United Nations Educational, Scientific and Cultural Organization

World Water Assessment Programme

UN WATER

The Implications of Climate Change on Water

Highlights on climate change from the UN World Water Development Report 3: *Water in a Changing World*

Evidence of the impact of climate change on the earth's hydrological cycle is mounting in many regions of the world, in the form of increased frequency of floods, droughts and other water hazards and changes in long-term trends in precipitation. In many countries, water "stress" in its various forms is likely to soon become the normal state of affairs.

Although much of the discussion at present is about ways to mitigate the pressures causing climate change, water is being heavily affected by climatic changes already under way and locked into the future. What matters for water is adaptation measures to enable it to cope with these changes. This paper reviews what this implies for different water services, water resource management, water-related hazards, data collection and monitoring, education, awareness, capacity building, and other necessary responses. In an uncertain future, the keynote for adaptation must above all be resilience – managing risks and building the capacity to deal with unpredictable events.

The World Water Assessment Programme launched the third UN World Water Development Report, *Water in a Changing World*, in March 2009 at the 5th World Water Forum in Istanbul. The present document summarizes some of the key messages from that report, highlighting the potential impacts of a changing climate on the availability of water and on the control of water extremes.

Water is the lifeblood of the planet and the state of the resource affects all natural, social and economic systems.

Water is the fundamental link between the climate system, human society and the environment.

Key messages

- There is mounting evidence in many regions of the impact of climate change on the earth's hydrological cycle
- Climate change is a basic driver of change in water resource availability and use alongside demographic, economic, social and technological forces, with which it interacts in a dynamic fashion.
- Lateral thinking 'out of the box' is essential both from those within the water sector and all others whose decisions have a major impact on water.
- Information about the status of availability and use of water and the potential impact of climate change is too poor to support informed policy decisions. There is an urgent need to gather, analyse and model data at all relevant levels – globally, regionally and locally – and to reverse the decline in observational systems.
- Alongside mitigation, Governments must adapt to climate change, and give priority to water resources management as a key aspect of adaptation to changes already in train.
- Due to future uncertainties, the keynote for adaptation must be resilience – managing risks and building the capacity to deal with unpredictable events. No-regret and low-regret measures should be prioritised.

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Introduction

There is growing evidence that human-induced climate change is happening in many regions. Our understanding of how climate change will influence global and regional temperatures is improving, though its impact on the water cycle, not least precipitation, remains uncertain. Climate change is likely to be an increasingly powerful driver of change for water, acting in combination with other drivers that are already having a serious impact on its quality and availability. This will happen regardless of the mitigation measures employed over the coming years.

Society needs to adapt to the changes that are expected, and to become more resilient in coping with outcomes that are still uncertain. Adaptation can have direct benefits, as well as making society better prepared for greater extremes of shortages and excesses. Investment in infrastructure is one vital measure, but there is also a need for better information for planning and decision making. Reforms to the governance and financing of water resources will be essential. Changes will also be needed in the way water issues are tackled by policy makers in other key sectors such as agriculture, energy and public health.

Our sustainable management of water will be the acid test of our success or failure in adapting to climate change. If we succeed, we will also reap the many other rewards that good water management brings.

The relationships between climate change and water resources

Climate change is one of the basic drivers of change for water, alongside demographic, economic, social and technological forces. Policies, laws and finance also condition the impact of these basic drivers. These factors are interrelated and the outcome is evolving in a dynamic fashion. Climate change can affect water resources directly, but also indirectly through its impact on the other drivers.

From the supply side, climate change can directly affect the water cycle and, through it, the quantity and quality of water resources available to meet human and environmental demands.

It can result in higher intensity precipitation causing floods and their consequent loss of lives and damage to infrastructure. It can lower minimum flows in rivers, affecting water availability and quality for flora and fauna, drinking water intake, energy production (hydropower), thermal plant cooling and navigation. Rising sea levels will have a serious effect on coastal aquifers, which are a major source of water supply to cities that are close to the coast and for regional water supply systems. Aquifers are also very important storages that help to buffer wet and dry spells.

