Cap-Net

UNDP

Climate Change Adaptation and Integrated Water Resources Management

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United Nations Institute for Training and Research

REDICA
Red Centroamericana de Instituciones de Ingeniería

WORLD METEOROLOGICAL ORGANIZATION

UN Environment-DHI Centre on Water and Environment

UN environment

DHI

UNDP partners with people at all levels of society to help build nations that can withstand crisis, and drive and sustain the kind of growth that improves the quality of life for everyone. On the ground in nearly 170 countries and territories, we offer global perspective and local insight to help empower lives and build resilient nations.

Photo: Ezra Comeau Jeffrey

Climate Change Adaptation & IWRM

Foreword

Water is critical for sustainable development and the eradication of poverty and hunger. Lack of access to safe drinking water, sanitation and hygiene, as well as other water-related disasters, including scarcity and pollution, are increasing because of climate change. Today, every country on every continent is affected by climate change. It is burdening national economies and affecting lives, costing people, communities and countries significantly. This phenomenon will only escalate in the future. Sea levels are rising, weather events are becoming more extreme, and greenhouse gas emissions are now at their highest levels in history. Without action, the world's average surface temperature is likely to surpass 3 degrees Celsius (°C) in this century, and this will have the greatest impact on the poorest and most vulnerable people.

There are, however, affordable and scalable solutions available to enable countries to develop more resilient economies. By implementing Integrated Water Resources Management (IWRM), we can address climate change challenges, through a range of measures that will increase adaptation efforts. Water is the primary medium through which we suffer from the impacts of climate change, and IWRM can play a crucial role in how the world can adapt to climate change and reduce its effects. Improving our management of water today will prepare us to adapt tomorrow.

This training material is intended to increase our understanding of climate change and to explore what we can do now. The most important immediate action concerns the way we manage our water resources. Enhanced understanding of our water resources will allow more efficient and flexible allocation systems and better-planned investment in infrastructure, both to improve access to water and reduce risks from climate change.

In order to meet the 2030 Agenda, the Sustainable Development Goals are a call for action by all countries – poor, rich and middle-income – to promote prosperity while protecting the planet. They recognize that ending poverty must go hand in hand with strategies that build economic growth and address a range of social needs, while tackling climate change. We must act now – and this training package can help us to identify those actions.

Our collaboration with WMO, UN Environment-DHI, IHE-Delft, REDICA and UNITAR provides the framework for this programme, and we are grateful for their support.

Themba Gumbo

Director, Cap-Net

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Cap-Net is an international network with a mission to strengthen individual and institutional knowledge, for sustainable water management at the local level. Established in 2002 as a global programme under the United Nations Development Programme (UNDP), Cap-Net is one of the delivery mechanisms in the Water and Ocean Governance Programme (WOGP) of UNDP, within the Sustainable Development Cluster of the Bureau for Policy and Programme Support (BPPS).

WMO

The World Meteorological Organization (WMO) is an intergovernmental organization with a membership of 191 member States and territories. It originated from the International Meteorological Organization (IMO), which was founded in 1873. Established by the ratification of the WMO Convention on 23 March 1950, WMO became the specialized agency of the United Nations for meteorology (weather and climate), operational hydrology and related geophysical sciences a year later. The Secretariat, headquartered in Geneva, is headed by the Secretary-General. Its supreme body is the World Meteorological Congress.

UN Environment-DHI

The UN Environment-DHI Partnership is a centre of expertise dedicated to improving the management, development and use of freshwater resources from the local to the global level. UN Environment-DHI is hosted at DHI, an independent, international consulting and research-based not-for-profit foundation of more than 1,000 employees, with offices in 30+ countries, and with more than 50 years of experience in water resource management.

IHE-DELFT

IHE-Delft Institute for Water Education is the largest international graduate water education facility in the world with a mission to work in partnership to strengthen capacity in the water sector to achieve global sustainable development.

REDICA

REDICA was founded in 1998 as a regional network to meet the economic, social, environmental and political changes that are affecting Central America and the need to mobilize national and regional capacities. REDICA was created as part of a framework for capacity development in sustainable development in Central America. REDICA members interact with local governments, technical organizations, non-governmental organizations related to water resources, and with vulnerable, rural, indigenous populations, as well as productive, industrial and agricultural sectors. Its mission is to articulate capabilities, resources and efforts in the region to improve the education, research, coverage, and service development and management of water resources, awareness of climate change and gender equity, as well as regional and bilateral cooperation with other regional and international organizations.

UNITAR

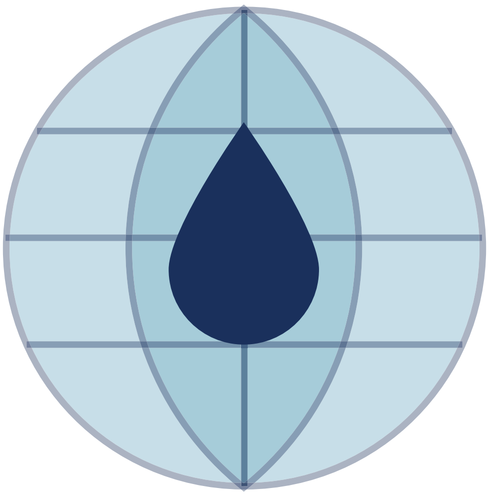
Established in 1963, the United Nations Institute for Training and Research (UNITAR), is an established UN body and a dedicated training arm of the UN system. it has the mandate to enhance the effectiveness of UN through diplomatic training, and to increase the impact of national actions through public awareness-raising, education and training of public policy officials.

