangetic Basin.

- The capacity for evaluating policy choices and water resources development options based on analyses of water and climate data needs to be strengthened in central agencies as well as in local and community organizations.

- Risk management approaches (decision tree analysis, robust decision making, stochastic and robust optimization, dynamic adaptive policy pathways, information - gap decision theory) should be employed when making investment decisions because of the high uncertainty associated with the effects of climate change on water resources.

WATER RESOURCES AND CLIMATE POLICIES AND INSTITUTIONS

GOOD RESOURCE GOVERNANCE WILL BE KEY TO SUCCESSFUL ADAPTATION IN THE WATER SECTOR. GOVERNANCE PROVIDES THE FRAMEWORK WITHIN WHICH WATER RESOURCES CAN BE PLANNED, DEVELOPED AND MANAGED SYSTEMATICALLY AT THE LOCAL, BASIN, STATE/PROVINCE, NATIONAL AND TRANSBOUNDARY LEVELS. A FUNDAMENTAL REQUIREMENT IS THE FORMULATION OF A WATER POLICY THAT ESTABLISHES OVER-ARCHING PRINCIPLES AND GUIDELINES SUCH AS ASSIGNING CUSTODIANSHIP OF WATER TO GOVERNMENTS, CLEARLY DEFINING ROLES, RESPONSIBILITIES AND ACCOUNTABILITIES FOR GOVERNMENT INSTITUTIONS INVOLVED IN WATER MANAGEMENT OR USE, ESTABLISHING MECHANISMS TO WORK WITH THE PRIVATE SECTOR, AND AN EFFECTIVE METHOD OF COORDINATING GOVERNMENT ACTIVITIES ACROSS SECTORS, MANAGING WATER ON A RIVER BASIN OR AQUIFER LEVEL, RECOGNIZING THE NEED FOR ENVIRONMENTAL WATER, AND ENCOURAGING GENUINE COMMUNITY PARTICIPATION IN WATER DECISIONS. A BALANCED WATER POLICY NEEDS TO INTEGRATE BOTH SUPPLY SIDE AND DEMAND MANAGEMENT OPTIONS AND ALSO RECOGNIZE DRIVERS OUTSIDE THE SECTOR THAT IMPACT WATER SUPPLY AND DEMAND

Climate policies should recognize the potential effects of global warming on water resources and include measures to promote adaptation to these effects. These adaptation measures are likely to extend well beyond the water resources sector and include actions by water-dependent sectors (including agriculture, energy, human settlements, tourism and the environment) and so the climate policies should provide mechanisms to coordinate responses across all these relevant sectors. Institutions need to be identified and empowered to undertake this coordination and to oversee implementation of adaptation actions.

This chapter, based on an analysis of water and climate related instruments (policies, strategies, legislation, and plans) for South Asian countries (Appendix 1), presents findings about: (a) the adequacy and suitability of the existing water resources policies and other instruments for improving water management and thereby adapting to climate change, (b) the recognition within climate change policies of the need for adaptation in the water sector, and (c) the institutional structure for ensuring coordination across the various affected sectors; and (d) recommendations for improved water resources governance. Financing climate change adaptation is discussed in a later chapter.

7.1. Main Findings

Water resources instruments (policies, legislation, strategies, plans). All governments recognize the complexities of climate related water resources challenges and are laying the foundations - knowledge, policy, institutions and infrastructure - for adapting to climate change. Probably the biggest gap in water instruments is the absence of agreed over-arching water policies and legislation in three countries – Nepal, Pakistan (Pakistan has recently drafted a new water policy) and Sri Lanka. Without a coherent whole-of-government policy response these countries are reliant on sub-sector instruments or the policies of water-related sectors such as drinking water supply, environment, energy and/or agriculture.

IWRM is accepted in the current water and climate policies of most nations as being the most relevant approach to water management, particularly when growing demand for water is placing the resource *base under increasing stress*. It is also seen as being well suited to improving water management under climate change because it is designed to address both the "availability" and the "variability" components of the region's challenge.

IWRM is designed to manage trade-offs between competing water users as access to water becomes more limited under variable hydrological conditions. Moreover, IWRM is an inherently adaptive approach that is well suited to increasing variability under climate change, emphasizing the importance of better information and more responsive institutions together with infrastructure investments and structural and non-structural responses at all levels. The principles of IWRM are formally adopted in water resources and climate change instruments in all South Asian countries except Sri Lanka.

Whilst IWRM is established in policies across the region, its practical implementation is limited, incremental and in its early stages. The region has made important advances in the development of surface and groundwater resources for different uses of water (drinking, industry, and irrigation, hydropower) and in building flood control structures. However, there is limited attention to the protection, conservation and management of rivers, lakes, aquifers and wetlands systems.

The water sector remains fragmented. There is minimal integration between agencies responsible for managing water quantity and water quality, responsible for surface water and groundwater, or between and with different water using sectors (e.g., agriculture, energy, industry, rural, urban or environment). Box 7.1 also highlights the policies and actions outside the water sector that can profoundly impact the water sector.

Existing water policies undervalue groundwater. Water policies remain biased towards surface water, and allocate the bulk of the budget for surface water infrastructure with groundwater management receiving much smaller share of the funding. The 2011 Indian draft Model Bill for the Conservation, Protection and Regulation of provides an example of the types of actions that can improve groundwater management and integrate it with surface water management. It is particularly important to break the nexus, often assumed, between land ownership and control of groundwater.

Most countries recognize the potential impacts of climate change in their water instruments. Four of the seven South Asian countries (Afghanistan, Bangladesh, Bhutan, and India) clearly recognize and incorporate climate change and its impacts in their water instruments while Pakistan, Nepal and Sri Lanka mention climate change in their sub-sectoral instruments. The 2012 Indian Water Policy clearly recognizes climate change as being one of three key pressures on water availability along with population growth and increasing demand, and the Policy has a detailed section on adapting to climate change. However, Nepal does not mention climate change in its 2002 Water Strategy or 2005 Water Plan (apart from the need to study this issue by establishing a Himalayan Climate Change Study Center), although its new Water Disaster Management Policy 2015 clearly includes the potential effects of climate change on floods.

Water rights or entitlements need to be clearly established in water resources instruments. All South Asian countries, with the exception of Pakistan and Sri Lanka, have clarified in their water instruments that water is owned by the people with the State adopting the role of trustee or custodian. All water extraction requires a permit, although most countries provide exemptions for basic human needs and sometimes other traditional uses. Permits are also required for discharge of pollutants to waterways and, in cases such as Bangladesh's Water Act, for diverting or impeding flows thus asserting government authority over embankments and other structures erected by land owners for flood control. Of course, all countries, including Pakistan and Sri Lanka, have long-established mechanisms for assigning water rights and for sharing water but this assertion of public ownership clarifies the right of governments to implement actions to help adapt to climate change, such as controlling over-abstraction, introducing artificial recharge and conjunctive use and having the mandate to re-allocate water during extreme droughts and national crisis.

Formal mechanism for allocating water. As demand for water increases due to growing population and economic development and competition over water and tensions and conflicts between and among sectors, states and provinces emerge, the need for formal mechanisms for allocating water become more important to ensure equitable, efficient and sustainable use of water.

This clarification about public ownership of and authority over water resources applies to both surface and groundwater in Afghanistan, Bangladesh, Bhutan, India and Nepal. In some countries, traditional beliefs that groundwater is the property of the owner of the overlying land persist, and is sometimes supported by colonial era common law principles. In India, private ownership of water is incorporated in the Constitution. This contributes to overuse of what is, in reality, a common pool resource.

Demand side management can be an effective, if under-utilized, tool for water allocation under conditions of scarcity. Demand management is generally endorsed in water instruments across South Asia although the specific mechanisms by which demand will be controlled are not always spelt out (e.g. Afghanistan's Water Sector Strategy has the explicit intention of elevating demand-side management to an equal status with supply augmentation, but does not provide details). However, India has a thorough description of its intentions to accelerate demand management by treating water as an economic good and encouraging states to introduce water regulators who can set water tariffs. The government sees demand management as a mechanism to help combat the impacts of climate change and calls for alignment with compatible agricultural strategies.

Establishing water prices that reflect the true cost of water is one of the important means for reducing water demand. Bangladesh, India and Pakistan propose pricing reforms in their water instruments. However, there are few practical attempts to bring about these reforms because of public opposition to charging for water which is often seen as a free good and because of the perceived impacts on the poor. Demand can also be reduced by removing perverse (energy) subsidies for farmers that encourage excessive agricultural water use (and groundwater depletion). India calls for the removal of these subsidies in its 2012 National Water Policy and in its water-related climate change document (the National Water Mission). However, removing these subsidies requires cooperation between the water, energy and agricultural sectors. Public education and participation programs can also help institute demand management by building awareness of the need to reduce unnecessary water use and build public ownership of the issue.

Most countries (Bangladesh, Bhutan, India, Nepal, and Pakistan) recognize the need for allocating water for the environment but in practice it is rarely allocated systematically. These environmental flow provisions are customized for the needs of each country - Bangladesh and Pakistan place emphasis on the provision of environmental water to maintain productive delta ecosystems and to prevent saltwater intrusion, while Nepal identifies the need to maintain ecosystems downstream of dams. Even though concerns over environmental flows are growing, for example, in hydropower developments in India, water allocation between provinces in Pakistan and water resources development in Sri Lanka, examples of systematically conducting environmental flow assessments to establish environmental flow requirements are the exception not the rule.