> The Himalayan Rivers and the basins fed by them are particularly vulnerable to the impacts of climate change. Half a billion people live in these river basins, supporting a further half billion with food and other needs in their hinterlands. The rivers in the southern Himalayas support wheat cultivation on a huge scale during the *rabi* season (November to March/April). A diminution of dry season flows from snowmelt due to the receding snow line from climate change would have a seriously adverse impact on the lives of over a billion people in Asia, aggravating the tensions over sharing dry season flows.
>
> – The International Commission on Irrigation and Drainage (ICID)

Water is part of the vital nexus of climate change, energy, food, environmental degradation and economic development. Climate change can also directly affect demand for water, for instance though changes in demands from industrial cooling, household use, or irrigation.

Processes such as these give rise to feedbacks: the way we manage water and adapt to climate change interrelates with other drivers of change, which in turn feed back onto water. Solutions for these major challenges (e.g. in the realms of bioenergy or food security), if conceived in isolation without considering their impact on water, can aggravate other issues and becoming self-defeating.

Managing water has always entailed the management of naturally occurring variability. Climate change threatens to make this variability greater, shifting and intensifying the extremes, and introduces greater uncertainty in the quantity and quality of supply over the long term. Climate change may alter the timing, magnitude and duration of precipitation events, which could pose problems for the sustainability of water supplies and the continuity of treatment.

Scenarios allow for the interactions between individual drivers, and thereby offer a more holistic picture. Since each external water driver is dynamic and evolving it is difficult to visualize the future by dealing with each driver independently. There is an important role for scenario analysis in considering water futures.

'Scenarios are not forecasts. Because the real world is so complex, forecasts are often wrong – especially those involving a time horizon of 20 years or more. Scenarios provide a means of looking beyond the water sector in search of an adequate causal understanding of different water issues.'

(WWDR-3, p. 74). See also, Joseph Alcamo and Gilberto Gallopin, 'Building a 2nd generation of world water scenarios', WWAP, 2009.

The evidence

Global warming is likely to result in an intensification, acceleration or enhancement of the global hydrological cycle. There is already evidence that this is happening in some regions through increased frequency of floods and droughts and changes in long-term precipitation trends.

The United Nations World Water Development Report 3: *Water in a Changing World* (WWDR-3) contains a detailed review of the evidence for changes in the land surface water cycle. The global picture is complicated and uneven, with substantial differences between regions and over time (WWDR-3, Chapter 11).

'Most climate scientists agree that global warming will result in an intensification, acceleration or enhancement of the global hydrologic cycle, and there is some observational evidence that this is happening already' (WWDR-3, p. 164)

Climate change is being superimposed on an already complex hydrologic landscape. Its signal is difficult to isolate, though its influence is suffused throughout the water supply, demand and buffering system.

Water is the lifeblood of the planet and the state of the resource affects all natural, social and economic systems.

Different regions and localities are affected to different degrees, and in different ways. Climate-related water hazards have become more frequent and more extreme in many regions, most clearly in the North and South Poles, Pacific islands, and coastal low-lying areas. Population pressure is resulting in more people occupying areas at risk of flood, cyclone or drought. The impact of past major flooding, which has resulted in many deaths and has cost billions of dollars in damages, is an indication of what could lie in store from future climatic variability. At the opposite extreme, the more intense droughts seen in the past decade, affecting an increasing number of people, have been linked to trends in higher temperatures and decreased precipitation, as well as human agency such as mismanagement of resources.

These impacts on water *quantity* are accompanied by trends on water *quality*: increases in the flow and inputs of chemical and biological waste from human activity have altered the water quality and ecological functioning of many of the world's rivers, making them more sensitive to climate change impacts. These trends imply that future water planning cannot safely assume 'business as usual' or *statistical stationarity*.

'Data limitations in length of record, continuity and spatial coverage contribute to the uncertainty, while natural climate variability and multiyear variability associated with large-scale atmospheric circulation patterns influence the interpretation of many trends in ways that are not yet fully understood. Improving data collection and reducing the uncertainties associated with modeling studies are important for future impact assessments.' (WWDR-3, p. 164)

Greater climatic variability and short term uncertainty is likely to be superimposed on any long term trend.