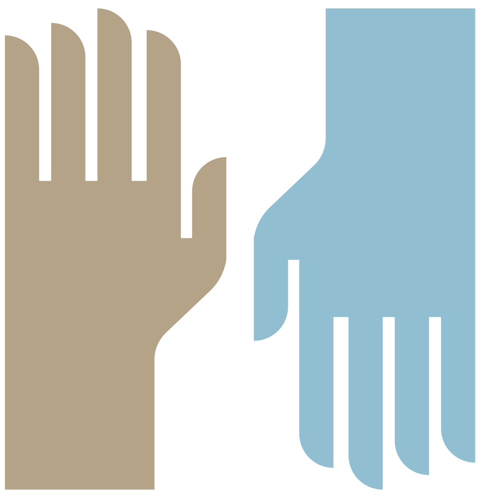
Acronyms

ACR	American Carbon Registry
ADAPT	Assessment and Design for Adaptation to Climate Change – A Prototype Model
AF	Adaptation Fund
AMOC	Atlantic Meridional Overturning Circulation
AR4	Fourth Assessment Report
AR5	Fifth Assessment Report
CAR	Climate Action Registry
CARE	Cooperative for Assistance and Relief Everywhere
CBA	Cost Benefit Analysis
CCA	Climate Change Adaptation
CCAI	Climate Change Adaptation Initiative
CCAIRR	Climate Change Adaptation through Integrated Risk Reduction
CC DARE	Climate Change Adaptation and Development Initiative
CDM	Clean Development Mechanism
CEDRA	Climate change and Environmental Degradation Risk and Adaptation assessment
CH_4	Methane
CO_2	Carbon dioxide
CRiSTAL	Community-based Risk Screening Tool – Adaptation and Livelihoods
CVCA	Climate Vulnerability and Capacity Analysis
CVI	Climate Vulnerability Index
DDR	Disaster Risk Reduction
DFID	Department for International Development
ENSO	El Niño-Southern Oscillation
ESMAP	Energy Sector Management Assistance Programme
EU	European Union
FDPI	Flood Disaster Preparedness Indices
GCF	Green Climate Fund
GCM	Global Circulation Model
GEF	Global Environment Facility
GFCS	Global Framework for Climate Services
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GWP	Global Water Partnership
HCFC	Hydrochlorofluorocarbon
HEAT	Hands-on Energy Adaptation Toolkit
HFC	Hydrofluorocarbon
HRWS	Human Right to Water and Sanitation
H_2O	Water vapour
ICESCR	International Covenant on Economic, Social and Cultural Rights
ICWE	International Conference of Water and the Environment
IDS	Institute of Development Studies
IFI	International Financial Institution
IHE	Institute for Water Education
IISD	International Institute for Sustainable Development
IMO	International Meteorological Organization
INDC	Intended Nationally Determined Contribution
IPCC	International Panel on Climate Change
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resources Management
KMFRI	Kenya Marine and Fisheries Research Institute
LDC	Least Developed Country
LDCF	Least Developed Countries Fund
LEG	Least Developed Countries Expert Group
LiDAR	Light Detection and Ranging
LNRA	Lake Naivasha Riparian

LOSU	Level of Scientific Understanding Authority
MCDA	Multi-Criteria Decision Analysis
MRC	Mekong River Commission
NAP	National Adaptation Plan
NAPA	National Adaptation Programme of Action
NAZCA	Non-State Actor Zone for Climate Action
NDA	National Designated Authority
NDC	Nationally Determined Contribution
NFCS	National Framework for Climate Services
NOAA	National Oceanic and Atmospheric Administration
N^2O	Nitrous oxide
OECD	Organization for Economic Cooperation and Development
OHCHR	Office of the High Commissioner for Human Rights
ORCHID	Opportunities and Risks for Climate Change and Disasters
O_3	Ozone
PFC	Perfluorocarbons
ppm	parts per million
REDICA	Central American Network of Engineering Institutions
SCCF	Special Climate Change Fund
SDG	Sustainable Development Goal
SF_6	Sulphur hexafluoride
SSWM	Sustainable Sanitation and Water Management
SuDS	Sustainable Drainage System
ToT	Training of Trainers
UNCED	United Nations Conference on Environment and Development
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNDRIP	United Nations Declaration on the Rights of Indigenous Peoples
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNGA	United Nations General Assembly
UNISDR	United Nations International Strategy for Disaster Reduction
UNITAR	United Nations Institute for Training and Research
VCS	Verified Carbon Standard
WG	Working Group
WGII	Working Group II
WHO	World Health Organization
WMO	World Meteorological Organization
WRG	Water Resources Group
WRI	World Resources Institute
WWDR	World Water Development Report
WWF	World Wildlife Fund

Content





1 MODULE 1. INTEGRATED WATER RESOURCES MANAGEMENT AND CLIMATE CHANGE

Photo: Mega Caesaria

Goal

The objective of this chapter is to provide an overview of the detrimental implications of anthropogenic climate change, and of the ways that implementing Integrated Water Resources Management (IWRM) can address the resulting challenges. Water is the primary medium through which we suffer from the impacts of climate change, and IWRM can play a crucial role in how the world can mitigate these effects and adapt to climate change.

1.1 Climate change impacts

According to the Intergovernmental Panel on Climate Change (IPCC), there are substantially more impacts attributed to climate change in recent decades - including on human and managed systems (IPCC, 2014). In addition, water crises are ranked the highest among the top 10 global risks in terms of impact and eighth in terms of likelihood (Global Risk Report, 2015). Water is, in fact, the first resource impacted by climate change, which is exacerbating other environmental, economic and social problems that threaten the development of economies and people's livelihoods.