Climate Change policies, strategies, plans, NAPAs and NDCs. All countries have either policies or plans for responding to climate change, including five (Afghanistan, Bangladesh, Bhutan, Nepal, Sri Lanka) that have plans and programs specifically focused on adaptation. All countries submitted Intended Nationally Determined Contribution (INDCs) reports to the COP21 meeting in Paris in 2015. The INDC reports focus on mitigation actions but most also include adaptation activities. However, overall progress towards the development of an adaptation capacity in the water sector to date is limited and is "a work in progress." A substantial amount of effort and investment is needed to develop effective adaptation frameworks for the water sector.

All countries mainstream climate adaptation into their respective national development programs. In Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka climate adaptation programs form an integral part of development objectives to enhance food security and reduce poverty, involving water related sectors. Climate adaptation programs are also closely linked with risk prevention and disaster management in Bangladesh, Bhutan, Pakistan and Sri Lanka, as well as with environmental issues (problems of desertification, in particular) in Afghanistan.

All countries with their many large and small transboundary rivers can benefit from taking a regional approach to climate change adaptation (Box 7.1). Water shortages could intensify existing tensions and create new conflicts over sharing of inter-state rivers within a country or transboundary rivers between countries. Many countries recognize this in their climate change documents. For example, the Pakistan government in its Climate Policy offers to explore joint watershed management of transboundary basins with neighbouring countries.

Box 7.1 - Regional cooperation is a critical element in adaptation

With 54 rivers shared between India and Bangladesh alone, the South Asian landscape is characterised by a highly-interconnected network of rivers and aquifers, except for Sri Lanka. These shared rivers and aquifers and the 'third pole' ice and snow mass in the Himalayas support the livelihoods of 400 million people across the Indo-Gangetic and Brahmaputra basins in Nepal, India and Bangladesh alone. Links between upstream glaciers and this network of transboundary rivers and aquifers highlights the limitations of adaptive action confined to national boundaries, especially in the case of lower riparian states, and underscores the need for regional cooperation. This is best illustrated by Bangladesh which not only depends on transboundary flows for 97% of its surface water but is also at risk from regular flooding from unregulated and uncontrolled river flows.

Cooperation amongst riparian countries however is limited, with agreements only for a few specific rivers, many of which pre-date full recognition of the risks posed by climate change. The focus on water sharing thus appears rather narrow when the need today is for cooperation along a broader front of water management needs and adaptive actions. The existing power asymmetries in economic and political systems, and across geographies and country priorities pose a significant challenge to achieving such cooperation. Central to these dynamics is India. Given its economic and political influence, and geographical positioning as a midstream country, India will continue to play a central role in shaping and reshaping governance structures and processes on regional cooperation. While regional political systems such as the South Asian Association for Regional Co-operation (SAARC) and the South Asia Co-operative Environment Programme (SACEP) exist, they have been slow to lead region-wide adaptation initiatives, leaving no clear pathway for scaling existing bilateral approaches at a truly regional level.

Source: Suhardiman et al (2017)

Efforts to promote regional adaptation will have to take into account the existing asymmetries in economic and political power, geography, resource endowments, skill, institutional capacities and country priorities. Central to these dynamics is India which, with its economic and political influence and geographic location at the center of the region, could play a key role in future regional cooperation for climate adaptation. To date, India has taken a bilateral approach to developing formal cooperation. The South Asian Association for Regional Cooperation (SAARC) has initiated many regional cooperation agreements, some directly on climate change. Of these, the Dhaka Declaration and SAARC Action Plan on Climate Change (2008), and the Thimphu Statement on Climate Change (2010) are two important milestones. The Thimphu Statement recognizes that climate change will require a regional response. The South Asia Groundwater Forum held in Jaipur (India) in June 2016 provided an important platform to share emerging research findings on the storage and priority threats related to the Indo-Gangetic Basin aquifers, knowledge on critical aspects of groundwater use and governance in general, including the opportunities for building drought and climate resilience.

Water resources and climate change institutions. A key institutional feature of IWRM, coordination across water dependent sectors is recognized as important in the water instruments of all countries. All countries have established institutions to coordinate water management across relevant sectors although the composition and authority of these bodies varies considerably. Approaches vary from Afghanistan's Supreme Council on Water Affairs Management, chaired by the First Vice-President and containing all relevant Ministers, to India's long-established National Water Resources Council, chaired by the Prime Minister, and Nepal's Water and Energy Commission which has limited authority and the role of which is not well recognized by some sector ministries (Suhardiman et al. 2015).

India has had for a long time separate surface and groundwater organizations (the Central Water Commission and the Central Ground Water Board); this has encouraged a lack of coordination and hampered attempts to manage water resources as a whole. A recent review has recommended that the functions of these organizations be combined into a National Water Commission which would also promote other IWRM principles such as participation by water users and river basin water allocation planning.[8]

Separation of regulatory and operational functions, is not widely recognized or implemented under South Asian water policies. Regulatory bodies are required to impartially oversee the allocation and operational management of water according to legislation and regulations. There are serious potential and actual conflicts of interest when regulatory and operational responsibilities are gathered within the same Ministry. In general, where water resources regulatory agencies exist they tend to be resourced poorly, inadequately staffed and have weak mandates. Consequently, regulations for water allocation, pollution control and land use planning are only weakly implemented across South Asia. Addressing these regulatory problems will be important in building climate change adaptation capacity.

A centralized approach to climate adaptation is common across South Asia. One or more government agencies are charged with leading, preparing and formulating climate adaptation programs at the national level. This is most evident in India, where the national response around climate change emerged through the Prime Minister's Office, with the creation of the Prime Minister's Council on Climate Change (PMCCC) in 2007. Similarly, the Government of Nepal (GoN) formed the Climate Change Council in 2009 as the national coordinating body to ensure effective implementation of climate adaptation policies. Though Nepal has also formulated its Local Action Plans for Adaptation (LAPA), in practice, adaptation planning through NAPA continues to dominate LAPA. Pakistan too has begun to take initiatives for employing LAPAs. A centralized approach to climate adaptation does not automatically result in good coordination or accommodate the inclusion of local coping strategies. In Nepal, the government established a Multi-stakeholder Climate Change Initiatives Coordination Committee (MCCICC) in 2009, and a National Climate Change and Knowledge Management Centre (NCCKMC) in 2010. While MCCICC has a diverse membership, it remains a nationally-centered institution, with very little connection to local communities. Similarly, while NCCKMC works towards a knowledge platform, it is unclear how local communities could access such a platform.

Climate adaptation implementation agencies need to address institutional ineffectiveness and weak cross-sectoral integration and collaboration. Driven by global climate policy discussions, national governments have appointed relevant sector ministries (e.g., Ministry of Science Technology and Environment in Nepal, Ministry of Environment

[8] http://www.livemint.com/Politics/Me6nyWGcM9xBkz4x9bbBIN/India-needs-National-Water-Commission-to-deal-with-new-chall.html. Also interview in The Hindu August 19, 2016.

and Forests in Bangladesh) or formed new inter-ministerial bodies to lead program implementation, as an 'ad hoc' response (Dubash and Joseph, 2016) to institutionalization. In practice, while the institutional structures for climate adaptation are in place, more needs to be done to improve the overall performance and institutional effectiveness of these bodies, both at ministerial and inter-ministerial levels. National coordination bodies (e.g. Climate Cells) struggle to cope with entrenched sectoral approaches, and lack of capacity to generate cross-sector collaboration.

Harmonization between climate change and water resources institutions is essential for effective adaptation. South Asian governments have created institutions to deal with climate change issues, either through the formation of inter-ministerial coordinating bodies, or through assigning the responsibility to tackle climate related issue to specific sector ministries at different scales. However, the climate change instruments, while detailing many aspects of water management, pay little attention to either the need for regulating water use or cross-sectoral coordination of water dependent institutions. The climate change inter-ministerial coordination bodies often do not function well, are constrained by current institutional set ups and lack of capacity, both in terms of budget and staffing. Table 7.1 provides an overview of the typology of institutional approaches in climate adaptation across the region, and their strengths and weaknesses.

Table 7.1 - Typology of institutional approaches in climate adaptation

Type of institutional framework	Strengths	Weaknesses	Study countries
Cross-sectoral collaboration through the establishment of an inter-ministerial coordinating body	• Provides the institutional set up for holistic program development, planning and implementation • Addresses climate adaptation more effectively (e.g., less overlapping between various government agencies)	• Unable to overcome the problem of sectoral fragmentation • Malfunctioning due to lack of a decision-making authority to direct and enforce sectoral ministries' conduct	• Afghanistan, Bhutan
Combined inter-ministerial coordinating body with sectoral leadership	• Facilitates the formation of networks for cross-sectoral collaborations • Facilitates the development of adaptive institutional frameworks, based on how relevant bodies perceive and negotiate their roles and interface	• Requires a lot of fine-tuning (across scales) to form solid, strategic alliances between relevant bodies • Requires clear division of tasks and responsibilities	• Bangladesh, India, Nepal, Pakistan
Sectoral leadership	• Direct access to decision-making authority to plan, direct and implement climate adaptation	• Sectoral approach to climate adaptation may not be sufficient to address widespread, cross-sectoral implications of climate change	• Sri Lanka
Government revenue and project fund as main financial source	• Continuous channeling of funds could increase the program's sustainability	• Requires more time and effort for fine-tuning in terms of financial mechanisms selected, division of tasks, activities selected, etc. • Requires strong commitment from both the government and international donors • Unclear prioritization of climate adaptation measures, since they are often implied in the government's national development programs	• Bangladesh, India
Project fund as main financial source	• Direct implementation of climate adaptation activities through various government agencies and NGOs • Effective implementation of climate adaptation through the project management unit	• Aid dependency often results in the program's unsustainability (ends after funds are fully allocated) • Parallel projects may not be effective to address cross-sectoral implications of climate change	• Afghanistan, Bhutan, Nepal, Sri Lanka

7.2. Recommendations

- Nepal and Sri Lanka could benefit from developing whole-of-government water resources policies that provide comprehensive guidance about water development, planning and management. Such policy development would only be successful if it was country-driven and took account of lessons learnt from previous attempts to introduce water policies (Ariyabandu 2008).