Society's response

Water is the concern of everyone, and information about it should be widely available.

In an era of climate change, water management will need to be based on the broad participation of the public in the development of policies and in adapting their own individual behaviour. Better information, communication and public awareness – when reinforced by the right incentives and sanctions – are required to produce changes in the behaviour of water users to complement other measures.

The perils and challenges facing water will call for thinking beyond the traditional sector compartments. Water professionals need to understand that the keys to many of the solutions to their problems are held by decision makers across the spectrum of other parts of society and the economy. Likewise, recognizing water as 'the lifeblood' implies that all major decisions, wherever they are taken, should factor in their potential impact on water.

An understanding of water issues and of the support needed for investments, institutions, incentives and capacity inside the 'water sector' requires partnerships between those responsible for the economy-wide benefits of water and those responsible for managing water. Leaders in the water sector must thus ensure that these leaders outside the 'water box' know the constraints and options for water resources and help them implement their decisions efficiently and effectively' (WWDR-3, p. 4)

'Getting out of the box'

WWDR-3 makes a strong plea for decision-makers both within and outside the water 'sector' to transcend their normal working boundaries in order to consider the wider ramifications of water and the forces affecting it.

Public policy in response to climate change has so far been dominated by the need for mitigation. WWDR-3 argues for a more judicious balance between mitigation and adaptation. Since climate change has some of its more serious effects on water, in its various aspects, adaptation in this sphere is vital. Water resources issues should therefore be prominent in climate change negotiations and governments should commit themselves to the necessary degree of support, including finance, for adaptation measures.

Adapting water resource management to climate change

Mitigation measures, including the reduction of greenhouse gas emissions, transferring clean technologies and protecting forests, are crucial to dealing with climate change. Though these measures will slow climate change, they will not halt or reverse it within the foreseeable future. In the meantime society needs a strategy to adapt to expected changes. Adaptation, as embodied in the Nairobi Work Programme of the UNFCCC, relies on a better understanding of the impacts of climate change and making informed decisions on measures to cope with it. Adaptation aims to increase the resilience and robustness of existing water management systems and accommodate uncertain future climatic scenarios.[1]

Responding to the challenges of climate change impacts on water resources requires regional, national and local level adaptation strategies. The National Adaptation Programmes of Action under the UNFCCC are still in their early phases and much remains to be done to coordinate climate- and water-related policies and actions. A growing number of countries and cities are including water-related adaptation into their planning, policy and institutional response to such predicted impacts as rising sea-levels, more frequent droughts and increased precipitation. Adaptation programs include both structural and non-structural measures, infrastructure and 'soft' programs: positive inducements and negative sanctions. Efforts must be made to survey on-going adaptation measures, particularly those being introduced locally that draw on traditional and indigenous knowledge. Such practices could enrich scientific knowledge bases for application more widely.

1. Eugene Stakhiv & Bruce Stewart, 'Draft 'White Paper': needs of climate information for decision making in the water sector'. Paper produced for Stockholm Water Week, August 2009.

Adaptation measures taken primarily in response to climate change can actually help respond to several other major global challenges – food, energy, and environment, as well as economic development. Countries are urged to identify and implement *no regrets strategies*[2] – measures that are worth taking even if the climatic forecasts on which they are based turn out to be wrong. Smart and flexible solutions, increasing the capacity to cope with variability, will be crucial. The UNFCCC National Adaptation Programmes of Action should also be further developed and implemented.

Adaptation must be considered in the context of development programming and emergency response to ensure sustainability of interventions. Disaster risk reduction as a tool should consider climate change impacts in its assessments.

Managing increasing variability and uncertainty

Greater climatic variability and short term uncertainty is likely to be superimposed on any long term trend.