1.1.1 Anthropogenic global warming

Human activities are estimated to have caused approximately 1.0 °C of global warming above pre-industrial levels, with a likely range of 0.8 °C to 1.2 °C. Global warming is predicted to reach 1.5 °C between 2030 and 2052 if it continues

Figure 1.1: Observed global temperature change and modelled responses to stylized anthropogenic emission and forcing pathways (IPCC, 2018). Orange dashed arrow and horizontal orange error bar show respectively central estimate and likely range of the time at which 1.5 °C is reached if the current rate of warming continues. The grey plume on the right shows the likely range of warming responses, computed with a simple climate model, to a stylized pathway (hypothetical future) in which net CO_2 emissions decline in a straight line from 2020 to reach net zero in 2055, and net non-CO_2 radiative forcing increases to 2030 and then declines.

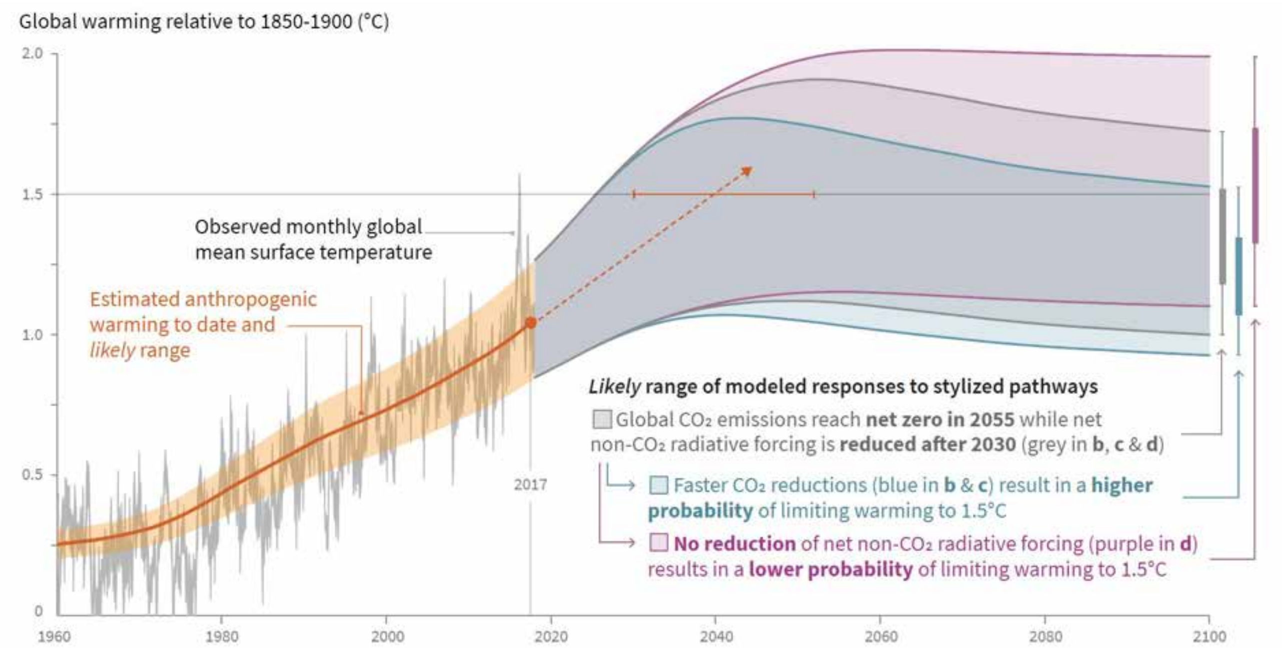
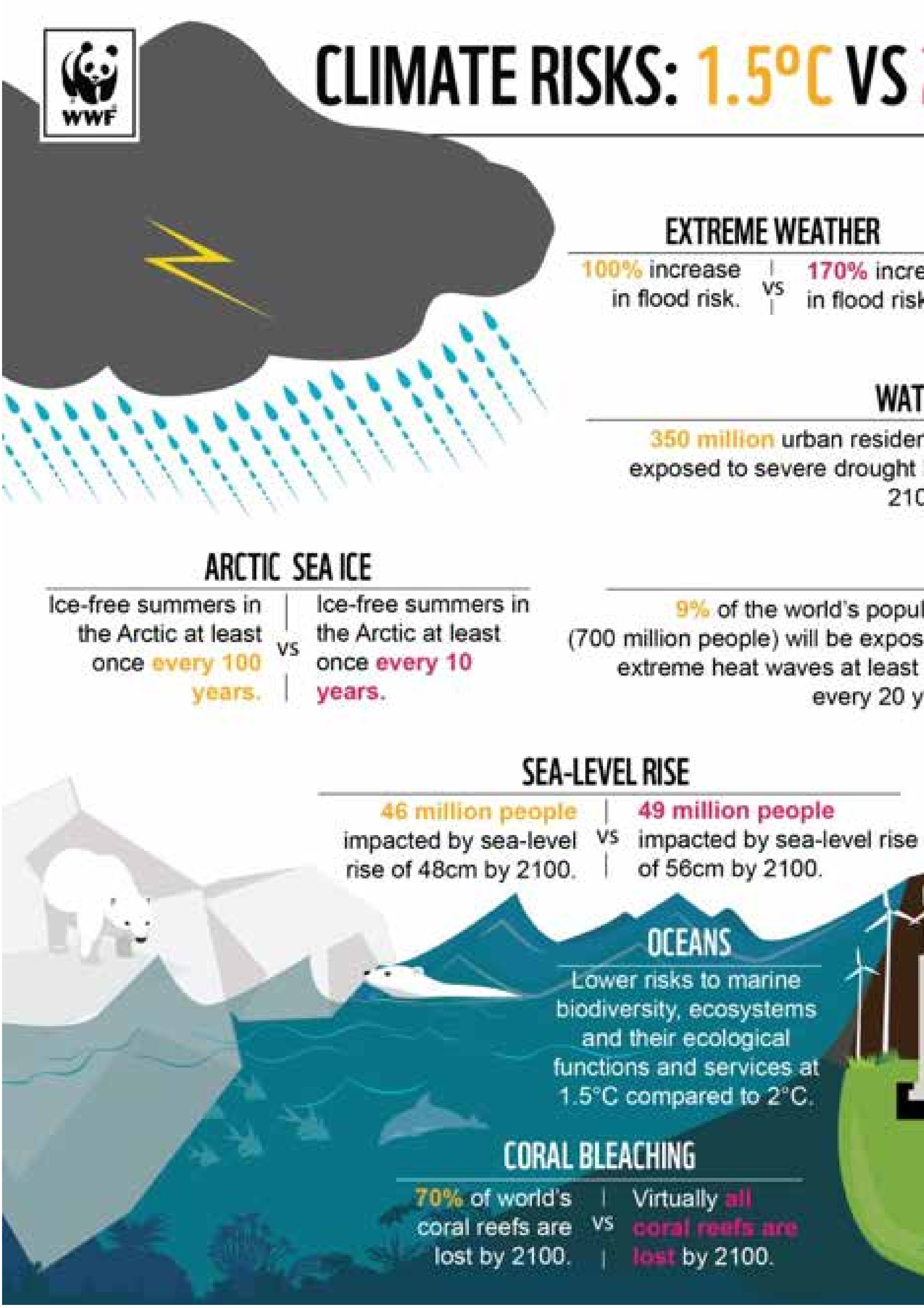
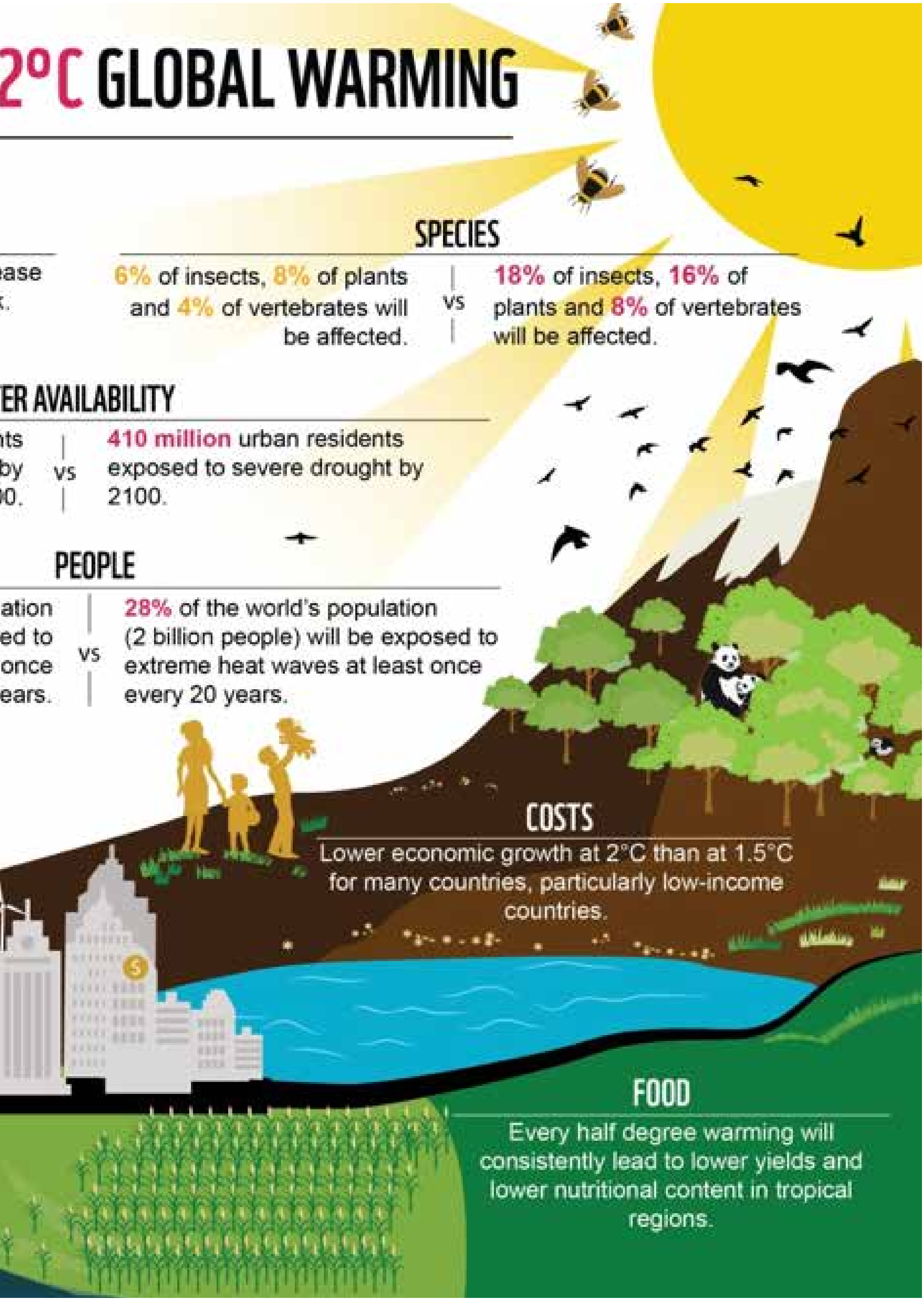