- Responsibilities for water resources regulation and operations need to be separated and placed in different institutions, preferably under different Ministries.

- Water rights, as defined in policies, should be introduced to water users through education programs to build up an understanding that water is a common pool resource needing communal management.

- More effort should be placed on demand management, including establishing prices that reflect actual water provision costs, to delay the need for expensive supply side investments. This includes removal of electricity subsidies that encourage excessive groundwater extraction.

- More attention should be paid to improving groundwater management, including controls over excessive groundwater use, avoidance of groundwater pollution and protection of recharge areas.

- While improved water management is, intrinsically, an adaptation response to climate change, it would be beneficial if water managers had a better appreciation of the potential impacts of climate change and worked within a risk-based adaptation framework that allowed them to assess whether these impacts were likely to be significant or not given the uncertainties associated with climate change projections.

- Adaptation should be included in future water resources development planning using a risk-based approach.

- Regional approaches for promoting opportunities for greater sharing of knowledge and cooperation (e.g., on flood early warning, cost effective approaches for dealing with arsenic in water supply and measures for preventing saltwater intrusion in coastal aquifers) and for mediation (in water sharing issues) is critical for transboundary cooperation towards more holistic adaptation measures in South Asia.

- Water resources institutions need to be fully engaged in climate change coordination arrangements in all countries.

- Local adaptation needs to be encouraged in all countries, with local communities being given central support but empowered to take the lead in adaptation activities.

WATER RESOURCES INFRASTRUCTURE

INFRASTRUCTURE – INCLUDING DAMS, WEIRS AND BARRAGES, FLOOD CONTROL STRUCTURES, AND INTER-BASIN TRANSFERS – PLAYS AN ESSENTIAL ROLE IN THE PROVISION OF WATER SUPPLIES, IN THE REGULATION OF RIVER FLOWS AND IN MITIGATING THE IMPACTS OF EXTREME FLOWS. SINGLE AND MULTIPURPOSE DAMS CAN BE USED TO REGULATE RIVER FLOWS, STORE WATER FOR IRRIGATION, HYDROPOWER, INDUSTRY AND DOMESTIC CONSUMPTION, CONTROL FLOOD FLOWS AND MANAGE VARIABILITY, THEREBY CONTRIBUTING TO ADAPTATION EFFORTS. HAVING SUFFICIENT WATER STORAGE WILL BECOME INCREASINGLY IMPORTANT AS GREATER RAINFALL VARIABILITY AND REDUCTION OF ICE AND SNOW (AS A RESULT OF CLIMATE CHANGE) EMERGE AND INCREASE STREAMFLOW VARIABILITY. REDUCING SEDIMENT LOADS CAN PROLONG THE LIFE OF EXISTING STORAGE RESERVOIRS (ANNANDALE ET AL 2016; PALMIERI ET AL 2003). NEVERTHELESS, EVEN WITH IMPROVED WATER USE EFFICIENCIES AND REDUCED SEDIMENT LOADS, INCREASED STORAGE (INCLUDING NATURAL STORAGE SUCH AS AQUIFERS AND SOIL MOISTURE) WILL BE REQUIRED TO COPE WITH INCREASED VARIABILITY IN PRECIPITATION, AS WELL AS REDUCED PRECIPITATION AND SNOW/ICE MELT IN SOME AREAS

Dams can also be designed to reduce flood risk while embankments and levees can protect critical areas from flood damage as part of more integrated responses that include non-structural measures (e.g. land use planning, zoning, education, early warning systems and increased use of flood insurance). Inter-basin transfers can help to move water from regions of relative water abundance to those where water is scarce. However, they require detailed technical studies, economic analyses, negotiations and benefit sharing before they can be implemented.

Aquifers provides a source of water that helps meet increased variability and existing groundwater supply, which can be augmented through artificial recharge (managed aquifer recharge MAR). Smaller-scale infrastructure such as household and community water tanks and rainwater harvesting can also help provide water during droughts. Aquifers and community water sources are discussed in the next chapter.

All infrastructure measures can have deleterious effects on downstream users and communities and need to be designed and operated in accordance with national social and environmental requirements. Dams, weirs and embankments can alter the patterns of river flow so that they provide too little or too much water to downstream ecosystems and communities, thereby lessening their ability to adapt to climate change. Infrastructure developments that interrupt flows therefore need to be operated according to environmental flow plans that minimize downstream disruption. Inter-basin transfers can impact both the exporting areas (e.g., water sources) and receiving areas (e.g., water bodies or storage structures).

An important caveat is that additional infrastructure can only provide a buffer against increasing variability if it is constructed and operated according to design rules that take account of climate change. Thus, new infrastructure, such as hydropower dams, needs to be accompanied by a review of design criteria and operational rules to ensure that it is adaptive to climate change – including coping with future extremes.

8.1. Main Findings

Dams and storages. Infrastructure expansion and rehabilitation will be needed to adapt to climate change. All countries, except Bangladesh, have plans to develop additional water storage. New water storage is recognized as being essential for development in Nepal, Pakistan and Bhutan. The need for additional water storage will be greatest in arid and semi-arid areas and where groundwater is depleted and worsening in quality (e.g., in the Lower Indus Basin) and where there may be reduced storage in glaciers and snow cover as a result of upstream climate change impacts. This means not only constructing more storage but also reducing sediment loads to prolong the life of existing storage by managing catchments in order to reduce sediment loads, manage sediments within reservoirs, and remove sediments from reservoirs (Annandale et al 2016; Palmieri et al 2003).

Existing storage can be operated more efficiently to postpone major investments in new infrastructure. Methods include making greater use of weather and climate forecasts, integrating operations within river basins, conjunctive use of surface storage and groundwater systems, de-silting of reservoirs and management of erosion within catchments, and technical improvements in control systems and off-takes.

Many South Asian dams are old and need to be assessed for safety. Dam safety inspections will become more important with changing hydrology under climate change. The failure of the Oroville Dam emergency spillway in California in February 2017 (following excessive rains after 5 years of drought) caused the evacuation of 180,000 people, illustrating the risks to major infrastructure of changing hydrological conditions.

There is a shift from single purpose to multipurpose dams. The Indian Water Mission climate change document sees this shift as providing more opportunity to respond to increased risk of flood as a result of climate change in addition to meeting growing water needs. The Mahaweli Development Programme, Sri Lanka's largest river basin development for irrigation development, hydropower production and flood control, represents an example of some of the pioneering work on multipurpose river basin development in South Asia.

Both existing and new infrastructure may need to be operated taking account of climate change and other concurrent environmental changes including changing land-use. Infrastructure design standards may need to be revised to take account of climate change, and dam operating rules will need to incorporate any changes in extreme flows. However, not all storage investments will require a detailed analysis of climate change impacts – other factors may have greater influence on design decisions. A detailed study of climate change impacts on Nepal's hydroelectric power production concluded that smaller run-of-river projects are more likely to be affected by climate change, that climate change induced hazards (increased sediment loads, extreme floods, geohazards) are the most important additional risk, and that, while climate change is important, it is outweighed by other issues and uncertainties (World Bank 2014).

Given the uncertainties from climate modelling and projections of changes in hydrological parameters, a risk-based management approach is recommended for decision making. Box 8.1 describes the Decision Tree Approach, a method funded by the World Bank for determining whether climate change is an important factor in designing infrastructure and its application in hydropower planning in Nepal.

Box 8.1 - The Decision Tree Approach and application to Upper Arun Hydropower project

Undertaking an analysis of climate change impacts on water resources infrastructure is usually expensive and potentially delays project commencement. The Decision-Tree Approach (Ray and Brown, 2015) provides a method for determining whether climate change is an important factor in designing infrastructure – and if not, then saving considerable time and expense.

The method was applied to the Upper Arun Hydropower Project in eastern Nepal and to the overall hydropower portfolio in the Koshi Basin (Karki et al., 2016). The analysis aimed to assess how climate change (i.e. ice- and snow-melt fed river inflow modified by changes in temperature and rainfall) and other variables (including supplied hydropower price and sediment load) might affect the project's optimal design capacity. Different combinations of planned hydropower capacity were also tested at the basin level. Performance metrics include the economic value of the project and the total and dry season hydropower production. The robustness of the project was tested by simulating various climate scenarios using a hydrological model including a glacier component and a water system model that translates water availability into hydropower production.

Results indicate that the original design of 335 MW was not able to exploit the predicted increase in flows during the wet season. A design capacity of 1,000 MW emerged as an attractive alternative, although it was more sensitive to increases in capital costs and electricity prices. Input variables were selected in consultation with the Nepal Electricity Authority and relevant literature to ensure that their ranges of values are realistic. Historical records of temperature and precipitation were adjusted with the intention of going far beyond the ranges covered by the IPCC projections to demonstrate the project resilience to climate change. The analysis went on to the later phases of the Decision Tree, even after climate risks were shown in Phase 2 to be low, because the investors and stakeholders wanted to know if a larger design size might capitalize on the opportunities for hydropower generation presented by more favorable conditions. The stakeholder-trusted model was used to simulate the basin system over a 30-year period, given various options for infrastructure development and operating rules. The model was optimized to identify a small set of the highest-performing portfolios (the most efficient and robust combinations of options). Stakeholder-preferred investment bundles were then stress-tested in detail to identify any vulnerabilities, including institutional and financial variables.