This will call for risk management of all kinds, at various levels. The menu of actions required will include improved observation networks, examination of the scope for more conjunctive use of groundwater and surface water supplies (including artificial aquifer recharge with freshwater or treated effluent), improved early warning and forecasting systems for hazardous events, and more generally raising community awareness of sustainable water use and individual responses to water-related hazards. Water operators will need to take account of climate change predictions and uncertainties and prepare for the opposite risks of drought and floods. Communities will need contingency plans for rapid and coordinated responses to floods and droughts to avoid outbreaks of disease and maintain safety and public health. Demand management in the major user sectors will also improve resilience.

More water storage of all kinds is likely to be required. Some of this will be *natural* – recharging aquifers, nourishing wetlands, restoring the levels of rivers and lakes, etc.. Some of it will be artificial, subject to safeguards for the environment and disrupted communities. Storage of both kinds will be required in many regions to insure against droughts and flooding, as well as to provide regular multi-purpose benefits (power, irrigation, household supplies, navigation etc). Creating the infrastructure of water resource development and distribution has been shown to have high macroeconomic benefits: conversely, countries lacking such infrastructure can suffer damaging shocks from droughts and floods.[3]

Technological advances in irrigation efficiency, the use of lower quality water (including reclaimed wastewater), the reduction of system losses from water systems, and other development

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indicate the potential for conserving existing water supplies and making better use of what is available. Technologies must be appropriate to local conditions, including the capacity to implement and operate them. Education and training of professionals is likely to be required.

Drinking Water Supply

Adaptation will call for coherent measures to address water security for all major users, starting with the basic needs of human consumption and subsistence.

Water is increasingly under stress from competing demands, affecting both quantities available and quality. Increasing and more mobile populations heighten the demands on water services and infrastructure designed for different circumstances. As other water users such as agriculture and industry also try to safeguard their share of a dwindling resource, conflicts and stresses will occur.

2. Or *low regret* strategies, where the possible negative outcomes are considered manageable.
3. WWDR-3, pp. 7–8.

Water governance

Managing the competing demands for water from various sectors will become more onerous in conditions of water scarcity and drought. Reforming existing water management institutions and creating new authorities will be important to allow for integrated control of increasingly scarce water resources and smoothing the transition to activities with low water requirements. In some countries this may require the creation of authorities with hydrological rather than political boundaries, and, where waters are shared, more effective regional water institutions.

Outside the normal water domain, decision makers in other spheres (finance, trade, power, housing, regional planning, agriculture, etc) must consider in a more systematic and coordinated manner the sustainability of their various demands on water resources. Country-specific solutions may include the creation of new institutions, networks and/or decision criteria incorporating climatic and water impacts. In every case, better coordination and exchange of information will be required.

Agriculture

The need for adaptation is especially great for agriculture.

The steadily increasing demand for agricultural products to satisfy the needs of a growing population continues to be the main driver behind water use. While world population growth has slowed since the 1970s and is expected to continue to slacken, the absolute numbers continue to rise. Economic development, in particular in emerging market economies, translates into a demand for a more varied diet, including meat and dairy products, which puts additional pressure on water resources. Agriculture, which is globally the largest water user, is both a source of greenhouse gases (methane and nitrous oxide) and a victim of the warming process. Although some regions and crops stand to benefit, others will suffer – and adapt or perish. Much of the adjustment will need to occur in poor and highly populated areas in developing countries.

The urban sector

Half the world's population is now urban, and the majority of these live within 100 km of the sea.

Increasing urban water use creates serious stress in the vicinity of cities. There is ample scope in most cities to improve water management, curtail losses, and increase the efficiency of water use. As part of adaptation, the potential use of non-potable water will need to be assessed (runoff, brackish water, grey water, even reclaimed wastewater for certain purposes). Coastal cities also have desalination as an option, subject to affordability.

Health

The World Health Assembly Resolution on Climate Change supports greater emphasis on adaptation measures in all sectors affected.