Figure 1.2: Climate risks: 1.5 °C vs 2 °C global warming (WWF, 2018)




2°C GLOBAL WARMING
SPECIES
ease
6% of insects, 8% of plants and 4% of vertebrates will be affected.
VS
18% of insects, 16% of plants and 8% of vertebrates will be affected.
ER AVAILABILITY
nts
by
00.
VS
410 million urban residents exposed to severe drought by 2100.
PEOPLE
ation
ed to
once
ears.
VS
28% of the world's population (2 billion people) will be exposed to extreme heat waves at least once every 20 years.
COSTS
Lower economic growth at 2°C than at 1.5°C for many countries, particularly low-income countries.
FOOD
Every half degree warming will consistently lead to lower yields and lower nutritional content in tropical regions.

to increase at the current rate (IPCC, 2018; Figure 1.1). Warming greater than the global annual average is being experienced in many land regions and seasons, including two to three times higher temperatures in the Arctic. Warming is generally greater over land than over the ocean. For instance, in Switzerland, the average annual temperature has already increased by around 2 °C since 1864 (as of 2018), for the most part in the last few decades. Warming from anthropogenic emissions from the pre-industrial period to the present will persist for centuries to millennia, and will continue to cause further long-term changes in the climate system, such as sea-level rise, with associated impacts (IPCC, 2014; Figure 2.1).

1.1.2 Impacts at 1.5 °C and 2 °C of warming

Following the 21st Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC) to adopt the Paris Agreement, in 2018, IPCC published a special report on the impacts of global warming of 1.5 °C above pre-industrial levels (in fact, relative to the period 1850-1900); and related global greenhouse-gas (GHG) emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (IPCC, 2018). It is based on the assessment of the available scientific, technical and socio-economic literature relevant to global warming of 1.5 °C, and for the comparison between global warming of 1.5 °C and 2 °C above pre-industrial levels.

Climate-related risks for natural and human systems are higher in the case of global warming of 1.5 °C than at present, but lower than at 2 °C (IPCC, 2018). These risks depend on the magnitude and rate of warming, geographic location, levels of development and vulnerability, and on the choices and implementation of adaptation and mitigation options. The differences in regional climate characteristics between the present day and global warming of 1.5 °C and 2 °C include increases in: mean temperature in most land and ocean regions, hot extremes in most inhabited regions, heavy precipitation in several regions, and the probability of drought and precipitation deficits in some regions.

Figure 1.2 summarizes some of the effects of climate warming of 1.5 °C and 2 °C on people and nature (WWF, 2018). With scientific evidence, it has now been established that many of the impacts we thought we'd see at 2 °C, are likely to be seen earlier, some at 1.5 °C or lower. Moreover, above 2 °C we may face irreversible impacts and unstoppable change - even if all countries met their targets to cut emissions; because of natural processes causing climate change such as permafrost melting and rainforests dying, releasing more CO_2 and methane into the atmosphere.

According to IPCC (2018), by 2100, global mean sea-level rise is projected to be around 0.1 metres (m) lower with global warming of 1.5 °C compared to 2 °C. Sea level will continue to rise well beyond 2100, although a slower rate of sea-level rise enables greater opportunities for adaptation in the human and ecological systems of small islands, low-lying coastal areas and deltas. Overall, climate-related risks to health, livelihoods, food security, water supply, human security and economic growth are projected to increase with global warming of 1.5 °C and increase further with 2 °C; whereas limiting global warming to 1.5 °C compared to 2 °C could reduce the proportion of the world population exposed to a climate-change-induced increase in water stress by up to 50 percent (IPCC, 2018).

1.2 Climate change mitigation and adaptation

1.2.1 Mitigation and/or adaptation

Today, many people lack access to water resources for drinking water supply, and many regions are faced with economic water scarcity. According to the Organization for Economic Cooperation and Development's (OECD) baseline scenario on the future of the environment, by 2050, 3.9 billion people (over 40 percent of the world population) will probably be living in water catchment areas with high water stress (OECD, 2012). Water stress is of particular concern in areas facing water scarcity at different time periods (both short-term and long-term weather variations) and/or significant variations in water demand; for instance, urban areas where water consumption is likely to double in the next decade.

Climate change mitigation and adaptation are two complementary strategies to reduce and manage the risk associated with climate change. As presented in Figure 1.3, mitigation measures in relation to climate change scenario are related to actions that reduce the emissions that contribute to climate change (i.e. the actions taken to reduce the severity); whereas adaptation measures are actions that minimize or prevent the negative impacts of climate change (i.e. responsive adjustment to an environmental condition). Therefore, mitigation represents the globally responsible thing to do, and adaptation the locally responsible thing to do.