Ultimately, this approach aims to help decision makers identify which investments can achieve robust outcomes and appropriately balance the system's benefits. When basins have complex interdependencies and when the various possible interventions are contested, such system-level trade-off analysis can help bring clarity and consensus (Geressu and Harou, 2015; Karki et al., 2016). The Decision Tree framework provides a way of evaluating across various climate models without having to rely on just one climate projection.

Source: Ray and Brown (2015)

Flood protection infrastructure. All countries include infrastructure protection against floods in their water instruments, although the extent and detail of coverage varies considerably. Afghanistan, Bhutan and Sri Lanka make only passing mention of infrastructure for flood protection in their water instruments; Nepal and Bhutan have taken a risk reduction approach for flood protection, requiring flood zoning, and hazard mapping and early warning systems for GLOFs; while Bangladesh's Coastal Zone Policy 2005 specifically links the need for flood protection infrastructure against the expected impacts of climate change, and India's National Water Policy and Water Framework Bill require that embankments and other flood infrastructure be designed to take account of climate change. Nepal has a specific Water Induced Disaster Management Policy 2015 that includes the need for detention basins and river training works (embankments), and classifies flood-affected areas into different zones and recommends different land uses for these zones.

There is a paradigm shift in addressing floods from flood control and protection to flood preparation and management. Most of the water instruments across South Asia couple structural measures (i.e., infrastructure such as embankments) with non-structural measures to protect against floods. In the case of India, the National Water Policy 2012 advocates an integrated approach ranging from early warning systems and flood forecasting to flood preparedness and flood protection to disaster recovery. Non-structural measures include rehabilitation of natural drainage systems, changes in reservoir operating procedures and community flood planning.

Flood protection infrastructure may need to be rehabilitated and upgraded. Extreme events, including floods, are likely to increase in severity under climate change. While non-structural measures (including land use zoning, maintaining flood dispersal channels and early warning systems) are often more cost-effective than investing in new infrastructure, it is still often necessary to protect high-value and vulnerable areas with embankments and other infrastructure. However, these investments should be subject to economic evaluations that incorporate the likely effects of climate change and the use of non-structural measures to adapt to increased flood risks.

Inter-basin transfers. There are few mentions of inter-basin transfers in South Asia's water instruments. Inter-basin transfers have been proposed in some South Asian countries (e.g. the Sutlej-Yamuna link between the Indus and Ganges basins within India) to move water from regions of relative water abundance to those where water is scarce. Sri Lanka's National Climate Change Adaptation Strategy proposes inter-basin transfers, but the National Water Use Master Plan has concluded that inter-basin transfers are a long-term option and could be contentious because of resettlement issues. Nepal's Water Resources Plan proposes that irrigation development should be integrated with multipurpose water storage projects and inter-basin transfers to reduce the potential impacts of climate change. However, these water transfers are contentious and require detailed negotiations and agreements on benefit sharing and environmental safeguards before they can be implemented. India has an ambitious National River Linking Plan that intends to transfer surplus waters from the Himalayan rivers to more deficient peninsular rivers.

8.2. Recommendations

- Prolong life of reservoirs by managing catchments to reduce sediment loads above reservoirs, particularly above hydropower dams.
- Undertake safety inspections for ageing dams and other critical infrastructure.
- Incorporate climate change into design of storage reservoirs using a risk-based approach such as Decision Tree Analysis
- Modify reservoir operating rules to incorporate climate change where this is likely to be a significant influence
- Continue to couple structural measures against floods with non-structural actions such as better forecasting of floods, floodplain mapping and zoning, and pre-emptive planning, and rehabilitation of natural drainage systems. Flood insurance may be a worthwhile option in some circumstances.

WATER RESOURCES PLANNING AND MANAGEMENT

GOOD WATER RESOURCES PLANNING AND MANAGEMENT CAN HELP TO SYSTEMATICALLY PLAN FOR AND MAKE BETTER USE OF EXISTING AND FUTURE WATER SUPPLIES IN THE FACE OF INCREASED VARIABILITY AND, IN SOME PLACES, REDUCED WATER AVAILABILITY AS A RESULT OF CLIMATE CHANGE. IN THIS CHAPTER WE PRESENT THE FINDINGS ON: (A) WATER USE PLANS FOR SYSTEMATICALLY ALLOCATING SURFACE AND GROUNDWATER AMONG COMPETING USES; (B) MANAGING WATER SHORTAGES THROUGH A VARIETY OF METHODS INCLUDING: (I) AUGMENTING SUPPLY (DEALT WITH IN PREVIOUS CHAPTER), (II) INTRODUCING WATER USE EFFICIENCY MEASURES, (III) CONTROLLING DEMAND THROUGH PRICING, (IV) CONJUNCTIVELY USING SURFACE AND GROUNDWATER WHERE POSSIBLE, (V) RECYCLING AND REUSING WATER, AND (VII) PUBLIC EDUCATION (INCLUDED IN NEXT CHAPTER); (C) PROTECTING WATER QUALITY TO BOTH INCREASE THE USABILITY OF WATER AND TO PROTECT PUBLIC HEALTH AND THE ENVIRONMENT; AND (D) MANAGING GROUNDWATER BECAUSE OF ITS IMPORTANCE FOR MANAGING CLIMATE CHANGE, AND (E) MANAGING FLOODS AND DROUGHTS THROUGH BOTH STRUCTURAL MEASURES (DISCUSSED IN PREVIOUS CHAPTER) AND NON-STRUCTURAL MEASURES SUCH AS PREPARATORY PLANNING, LAND USE CONTROLS, EARLY WARNING SYSTEMS AND ASSISTING LOCAL COMMUNITIES IMPLEMENT LOCAL SOLUTIONS

9.1. Main Findings

Water Resources Planning. Afghanistan, Bhutan, India, and Nepal have adopted basin-level water resources planning and management in their water resources instruments but actual implementation is limited and ad hoc. The functions of Basin authorities in these countries are generally similar– developing water allocation plans with participation from water users (sometimes devolving responsibility to the sub-basin level), issuing water use permits taking account of water availability, monitoring water use and enforcing action if there are breaches of water use permits. In some countries, basin authorities also have water infrastructure development responsibilities.

Bangladesh, in its Water Policy 1999, has developed a national water management plan (2001) that recognizes different geographic areas of the country, rather than basin-level plans. Bangladesh agrees in principle with basin planning but points out that it means greater cooperative management of the Ganges River basin as over 95% of its inflows originate outside its jurisdiction. Pakistan does not include basin-level water management in its water instruments, presumably because the Indus River Basin is already the focus of its management attention. There are Sri Lankan agencies (primarily the Irrigation Department and the Mahaweli Authority) responsible for river basin development for hydropower generation and irrigation in Sri Lanka, but these do not undertake the planning and management functions of river basin agencies envisaged in the IWRM model and there are clear conflicts of interest with the Irrigation Ministry being both the river basin manager and the major water user in most basins.

Water planning should assess whether climate change is likely to impact on both water availability and water demand during the life of the plan. However, India is the only country that specifically requires that basin-level plans take account of climate change in its water instruments. Afghanistan, while it does not require that climate change be incorporated into basin plans, does require that climate change be included in the national water resources development plan with which the basin plans need to be consistent. Box 9.1 is an example of how climate change analysis was systematically incorporated in the preparation of the Rufiji Basin integrated river basin development and management plan in Tanzania.

Box 9.1 - The Rufiji Basin Plan, Tanzania

The Rufiji River basin, covering 20% of Tanzania, is vital to the country's economic development. It provides over 80% of the country's hydropower capacity, contributes 15-18% of GDP through agriculture, and contains the country's largest national park – a major tourist attraction. The catchment's water is already heavily committed with water use permits representing 61% of annual average water supply in 2015 and water use projected to reach 82% of water availability in 2035. The catchment's wetlands, including the Great Ruaha National Park, have experienced severe water shortages because of upstream irrigation areas, with wetland areas contracting from 180 km^2 in 1990 to 120 km^2 in 2016. Power generation has also been affected by upstream irrigation abstractions, with frequent load shedding during the dry season. Sectoral plans for expansion of irrigation areas and development of further hydropower stations are unsustainable at present rates of water use.

Climate change will exacerbate the situation with temperatures projected to rise by 1.5-3.9C by 2097, potential evapo-transpiration will increase by 7-11%, while annual precipitation will increase by 3-5% in the wet season and decrease by 11-21% in the dry season. Proposed increases in water use combined with the effects of climate change could see annual runoff decrease by about 60%.

The Rufiji Integrated Water Resource Management and Development Plan is based on a detailed hydrological and climatological study that incorporates the potential effects of climate change on water availability and irrigation water demand. The Plan proposes a wide variety of actions across five key areas – social development, environment, economic development, disaster management, and water governance. The key to meeting development plans is to make irrigation water use more efficient through technical improvements together with stricter regulation. With these improvements, a new hydropower dam can be developed and wetlands can be restored while providing minimum environmental flows to the National Park.

Source: Georgakakos 2016

Water use efficiency. Most countries see improved technical ways of increasing water-use efficiencies as the primary response to the threat of more frequent and more severe droughts due to climate change. Such measures to improve the efficiency of irrigation, urban and other water uses are widely included in water instruments. Techniques include drip and sprinkler irrigation and better crop management and are present in the water resources and irrigation instruments of most South Asian countries. In Pakistan, there is considerable scope for improving water use efficiencies, not only to reduce demand on water sources but also to halt salinization and loss of useable groundwater. The Pakistan Water Sector Strategy estimates that there is the potential to save 5.8 BCM annually by 2025 through increasing irrigation efficiency from current efficiency levels of 40%-45%.