Climate change is likely to affect human health through water-related impacts of various kinds – vector-borne diseases, reduced access to safe drinking water, malnutrition due to water shortages, problems following flooding, and other effects likely to be identified through health impact assessments. The potential effects of these outcomes on human health urgently need to be subject to comprehensive risk assessment and management planning. Adaptation measures in all sectors ultimately depend on the fitness and health of the human populations concerned. More generally, decision-makers are urged to give greater attention to the nexus of human health, climate change, and improved water management practices, including increasing access to water supply and appropriate sanitation services.

Water-related hazards

Society needs to adapt to the full range of water-related hazards that will accompany climate change.

These can result from too much water (causing floods, erosion, landslides, etc) or too little (droughts, forest fires, loss of wetlands or other habitats, saline encroachment, etc) and from the effects of chemical and biological pollution on water quality and in-stream ecosystems. Global warming is expected to have substantial effects on the flow of energy and the recycling of matter through its impact on water temperature, resulting in algal blooms, increases in toxic cyanobacteria bloom and reductions in biodiversity. Climate change will make the management of waste water and water pollution even more urgent.

Information for decision making and planning

Meeting the challenge of climate change will be impossible with the present state of information about the state of the resource and how it is changing. Information is weak at all relevant levels – global, regional, national and sub-national.

It is a matter of serious concern that global water observation networks provide incomplete and incompatible data on water quantity and quality – and even existing networks are at risk of further decline. Nor is there comprehensive information on wastewater generation and treatment or of water quality on a regional or global scale. While new technologies based on satellite remote sensing and modeling offer opportunities for data collection, their value is limited by the scope for ground-truthing and validation of the simulated information.

Even the data that exists is not efficiently used. There is little sharing of hydrologic data, due largely to limited physical access, policy and security issues, and a lack of accepted protocols for sharing; as well as commercial considerations. These factors hamper regional and global projects that rely on shared datasets. Most countries, developed and developing, need to give greater attention and more resources to monitoring, observations and continual assessments of the status of their water resources.

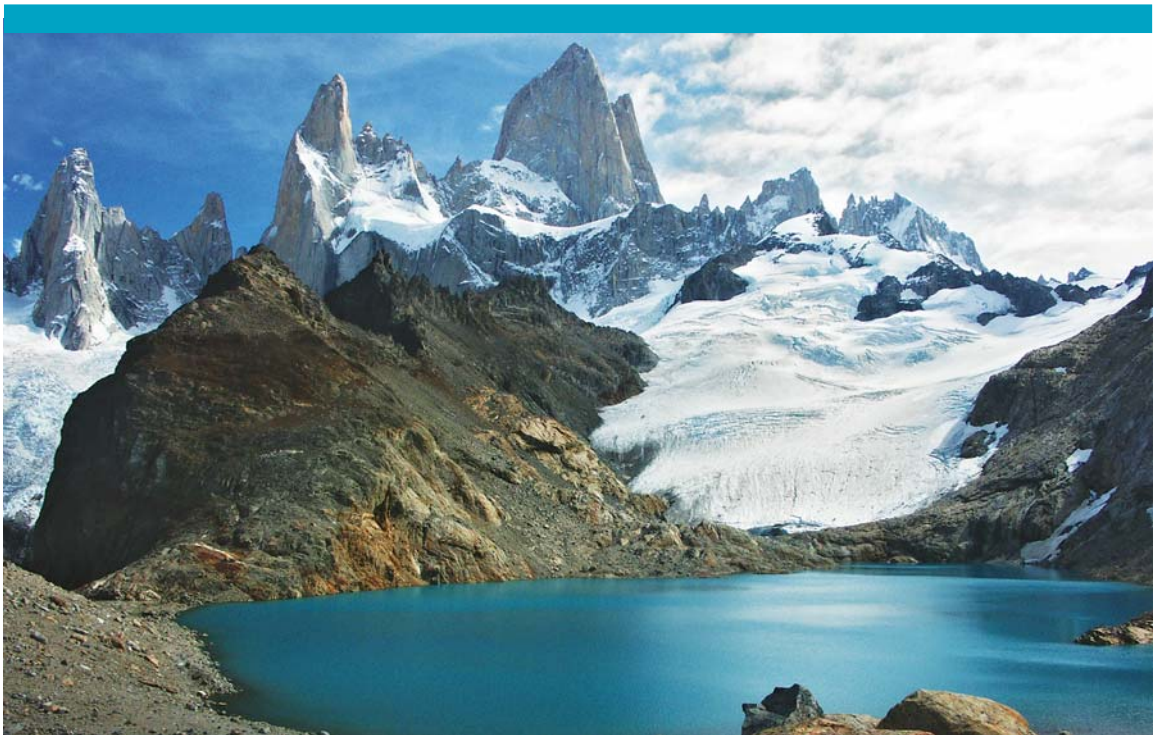
Since the impact of climate change is very diverse, data collection and monitoring is needed at sub-regional level. However, there is also a specific need for international support for global and regional hydrological data collection and analysis, which has been increasingly neglected. National governments should also support international efforts in this regard, and do much more to encourage data sharing. Information science and knowledge management for hydrological data is rapidly evolving and governments should do everything possible to encourage this and use its results.