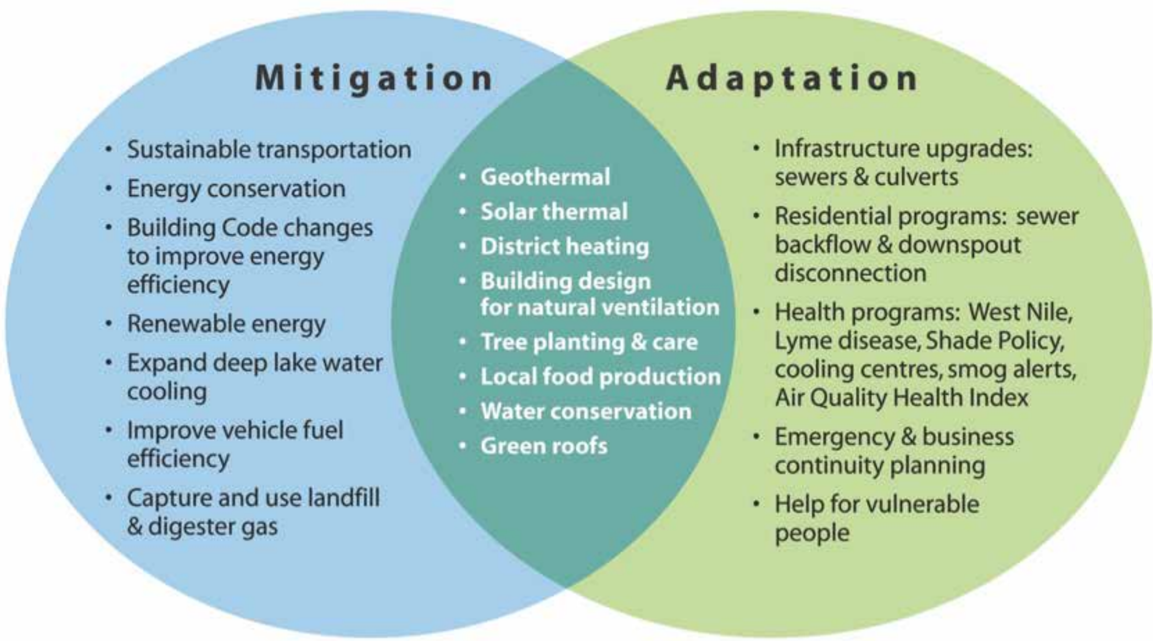
Building resilient water and energy systems are two of the main issues that need to be addressed in the face of climate change. Increases in energy production, which are typically associated with proportional increases in GHG emissions (because of fossil-fuel combustion), lie at the heart of climate change mitigation strategies of industrialized countries. In this context, the development of renewable and carbon-neutral energy sources (e.g. geothermal and solar thermal) is strongly recommended for climate change mitigation and adaptation policies (Figure 1.3). In the same way, hydropower dams which contribute to climate change mitigation by reducing GHG emissions can also be used as a means of adaptation by maintaining the availability of water resources through the dry season – and by mitigating the risk of overflow in the catchment following high precipitation events.

In 2018, the World Water Development Report (WWDR) highlighted the potential of nature-based solutions to address contemporary water resource management challenges across all sectors, particularly regarding water for agriculture, sustainable cities, disaster-risk reduction and water quality (WWDR, 2018). Nature-based solutions include green infrastructures that can substitute, augment or work in parallel with grey infrastructure (i.e. projects that use concrete and steel) in a cost-effective manner. They are cross-sectoral in nature and effective in addressing issues of climate change, water and agriculture in an integrated way.

1.2.2 Obligations related to adaptation and mitigation

The improvement of (waste-) water management infrastructure (e.g. treatment systems to reduce and reuse domestic/municipal waste water) is also a key priority to protect human health and provide help for the most vulnerable people. It is imperative to respect and fulfil the human rights to water and sanitation for the groups in vulnerable situations, including women, children

Figure 1.3: Adaptation and mitigation of climate change (http://renewcanada.net/wp-content/uploads/2009/10/mortimer-diagram.jpg)



and indigenous peoples; because States have a duty to secure the livelihoods of indigenous peoples and to recognize their rights with respect to the natural resources (including water) and territory that they have traditionally occupied (UNDRIP, 2007; Cap-Net, 2018). Thereby, States and other duty-bearers (including businesses) have the obligation and responsibility to foster policy coherence and help ensure that climate change mitigation and adaptation efforts are adequate, sufficiently ambitious, non-discriminatory and compliant with human rights obligations (OHCHR 's Key Messages on Human Rights and Climate Change).

In October 2018, a court of appeal in The Hague has upheld a precedent-setting judgment that forces the Dutch government to take measures to cut domestic GHG emissions to at least 25 percent below 1990 levels by 2020. In fact, the Netherlands has pledged to reduce emissions by 49 percent by 2030, but has so far achieved only a 13 percent drop from 1990 levels. The court cites the State's legal duty of care for its citizens, which is enshrined in the European Convention on Human Rights. Similar court cases are now ongoing in several countries, including the United States, Belgium, Norway and Ireland.

The recent international mobilizations of scientists, civil society and political decision makers to cope with climate change impacts on water and human rights, point out the obligations of both governments and private actors in responding to climate change; including those relating to rights to information, public participation in decision-making and access to justice, as well as obligations relating to adaptation and mitigation. In 2015, UN Environment published a report assessing the relationship between climate change and human rights laws, stressing some of the obligations of governments and private actors to respond to the human rights implications of climate change.