There is also considerable scope for water-efficient technologies in urban water supply systems. Both Pakistan, through its Drinking Water Policy 2009, and Sri Lanka, through its National Drinking Water Policy, propose technical means to reduce urban water wastage such as replacing old pipes, detecting illegal connections, using water saving plumbing, and replacing common outlets with individual connections (Fan 2015). Markandya et al (2017) have undertaken a preliminary assessment of the investments needed to achieve different levels of improvement in water-use efficiency in South Asian countries. A 10% improvement in India requires an investment of $27 per ha, they calculate, while the same level of improvement in Sri Lanka requires a $41 per ha investment.

Conjunctive use and management of surface and groundwater. Conjunctive use is widely proposed in South Asia government instruments to augment water supply in areas of water shortage. Foster in Shah and Lele (2011) believes that conjunctive use of surface and groundwater, especially by increasing groundwater use in upstream areas and improving surface water availability downstream, is of central importance in the Indo-Gangetic Plain and in Pakistan's Punjab. Given the leakiness of many irrigation canals, there are considerable opportunities to introduce deliberately-managed conjunctive use in Pakistan, India and Bangladesh. Conjunctive use is included in the Water Plan and the Irrigation Policy of Nepal, while Bangladesh's National Water Policy 1999 and Water Management Plan 2001 both encourage conjunctive use. India's Water Policy calls for investigations into the effectiveness of conjunctive use while Pakistan has commissioned a specific study into opportunities for conjunctive use (Associated Consulting Engineers et al 2011) that identified areas where conjunctive management of surface and groundwater in irrigation areas could be employed by regularizing and controlling the current excessive leakage of surface water into groundwater systems, while maintaining water quality.

Reuse and recycling. Reuse and recycling of treated urban and industrial wastewater and irrigation return flows are also widely proposed in water instruments. India's Water Policy calls for wastewater reuse and its Water Mission specifically proposes effluent reuse onto crops as a mechanism to help combat the likely effects of climate change. India also has subsidies for industrial recycling and reuse as well as recycling and reuse of irrigation drainage waters in its National Water Policy. Nepal and Bhutan do not face water shortages and do not propose implementation of reuse and recycling in their Water Plan and Policy, although Bhutan proposes to study these approaches. Bangladesh wants financial incentives for water reuse and conservation, while Pakistan and Sri Lanka advocate reuse in their Drinking water policies.

Recycling and reuse of effluent carries considerable health risks and pose a serious public health hazard unless the current weak water quality management and regulatory capacity is improved across South Asia. Water quality guidelines and regulations are essential for water recycling and reuse, especially where treated wastewater is the water source. Technical guidelines and coordination between surface and groundwater managers are also important for conjunctive use.

Protecting water quality. Although country policies and legislation focus primarily on protecting surface water quality, there are also protections for groundwater quality in the instruments of Bangladesh, Bhutan, India, Pakistan and Sri Lanka. The Indian Water Policy points out that groundwater quality requires special attention because of the difficulty of remediating groundwater once it is polluted. India's Model Bill for the Conservation, Protection and Regulation of Groundwater has the prevention of groundwater pollution and degradation as one of its objectives.

South Asian water resources instruments recognize the need to prevent contamination of surface waters from erosion, landslides and consequent sedimentation. Not surprisingly, Bhutan and Nepal have detailed prescriptions for controlling erosion and landslides in their instruments. In Bhutan, the National Environment Commission can declare threatened water sources as Water Management Areas where special controls can be applied, while the National Environment Strategy advocates maintenance of watersheds to reduce erosion and sediment loads. In Nepal, the Water-Induced Disasters Management Policy calls for catchment conservation works to prevent landslides and river corridor tree plantings and inclusion of environmental conservation as part of watershed conservation, while the National Water Plan proposes an environmental action plan to rehabilitate degraded watersheds to reduce erosion and the danger of landslides. The Indian National Water Policy recognizes that climate change is likely to make erosion worse because of increased rainfall intensity.

Landslides and sedimentation from catchment erosion are threats to hydropower systems, particularly in Nepal and Bhutan, because of abrasion in turbines. Nepal is undertaking a project to develop methods for protecting hydropower plants from incrased sedimentation risk arising from climate change.

Managing groundwater decline and deteriorating quality. *Groundwater levels and quality are already major issues in Bangladesh, India, Pakistan and Sri Lanka*. Both groundwater quantity and quality are likely to deteriorate further under climate change unless remedial actions are taken. Bangladesh, Bhutan, India, Pakistan, and Sri Lanka all have special provisions in their water policies to protect groundwater quality, while India has developed a draft model bill for groundwater.

Climate change will affect both the supply and the demand for groundwater. In addition to affecting the supply of groundwater in direct and indirect ways, climate change is also likely to affect the demand for groundwater for irrigation because of increased temperatures and evapo-transpiration. However, the actual impacts on groundwater are complex and have received little attention in the scientific literature or in policy compared to surface water. Attempts to raise the profile of groundwater management (e.g. India's draft Groundwater Bill) have had little impact in practice. Given that the region has come to depend heavily on groundwater irrigation, greater analysis and sound policy on groundwater are critical for South Asia's agricultural future.

Box 9.2 - Adaptation Options for Groundwater

Clifton et al (2010) provide a useful categorization of climate change adaptation options based on five groundwater processes:

1. *Managing groundwater recharge*. This can be undertaken by managing vegetation cover in recharge zones, using managed aquifer recharge (MAR) methods, controlling different land uses in recharge areas, and regulating river flows over recharge beds.
2. *Managing groundwater storage*. This can be achieved by increasing storage capacity through hydro-fracturing, dissolution or pressurization, managing storage levels in anticipation of high recharge events, MAR, improving scientific knowledge and forecasting skills.
3. *Protecting groundwater quality*. This can be achieved by regulating surface water levels to avoid acidification from acid sulphate soils, drawing down saltwater aquifers in coastal areas to protect freshwater aquifers, using MAR to maintain coastal aquifers, managing groundwater use to avoid contamination of freshwater aquifers by contaminated aquifers, treatment of groundwater to obtain necessary water quality, land use planning to avoid agriculture, industries and other contaminating land uses, educating land users to avoid contamination of aquifers, and the development and enforcement of water quality standards.
4. *Managing demand for groundwater*. This can require the capping of artesian bores and reducing wastage, using pipes and sealed channels rather than open channels, improving seasonal forecasts for crop planting decisions, developing systems of water restrictions during times of shortage, using appropriate groundwater quality for different uses, using MAR to bank water during times of plenty, monitoring groundwater use, improving water use efficiency, selecting crops with low water demands, using land use planning to match demand with water availability, conjunctive management, establishing standards surrounding groundwater use, using economic tools such as pricing to control demand, measuring and reporting groundwater use, education and behaviour change amongst groundwater users, and community participation in groundwater planning.
5. *Managing groundwater discharge*. Limit forestry plantations in shallow aquifer zones, land use planning that restricts high water using species, market mechanisms to account for groundwater use by forestry and similar activities.

Source: Clifton et al 2010.

Managed groundwater offers vital adaptation opportunities. Box 9.2 summarizes the main adaptation opportunities offered by managed groundwater. Because groundwater is better buffered against increasing climate variability and is not subject to evaporative losses compared to surface water, it is likely to become a more significant source of water under climate change.

Artificial recharge will increasingly be an important part of managing groundwater. India, in its 2011 Model Bill for the Conservation, Protection and Regulation of Groundwater, encourages artificial recharge of aquifers as one method for combating the overuse of many groundwater areas. Protection Zones can be declared that allow managed aquifer recharge through rainwater harvesting and other methods.

Flood management. *Countries recognize the importance of non-structural responses to flood management*. There is a widespread recognition of the need to map flood-prone areas to limit settlements in exposed areas, and instituting flood forecasting and early warning to allow time for exposed populations to prepare for these events. Both flood mapping and forecasting as well as early warning systems should incorporate the expected effect of climate change on rainfall patterns and associated flow regimes (Box 9.3). These people-centered approaches are low-cost, effective, and relevant to local conditions in flood-prone areas.

Nepal and Bhutan, in particular, have taken a risk reduction approach for flood protection, requiring flood zoning, hazard mapping and early warning systems for GLOFs. Bhutan instituted a Disaster Risk Management Framework in 2006 and a Disaster Management Act in 2013, while both Bhutan and Nepal specifically want to institute village-level early warning systems for floods (including GLOFs) and landslides.

Box 9.3 - Improving Flood preparedness

While the mapping of flood-prone areas helps limit vulnerable settlements in exposed areas, forecasting floods improves the preparedness of exposed population. Mapping flood-prone areas requires the collection of data on climate, hydrology, topography, geology, land-cover, soil, and satellite images of vulnerable infrastructures. Hydrological models predict and forecast future flood extents and their magnitude and frequency. Early warning systems aim to provide time for the exposed population to take appropriate actions to minimize flood-induced damage and risk to life. Forecasting involves the conversion of data into forecasts (using hydrological models) that are transmitted to decision makers who then provide advance warnings for local authorities to take appropriate actions. Early warning systems generally operate at watershed scales while action units follow administrative boundaries. Improvement of forecast dissemination requires précis identification of the path of warning from forecast to persons responsible for actions. A way to reach this goal is to encourage sharing of information, especially in border areas where international cooperation is required to establish evacuation plans. People-centered approaches should be prioritized as they are low-cost, effective, and relevant to local conditions in flood-prone areas.