Water resources issues should be prominent in climate change negotiations and governments should commit themselves to the necessary degree of support, including finance, for adaptation measures.

Financing

Developing countries currently lack effective funding mechanisms to support adaptation to climate change.

As an example, in Africa the potential impact of climate change could include increased energy shortages, reduced agricultural production, worsening food security and malnutrition, spread of disease, humanitarian emergencies, growing migration and increased risk of conflict over scarce land and water. Yet many African countries are least able to meet the costs of adapting to these impacts and receive the least from current adaptation funds. The various costs of adaptation should be assessed at country level, and spending priorities established. Access to existing adaptation funds should be improved, and funding for adaptation increased across the board for all sectors concerned.



Education, Training and Capacity Building

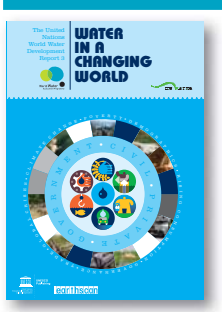
This paper calls for the greater appreciation by global society at all levels of what needs to be done in the water domain to adapt to the consequences of climate change.

The menu of actions implies the development of capacity both to understand the physical processes involved and the social measures necessary to adapt to them. Education and training of water professionals, at all levels, and capacity building of professional groups and management institutions are an essential condition of successful adaptation Adapting water management to the challenges of climate change and other forces will require much more information, greater and more widespread understanding of its implications, and the development of capacity to act.

Transboundary cooperation

Transboundary cooperation in the development of adaptation strategies will help to minimize any negative impacts from unilateral national actions but can also bring mutual benefit for all riparian parties – for example sharing costs and benefits of adaptation measures, or reducing uncertainty through exchange of data and information. Transboundary cooperation can widen the knowledge/information base, enlarge the set of available measures for prevention, preparedness and recovery and thereby help to find better and more cost effective solutions.

The paper has benefited from many detailed comments from members of the UN-Water Task Force on Climate Change, the WWAP Secretariat, the WWAP Technical Advisory Committee, the WWAP Expert Group on Water and Climate Change, the WWDR-3 Content Coordinator, the UN-Water Chair CTA and others. The contribution of James Winpenny, of Wychwood Economic Consultants Ltd, to the preparation of this document is also acknowledged.



The United Nations World Water Development Report 3: Water in a Changing World

Coordinated by the World Water Assessment Programme, the *United Nations World Water Development Report 3: Water in a Changing World* is a joint effort of the 26 United Nations agencies and entities that make up UN-Water. The report brings together some of the world's leading experts to analyse the state of the world's freshwater resources: it monitors changes in our water supplies and in how we manage them, and tracks our progress towards achieving international development targets.

The *World Water Development Report* also provides decision makers with the tools to implement sustainable use of our water – offering best practices to help stimulate ideas and actions for better stewardship of this most essential resource.

An accompanying case studies volume, Facing the Challenges, examines the state of water resources and national mechanisms for coping with change in 23 countries and numerous small island developing states.

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