1.3 Water and climate change adaptation challenges

UN estimates that, in the last 10 years, climate-related disasters have caused US$1.4 trillion of damage worldwide. In recent years, water-related disasters (floods, droughts and windstorms) accounted for almost 90 percent of the most disastrous events. Water challenges related to climate variability can be considered under six broad themes as illustrated in Figure 1.4. Within each of these, a number of adaptation response

Figure 1.4: Climate change adaptation challenges related to water

options are presented below and illustrated in Tables 4.1-4.6.

1.3.1 Climate risks

Risk and uncertainty are inherent challenges for any water manager, and these challenges are exacerbated by climate change. Risk and uncertainty can be reduced by applying approaches and technology advancements that help in understanding and quantifying the anticipated impacts of climate change on the water resources of a given river basin, community, location, or an ecosystem. Through improved understanding of the impacts and their distribution, the most appropriate adaptation response actions and technologies can be identified.

Living with the risk of various climate-related hazards is not a new phenomenon in many communities across the world. Seasonal floods, for example, are part of the hydrological cycle in many river basins. Climate change, however, is likely to exacerbate current challenges and increase both the severity and unpredictability of these patterns, including changing the distribution and severity of extreme weather events. Understanding these increasing and emerging hazards, and assessing the level of risk that they present to communities, is essential for any water manager in identifying and designing best possible adaptation strategies and actions.

1.3.2 Too little water

The changing variability of rainfall patterns and rising temperatures associated with climate change are expected to contribute to increased frequency of water scarcity and droughts (UNFCCC, 2014). In general, water scarcity can be linked to two core drivers - natural and human. Water scarcity originating from natural factors can be a result of lower precipitation and freshwater flows than usual, leading to a physical lack of water. Water scarcity can also be, and often is, caused by unsustainable resource use, irrespective of whether the physical availability of water and rainfall patterns have changed. Increasingly competing demand and over-abstraction of groundwater and surface water, as well as uncoordinated resource development for various purposes simultaneously, are common causes of water scarcity in many regions.

1.3.3 Too much water

Global warming is expected to contribute to increased intensity of rainfall in some areas, and increased variability of seasonal distribution of

Photo: Micah Albert

rain. The growing temperatures mean that the atmosphere is able to hold an increasing amount of moisture, leading to higher potential volumes of rainfall, and thus increased risks of flooding. Communities will have to adapt to riverine floods, flash floods, urban floods and sewer overflows, as well as flood risks resulting from glacial lake bursts, which are particularly relevant in the context of global warming.

The immediate impacts and damage of flooding depend on many factors, such as soil character,

Table 1.1: Potential impacts of climate change on major water sectors focusing on water scarcity, flooding and consequences of sea-level rise

	Too little water	Too much water	Sea-level rise
Environment	• Reduced environmental flows, lowering groundwater tables • Drying wetlands • Declining fisheries • Forest fires • Water pollution (dissolved matter) • Saltwater intrusion	• Floods • Landslides • Drowning vegetation/ animals • Water pollution (solids), erosion	• Coastal erosion • Saltwater intrusion • Loss of coastal ecosystems
Agriculture/ aquaculture	• Loss of crops and livestock • Reduced aquaculture production • Salinization	• Drowning of crops • Livestock diseases	• Loss of land • Salinization of soils and water supply
Water supply and sanitation	• Shortage of drinking water • Reduced hygiene • Disease outbreaks • Waste accumulation	• Overflowing sewers • Waterborne disease outbreaks	• Salinization of water supply
Energy/industry	• Reduced hydropower capacity • Lack of cooling and production water • Concentration of pollutants	• Disruption and destruction of infrastructure	• Disruption and destruction of infrastructure
Infrastructure	• Disruption and destruction of infrastructure • Limited navigation	• Disruption and destruction of infrastructure • Limited navigation	• Disruption and destruction of infrastructure
Housing		• Loss of housing and habitable areas	• Loss of housing and habitable areas

wetness, urbanization and land cover, and the existence of dikes, dams or other flood prevention structures. However, for our societies, it is also to a large extent dependent on the concentration of socio-economic activity in flood-risk zones (densely populated areas vs remote areas) and the general level of flood preparedness and response.

1.3.4 Water pollution

Changing climate is affecting the global hydrological cycle in its entirety, and the increasing temperatures can have a direct link to water quality. Drivers of water-quality degradation include the increasing frequency of floods and droughts, as well as increase in water temperatures – all combined with the impacts of human activity - which remains the primary cause of water-quality degradation (e.g. industrial accident). It is also expected that many forms of water-quality degradation will be indirectly exacerbated as a result of rising temperatures and precipitation intensity (e.g. eutrophication).

The lack of appropriate wastewater treatment, the increasing pressures of population growth, and the limited capacities of treatment systems are issues that have to be addressed in parallel to climate change mitigation efforts.

Nutrient (especially phosphorus and nitrate) pollution from agricultural activities and domestic waste water is a current problem in water resource management, and one of the principal threats to water quality and the health of freshwater ecosystems. As a result of climate change, the higher-intensity rainfall can contribute to increased nutrient leakage and consequently eutrophication of waterbodies. The eutrophication process is also enhanced by higher temperature which sustains algae proliferation, leading to oxygen depletion in the surface waters and dead zones.

1.3.5 Sea-level rise

Coastal communities are particularly at risk of climate-change-induced sea-level rise and extreme weather events caused by extreme conditions in the sea – including coastal storms (storm surges), high tides and tsunamis. With increasing sea levels, the risks of tidal flooding are particularly high, and existing defences (where they are present) are more prone to be breached, causing severe flood damage.