Source: Lacombe et al (2017)

9.2. Recommendations

- Develop water plans at catchment and aquifer levels to establish safe withdrawal limits and to describe rules for water sharing, maintaining environmental functions, protecting water quality, and managing extreme events. Where risk assessments indicate, the impacts of climate change should be included in these plans.

- Encourage greater implementation of conjunctive use where it is technically and economically sensible to help buffer against seasonal and inter-annual variability (to the extent possible).

- Improve regulatory systems so that reuse of wastewater and industrial effluents can be conducted safely and environmentally responsibly.

- Groundwater needs greater protection in policy, legislation and plans from over-abstraction and water quality degradation given its buffering qualities against the impacts of climate change.

- Managed aquifer recharge (MAR) using storm-water runoff should be encouraged where it is feasible to offset overuse of aquifers. Water quality standards need to be established and enforced to ensure that aquifers are not contaminated by MAR activities.

- Non-structural flood management, such as mapping and zoning flood plains, establishing flood forecasting and early warning systems can be used more widely in flood affected areas.

COMMUNICATIONS, EDUCATION AND PARTICIPATION

WATER MANAGEMENT, INCLUDING MANAGEMENT FOR CLIMATE CHANGE, REQUIRES ACTION AT ALL LEVELS FROM NATIONAL AND LOCAL GOVERNMENT DOWN TO COMMUNITY LEVEL. COMMUNICATIONS PROGRAMS ARE NEEDED TO BUILD AN UNDERSTANDING OF WATER MANAGEMENT ISSUES AND GOVERNMENT RESPONSES, AS WELL AS REFLECT LOCAL-LEVEL CONCERNS AND OPPORTUNITIES AT HIGHER LEVELS OF DECISION MAKING.

Capacity building and education will be needed to ensure that institutions possess sufficient skills to understand water management issues, including those that will potentially arise from climate change, and the range of responses available to manage these issues. This involves not only technical skills but skills in administration of cross-sectoral collaboration and work, obtaining and managing finances, and working with State/Provincial institutions and local bodies.

Participation at local level helps broaden water management from a technical and professional activity to one that includes all local water users. Community-level adaptation is important because local impacts are finely-grained and it is important to take advantage of the full range of local experiences in dealing with variability in water availability, as well as to build ownership among water users.

This chapter summarizes the findings under: (a) targeted and broad communications campaigns; (b) strengthening capacity in institutions such as irrigation organizations and policy departments, and (c) participation by local and community groups; and (d) recommendations.

10.1. Main Findings

Communications. There is widespread agreement in both water resources and climate change instruments about the importance of improving and elevating the understanding of climate change and its implications for water resources amongst sector groups and decision makers as well as the general public. In spite of the importance of building public support for water reforms, it was common to find only passing attention paid to this requirement in the instruments analyzed. However, Bangladesh recognizes in their National Water Management Plan 2001 that there is a need to improve water knowledge, and to raise public awareness of sustainability, while the Nepal Water Plan 2005 recognizes the need to raise awareness of the advantages of IWRM among all stakeholders, general public, legislators, political activists, civil societies and professional societies. The LAPA process in Nepal relies on NGOs to coordinate stakeholders, support field research and educate community members about adaptation to climate change impacts. However, information is difficult to obtain about the effectiveness of these local education efforts. Pakistan has perhaps the most comprehensive requirement for public and interest group education across its water and climate change instruments.

Strengthening institutional capacity. *While there are very large and diverse risks from water-related impacts of climate change across South Asia, there is little appreciation of the scale of the potential impacts amongst decision makers or the options for adaptation*. For example, in Sri Lanka, Bhutan, Pakistan and Afghanistan, the absence of a strong climate adaptation program is not only due to the lack of funding, but also related to very low institutional capacity to implement such programs across scales, with most government staff involved having little knowledge on climate adaptation issues and approaches. There is little understanding that implementing IWRM principles of good water management constitutes a no regrets action that goes a long way towards building adaptability to climate change. More generally, there is a need to provide information and training on climate change and its potential impacts on water resources managers and users, so that they can make informed decisions about adaptation activities.

Lack of technical and administrative staff capacity is a significant issue for climate change adaptation. In Sri Lanka, Bhutan, Pakistan and Afghanistan, the leading government agencies on climate adaptation have very limited capacity to monitor program implementation on the ground. In India, state governments directed the formulation of their State Action Plans on Climate Change (SAPCC) almost entirely towards the National Action Plan on Climate Change (NAPCC). This means that the formulation and implementation of climate adaptation programs continues to be directed by centralized funding mechanisms (both from donors and the government's budget). There is a need to increase the overall capacity and performance of water resources and climate change agencies, and to undertake budgetary reform to ensure that funding for climate adaptation can be channeled most effectively.

Community participation. All countries support community-level participation in adaptation activities in their water resources and climate instruments. However, across the seven countries, local communities continue to be positioned as recipients of (nationally-defined) adaptation programs, rather than as actors capable of shaping their own adaption measures. Nevertheless, local communities continue to cope with climate variability and show capacity to deal with the additional impacts from climate change. Engagement of local stakeholders and potential users/beneficiaries is important from planning and design through to implementation and monitoring of impacts.

The irrigation sector, the largest water using sector, has the greatest experience with devolving responsibility to local water user associations. While there is little evidence that self-management of irrigation districts improves agricultural productivity (Samad and Vermillion 1999), participatory management may help improve adaptive behaviors in the face of a changing climate. Currently, ongoing policy discussions on climate adaptation in general, and IWRM in particular, have failed to include local communities and marginalized groups into the shaping of adaptation strategies. This highlights the need to strengthen the role of local communities, NGOs and research organizations as an integral part of the institutional landscape in climate adaptation. Across the seven countries, Water Users Associations (WUAs) can be used as a starting point for better understanding farmers' adaptation strategies. For instance, the process by which WUAs and farmers decide to change the overall water delivery schedule to deal with climate variability can be incorporated into the design and development of local climate adaptation programs. In addition, the establishment of BCAS, CEGIS and BIDS in Bangladesh could potentially contribute to the provision of scientific information on climate adaptation. At present, WUAs and FOs are rarely consulted, whilst formulating adaptation strategies.

10.2. Recommendations

- Programs and special briefings are needed to educate sectoral groups as well as community leaders and the general public about the potential impacts of climate change on water resources and possible adaptation actions that can reduce these impacts. These programs could start with irrigation WUAs where they are already well organized.
- Adequate staffing and training following a skills gap assessment can improve performance of national water resources and climate change adaptation agencies towards more effective climate adaptation.
- Build an understanding in national water institutions about the advantages of devolving responsibility (and providing resources) for adaptation actions at local level. LAPAs in Nepal, while needing further strengthening, provide a model for community level adaptive action.

FINANCING CLIMATE CHANGE ADAPTATION

GLOBALLY, ADAPTATION IS UNDERFUNDED WHEN COMPARED TO MITIGATION, WITH ONLY 24% OF THE CLIMATE CHANGE FUNDING MONITORED BY CLIMATE FUNDS UPDATE BEING ALLOCATED FOR ADAPTATION (TRUJILLO ET AL. 2015). FUNDING FOR ADAPTATION IN THE WATER RESOURCES SECTOR COMES FROM BOTH PROGRAMS TO IMPROVE WATER PLANNING AND MANAGEMENT, DELIVERED THROUGH THE WATER SECTOR, AND THROUGH PROGRAMS INTENDED SPECIFICALLY FOR CLIMATE CHANGE ADAPTATION.

Findings about financing are organized under the headings: (a) assessing the cost of climate change impacts; (b) financing adaptation, and (c) strengthening institutions for managing adaptation finances. This study did not assess the magnitude of financing required to implement planned adaptation activities, partly because it was a desk study limited to existing information and partly because of the complexities of estimating costs when adaptation activities can occur through multiple sectoral budgets.

11.1. Main Findings

Assessing the cost of climate change impacts. *Existing adaptation cost assessments are patchy with fragmented sector-by-sector coverage*. This impedes the proper assessment of a country's risks and financing needs and priorities.

Current cost estimates expressed as a percentage of GDP mask important geographic and demographic differences that may mean vulnerable groups as well as key sectors are overlooked or under represented.

The majority of funds for adaptation cannot be clearly identified, making any assessment of spending on climate adaptation, including in the water sector, only approximate. There is, however, some progress in attempting to better identify climate change financing in different countries. The clearest examples are the two major evaluations of structural weaknesses in climate change finance spending in Bangladesh, commissioned by the Ministry of Finance, which provides detailed means of addressing key weaknesses. Other examples include the Climate Expenditure Report commissioned in Pakistan in 2015 to identify adaptation and mitigation spending as well as the relevant government ministries responsible for financing, though there are, as yet, few institutional adjustments to achieve better finance-planning linkage. In Bhutan, another example is the Mainstreaming Reference Group's aim to more systematically incorporate climate change considerations into national- and local-level planning.

Financing adaptation. *A significant financing effort will be required if adaptation plans and priorities are to be fully and effectively implemented*. All the countries, with the exception of Bangladesh and India, exhibit a high dependency on external funding (Sharma 2011). While this is not surprising given the much smaller economies of many of these countries, it implies that adaptation costs will increase given that external funding has shifted from grants to loans especially for Afghanistan and Nepal, where grants currently make up a significant portion of external climate adaptation financing. Even in Bangladesh and India, where adaptation financing has been strongly driven by government spending, significant reductions in government allocations for adaptation in current budgets suggest this trend may be changing. These countries are likely to need to obtain bilateral, multilateral and private funding, and to compete for scarce global funding on climate adaptation.

The role of the private sector, in providing credit and insurance facilities, could be increased. Indexbased insurance schemes are an innovative approach to developing effective safety nets for low-income, flood-prone communities. Whereas traditionally, flood-risk management has focused on engineered responses, such as dams and flood walls, with compensation often an ad-hoc post event response, the insurance schemes secure funds for compensation before a flood occurs, and in a systematic manner. These schemes can accommodate poorer households farming even less than 1 ha of land, whereas traditional insurance works best for smaller numbers of larger farm units and high value crops.

The mechanisms for financing climate change adaptation are scattered, resulting not only in inaccurate estimates of adaptation costs related to specific climate risks, but also in uncoordinated funds channeled for climate adaptation across the different sectors and levels.

Although water-specific financing data was hard to locate, the little information available suggests that the water sector is generally not a priority for climate change institutions. In a majority of South Asian countries agriculture is generally the most funded, with water failing to feature in the top-funded sectors even though there is a strong overlap with agricultural water management and development for adaptation. At the same time, better water resources management contributes to adaptation and so expenditures that are not specifically tagged as being for adaptation are likely to be net contributors to adaptation outcomes. Thus, Bangladesh has established an estimated 165,000 deep tube wells since 2000 (Winston et al. 2013) to increase food security and meet the growing demand for supplementary irrigation attributed to climate change. While this investment is justified under supporting food security, at the same time it also contributes to water resources adaptation.

Strengthening institutions. The smaller economies struggle to navigate a complex and competitive external funding landscape with under-developed in-country capacity. They do not have the skills and expertise to make submissions for financing projects and so are disadvantaged in tackling adaptation activities.

Mainstreaming adaptation into sectoral programs is widely recognized in all South Asian countries as being central to uptake. While mainstreaming adaptation activities is commendable, it may simply shift the responsibility for climate change adaptation onto sector agencies that have little knowledge about climate adaptation issues and approaches. Mainstreaming needs to be accompanied by a clear plan towards institutional strengthening for the specific sectors playing a crucial role in climate adaptation (e.g., agriculture, water, energy).

11.2. Recommendations

- Climate change cost estimates should be disaggregated across sectors. Although some countries have started taking initiatives in this regard (e.g. Bhutan with SAPAs) further work needs to be done. Identification of inter-sectoral linkages can indicate where multiple costs can be avoided or minimized through the same investment.
- Cost estimates should reflect the different vulnerabilities of specific population groups, key sectors and geographical areas in order to provide a more spatially and socially nuanced set of adaptation responses.
- A tracking mechanism such as a climate marker being considered by the Government of Bangladesh could support the development of a 'value for money' accountability mechanism. This would help track the total amount of resources spent on climate-related expenditure against the impact generated.
- South Asian countries will need to tap a wider range of adaptation financing sources, including the private sector for credit and insurance facilities.
- Staff in both climate change agencies and sectoral agencies that are being asked to take responsibility for adaptation activities need training in both technical and administrative topics.

RECOMMENDATIONS FOR BUILDING ADAPTATION CAPACITY FOR THE WATER SECTOR

THIS CHAPTER PRESENTS SIX BROAD SETS OF RECOMMENDATIONS FOR IMPROVING ADAPTIVE CAPACITY IN THE WATER SECTOR (TABLE 5.1). THESE RECOMMENDATIONS ARE STRUCTURED AROUND THE 6 ELEMENTS OF THE ADAPTATION FRAMEWORK DISCUSSED IN PART 2: (I) WATER RESOURCES KNOWLEDGE, (II) WATER RESOURCES GOVERNANCE, (III) WATER RESOURCES INFRASTRUCTURE, (IV) WATER RESOURCES PLANNING AND MANAGEMENT, (V) COMMUNICATION, EDUCATION AND PARTICIPATION., AND (VI) ADAPTATION FINANCING.

While these recommendations represent an overview of activities that would help build resilience to climate change in the water sector, not all activities are relevant to each country. Each country faces a different risk profile (Table 4.1) and each has developed priorities for its climate related activities. Thus, the recommendation for a transboundary flood early warning system would not be relevant to Sri Lanka while the proposed seawater intrusion initiative would not be relevant to Bhutan and Nepal.

12.1. Water Resources Knowledge

1. Build capacity of South Asian countries to use near real-time remotely-sensed water-related indices of floods and droughts.

2. A jointly developed flood early-warning system pilot on one of the region's major shared transboundary rivers could examine both the technology required and the means of disseminating possible flood conditions to potentially-affected communities. This would integrate existing national systems and support development of a region-wide network.

3. Achieving improved water-use efficiencies will require better collation and dissemination of knowledge from research institutions through agricultural extension services to farmers, and the development of capacities to implement these efficiency measures. Identifying good practice examples and using as models for disseminating more widely scientific understanding to irrigators is suggested.

4. Several countries proposed sharing water data across transboundary river basins and aquifers. Identify and develop opportunities for shared early warning systems for flood (including GLOF) and landslide forecasting through design of an online method for collating and reconciling data collected through different protocols across countries. Identify administrative issues that require further study for conjunctive use and management of surface and groundwater.

5. For community-level adaptation to become a successful part of the response to climate change, community-level monitoring and data sharing needs to be organized and funded so that it can also contribute to higher levels of management. Nepal can be used as a case study to develop protocols for community led data collection, training and capacity development.

12.2. Water Resources Policies and Institutions

1. Institutional impediments to effective coordination between highly water-dependent sectors and between water agencies and institutions responsible for climate change in each country needs to be reviewed, leading to recommendations for reforms and incentives for improving coordination between the water agencies, environmental agencies, and/or independent coordinating committees.

2. Develop an initiative that will support effective mainstreaming of climate change adaptation across water-dependent sectors. This could include improving understanding by water and climate managers of the role and benefits of taking an IWRM approach (even if implementation is difficult) as an adaptation response; educating officials in water and climate related Ministries on improving coordination with agencies responsible for climate change; and properly defining adaptation activities and tagging them within Ministry budgets without incurring excessive overheads.

3. In federal systems (India and Pakistan) a significant proportion of the adaptation budget is directed through state and provincial agencies. A review of these arrangements will help to understand the impediments to coordination between state and provincial agencies and national agencies and, also, with local adaptation activities and identify actions for improving fund flow and coordination.

4. Develop a groundwater–climate change initiative that would support elevating attention to the role of groundwater in adapting to climate change in policy, practice and in financing, and that would promote best practice in controlling groundwater use in different hydro-geological and socioeconomic settings.

5. Review how center-local linkages for implementing adaptation programs could be strengthened. While ministries in charge of local government are included in central decision making bodies, what is lacking is an explicit mechanism to reflect adaptation needs from the ground-level upwards. This would enable planning, allocation and tracking of climate funding to support priority needs more effectively and efficiently, and to ensure accountability in the conversion of funds into results.

12.3 . Water Resources Infrastructure

1. Develop a climate adaptation/infrastructure management and development initiative. Major infrastructure will only provide adaptation to climate change if it is planned, designed and operated to take account of climate change and if it is cost-effective compared to other options such as improving water use efficiencies in irrigation, power generation and other industries. This initiative would not only focus on major structures for storage but also rehabilitation and restoration of local structures, traditional storage mechanisms (including tanks) and groundwater storage (including MAR and sand dams). A review of the design standards and operating rules to ensure that they take account of climate change should also be included. The design of new storage infrastructure will require greater attention to issues of soil erosion and siltation because of the frequency and intensity of major storms anticipated under climate change scenarios. The initiative should also include a review of flood embankments, dam design standards and dam safety measures and monitoring requirements.

12.4. Water Resources Planning and Management

1. Coordinating across national boundaries to develop water-sharing plans that incorporate the effects of climate change will become more important as rainfall and river flows become less reliable and more uncertain. A preliminary review of existing water sharing treaties would help build confidence and tackle technical issues to support transboundary water planning.

2. Introducing basin-level planning and management is a major challenge. An initiative on regional basin

planning for climate change could draw lessons from experience in incorporating climate change into basin-level water resources plans elsewhere (e.g. Rufiji Basin Tanzania, Box 9.1) and apply them through pilot studies in South Asian countries that are actively attempting to introduce basin planning (including Nepal, Pakistan and India).

3. A saltwater intrusion initiative could be developed for protecting coastal water supply. Saltwater intrusion into coastal aquifers will affect rural and urban communities along the over10,000 km long Bangladesh, India, Pakistan and Sri Lanka coastline. However, it receives relatively little attention in climate changes strategies. A review of pilot urban and rural water supply systems from within and beyond South Asia can help define the specific steps to be taken to properly monitor saltwater intrusion, develop cost-effective protective measures and improve overall urban and rural water supply planning, management and operations.

4. An integrated pilot study of drought resilience could be undertaken using a combination of actions – demand management, regulation, water efficiency improvement, MAR, and monitoring – with the goal of scaling up lessons more widely across South Asia (Box 12.1). The study could draw on the experience of the Niger Basin Climate Resilience Investment Plan which uses existing regional institutions to develop a prioritized investment plan with which to improve resilience to climate shocks. Such an approach would not only improve adaptive responses but would also serve to support efforts to improve water management through IWRM. The Bank's work in Brazil has highlighted the importance of surrounding an early warning system with vulnerability impact assessments, drought contingency planning and the strengthening of institutional capacity to take advantage of early warning data.

5. Urban areas are likely to be severely impacted by the effects of climate change. Current activities to improve urban water management in South Asian countries could incorporate the effects of climate change. Possible responses include urban planning, protection of urban water utilities, storm water management, sewage management and urban water supply.

Box 12.1 - Improving resilience to droughts

Solutions include reduced water use, better understanding of hydro-meteorological processes, more powerful models to predict droughts and sound selection of sites and structures to store water. Improved water use efficiency and productivity include stemming water losses through leakage in irrigation canals, reducing evaporation from soils and reservoirs and by encouraging deep percolation from the root zone. To attain these objectives, it is necessary to better disseminate knowledge from research institutions through agricultural extension services to farmers, and to implement agricultural policies. At the plot level, drip-irrigation, soil mulching and soil amendments are options to reduce water losses through evaporation and percolation. Water use efficiency should also be considered at the scale of transboundary river basins where water should be equitably shared between countries (i.e., between India and Pakistan in the Indus Basin; and between India and Bangladesh in the GBM). Multi-year reservoir storage capacity is required especially where groundwater levels are declining and aquifers worsening in quality (e.g. in the Lower Indus Basin). More storage not only requires the building of new storage but also reductions in the sediment loads of rivers through improved management of upstream landscapes. In the HKH, most of the hydropower barrages are run-of-the-river with limited storage capacity. With the reduction or total disappearance of glaciers and snow that provide storage to sustain dry-season flows during the summer, more storage capacity will be required to buffer against greater seasonal variations in river flows.

Source: Lacombe et al (2017)

12.5. Communication, Education and Participation

1. A review of Bangladesh and Nepal case studies to learn lessons about of successful community engagement in adaptation actions would be timely. Nepal now has 200 LAPAs in progress, while Bangladesh has a history of community-level adaptation to extreme climate events. The review could assess how well they work, what aspects have been successful, what lessons have been learnt, how to organize local adaptation initiatives into nationally-coherent responses while still retaining local control, how to finance and develop skills at a local level, and how to disseminate lessons from each local initiative.

2. A water, climate, poverty and gender initiative could help design water-related adaptation measures to better benefit the poor and disadvantaged communities and to integrate gender-responsiveness into current and future adaptation approaches.

3. A regional educational initiative on climate adaptation and water management could be undertaken to develop the best way to raise general understanding of climate change impacts. Sri Lanka says that generic media campaigns are not effective (because of deep public mistrust of donor-driven processes) and that targeted approaches through selected on-ground implementation agencies and small groups are more effective. The initiative would develop criteria for targeted approaches in different countries.

4. A climate change adaptation and groundwater initiative would support the increasingly important role of groundwater in climate change adaptation. The initiative would also improve support groundwater users in understanding the nature of the common pool resource, and develop education and technical knowledge to avoid unsustainable abstraction in groundwater-dependent communities.

5. An initiative could be undertaken to make community-level adaptation a major component of adaptation activities. It would review how existing community and local institutions, including local government, can be utilized more effectively. It would also review the guidelines, regulations, education and technical support (including access to knowledge and information) needed to help them become involved in adaptation planning and decision making. It would support better linking strategies of government agencies in climate adaptation with local community strategies to cope with climate change. It would consider climate-smart villages, in which researchers document local villagers' adaptation strategies in agricultural development and water use, and would support development and sharing of 'water-smart agriculture' ideas across the region.

6. Promote an education initiative for improving the understanding of climate change impacts in the water sector by decision makers. An analysis of potential bottlenecks in the uptake of scientific information and actions to reduce any bottlenecks would be timely. Training in the use of techniques such as Decision Tree analysis and integrated river basin planning would help decision makers appreciate the sensitivity of proposed projects to climate impacts and the role of river basin plans to inform future development, operational and management decisions, respectively. This would enable better use of science to influence adaptation decision making.

12.6. Adaptation Financing

1. Consistent with the climate and water policies, investing in IWRM needs to be central to the national adaptation strategy in view of water's multi-sectoral relevance, with explicit financing.

2. Sections 12.1 - 12.5 above define the recommended areas to be funded for building the water sector adaptive capacity. These need to be tailored to the priorities in each nation.

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APPENDIX 1: WATER AND CLIMATE CHANGE INSTRUMENTS REVIEWED

THE INSTRUMENTS IN BOLD WERE INCLUDED IN THE POLICY REVIEW DESCRIBED IN PAPER 2 (DAVIS AND HIRJI 2017).

Water Sector Instruments

	Policy	Legislation	Strategy/Plan	Other
Afghanistan	• Strategic Policy Framework for Water Sector 2005 • Agriculture and Natural Resources Policy and Strategy 2005 • Groundwater Development Policy	• Water Law 2009 • Environment law 2007	• Water Sector Strategy 2008	• National Development Framework 2002
Bangladesh	• National Water Policy 1999 • National Agriculture Policy 1999 • National Agriculture Policy 2010 (draft) • Coastal Zone Policy 2005 • National Policy for Safe Water Supply and Sanitation 1998 • National Agricultural Extension Policy (draft) 2012	• Water Act 2013 • Environment Conservation Act 1995 • Environment Conservation Amendment Act 2010 • Water Development Board Act 2000 • Disaster Management Act 2012	• National Water Management Plan 2001 • National Plan for Disaster Management 2010-2015	• Guidelines for Participatory Water Management 2001 • Water Rules (draft) 2015
Bhutan	• National Irrigation Policy 2011 • Bhutan Water Policy 2007	• Water Act 2011 • National Environment Protection Act 2007 • Disaster Management Act 2013	• National Integrated Water Resources Management Plan (draft) 2016 • National Environment Strategy (The Middle Path) 1998 • National Disaster Risk Management Framework 2006 • Power System Master Plan 2003-2022 2004	• Water Regulation of Bhutan 2014

Water Sector Instruments (continuation)

	Policy	Legislation	Strategy/Plan	Other
India	• National Water Policy 2012 • National Urban Sanitation Policy 2008 • New Agriculture Policy 2000	• Water (Prevention and Control of Pollution) Cess Amendment Act 2003 • Water Prevention and Control of Pollution Act 1974 • National Water Framework Law (draft) 2013 • Model Bill for the Conservation, Protection and Regulation of Groundwater (Draft) 2011 • Interstate Rivers Dispute Act 1956 • River Boards Act 1956	• Ministry of Water Resources Strategic Plan 2011	
Nepal	• Irrigation Policy 2013 • National Water Supply and Sanitation Sector Policy 2014 (draft) • National Rural Water Supply and Sanitation Policy 2004 • National Urban Water Supply and Sanitation Sector Policy 2009 • Water-Induced Disaster Management Policy 2015 • Hydropower Development Policy 2001	• Water Resources Act 1992 • Irrigation Act 2016 (In Parliament) • Irrigation Rules1999 • Electricity Act 1992 • Electricity Rules 1993 • Drinking Water Rules 1998	• Water Resources Strategy 2002 • National Water Plan 2005 • Renewable Energy Investment Program Plan 2011	
Pakistan	• National Water Policy (draft) 2006 • National Water Policy (draft) 2015 • National Sanitation Policy 2015 • National Drinking Water Policy 2009 • National Environment Policy 2005 • National Wetlands Policy 2009 (Draft)	• Water and Power Development Authority Act 1958	• Water Sector Strategy 2002	• Pakistan 2025 One Nation-One Vision 2014

Water Sector Instruments (continuation)

	Policy	Legislation	Strategy/Plan	Other
Sri Lanka	• National Drinking Water Policy • National Rural Water Supply and Sanitation Policy 2001 • National Disaster Management Policy 2013 • National Environmental Policy and Strategies 2003 • National Wetland Policy and Strategy 2006 • National Policy on Protection and Conservation of Water Sources, Catchments and Reservations in Sri Lanka 2014 (draft)	• Water Resources Board Act 1999 • Irrigation Amendment Act 1994 • Disaster Management Act 2005 • Agrarian Development Act 2000 • Mahaweli Authority Act 1979 • National Environmental Amendment Act 1988 • Irrigation Amendment Act 1994		

Climate Change Instruments

	Policy	Legislation	Strategy/Plan	Other
Afghanistan			• National Adaptation Program of Action 2009 • National Climate Change Strategy and Action Plan 2015 • National Adaptation Plan 2015	• INDC 2015 • First National Communication UNFCCC 2013
Bangladesh		• Climate Change Trust Fund Act 2010	• National Adaptation Program of Action 2009 • Climate Change Strategy and Action Plan 2009	• Second National Communication UNFCCC 2012 • INDC 2015
Bhutan			• National Adaptation Program of Action 2006 • Renewable Natural Resources Sector Adaptation Plan of Action 2013	• Second National Communication UNFCCC 2011 • INDC 2015
India			• National Action Plan on Climate Change 2008 • National Water Mission (under Action Plan on Climate Change) 2008	• Second National Communication UNFCCC 2012 • INDC 2015 • First Biennial Update Report 2016
Nepal	• Climate Change Policy 2011		• National Adaptation Program of Action 2010	• Second National Communication UNFCCC 2014 • INDC 2016
Pakistan	• National Climate Change Policy 2012		• National Framework for Implementing Climate Change Policy 2013	• First National Communication UNFCCC 2003 • INDC 2015
Sri Lanka	• National Climate Change Policy 2012		• National Climate Change Adaptation Strategy 2011-2016 (2010) • Information, Education and Communications Strategy for Climate Change Adaptation 2010 • National Adaptation Plan for Climate Change Impacts 2015	• Second National Communication UNFCCC 2011 • Water Sector Vulnerability Profile 2010 • Technology Needs Assessment and Action Plans 2011 • INDC 2015