Coastal areas are home to some of the most populated and economically significant cities in the world, with growing density and size, and are often particularly exposed due to high population density and low-lying areas. It is predicted that by the end of the century, the number of people affected by annual floods and storm surges will be measured in millions (IPCC, 2007).

1.3.6 Disaster preparedness

Hydrological disasters represent the largest share of natural disasters worldwide today, causing the deaths of thousands of people, and annual economic damage of billions of dollars. Floods in particular affect more people than any other hazard (UNISDR, 2015). Climate change is expected to exacerbate these losses, due to rising sea level, increased frequency of floods and droughts, coastal storm surges, as well as risks related to glacial lake bursts.

A wide array of adaptation responses to climate change targeted at mitigating flood, drought and coastal zone disaster impacts have already been mentioned. On many occasions these adaptation responses can only limit the extent and mitigate the severity of disaster impacts, but not prevent the event altogether. Furthermore, appropriate measures for disaster preparedness need to be in place to evacuate people and protect key infrastructure.

Table 1.1 gives examples of potential impacts on major water sectors related to water scarcity, flooding and consequences of sea-level rise. One potential exercise is to have participants fill in the table from scratch and add more sectors as they come to mind. The example here only considers three impact themes, but more can be added.

1.4 Cross-sectoral integrated water management

1.4.1 Why an integrated approach?

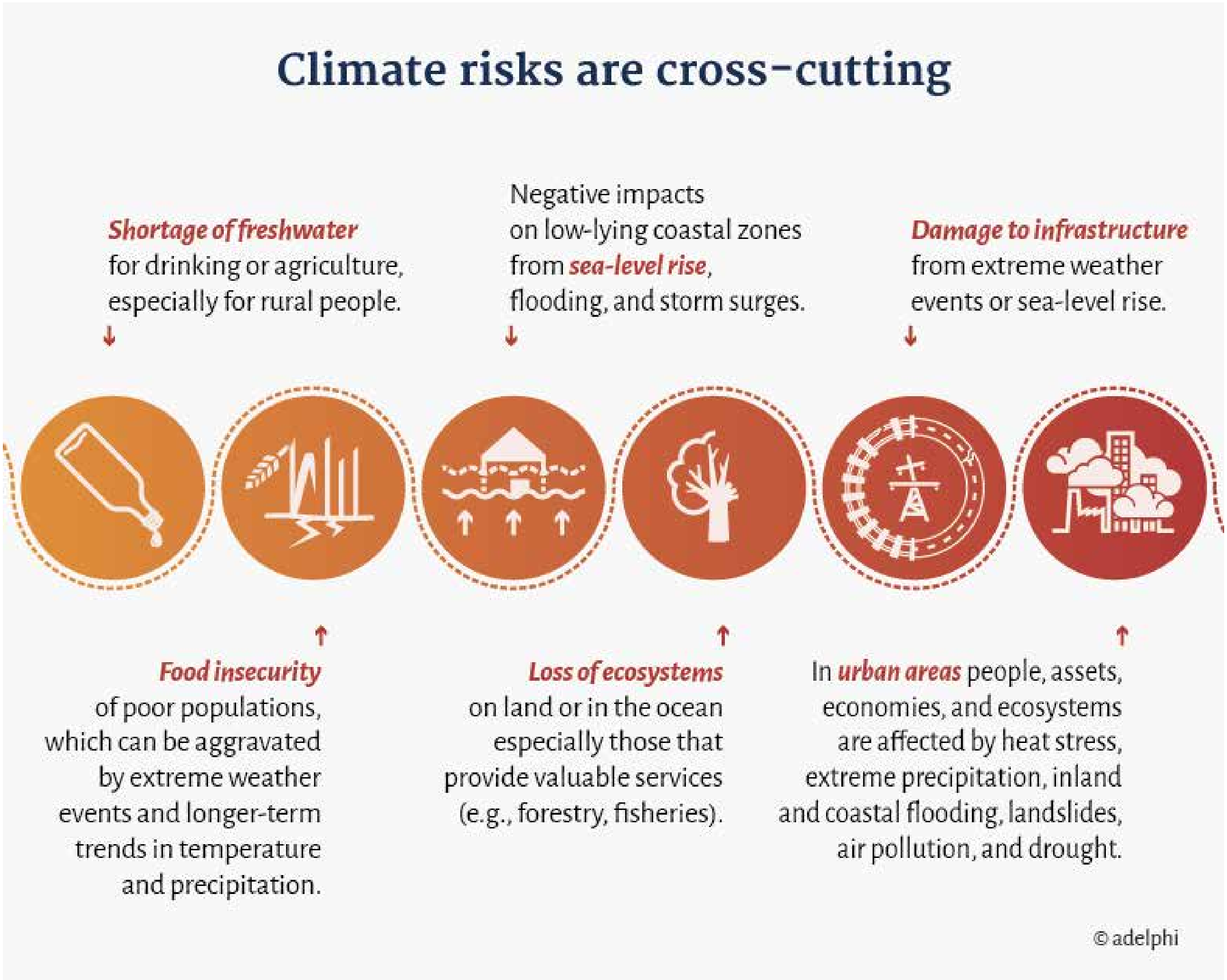
As shown in Figure 1.5, climate risks are cross-cutting, and climate-related risks to health, livelihoods, food security, water supply, human security and economic growth are projected to increase with global warming of 1.5 °C and increase further with 2 °C (IPCC, 2018). Water management, sanitation and agriculture are also intrinsically linked: when people use water for agriculture, households or industries, water becomes contaminated with different substances. In fact, sectoral thinking and modern approaches to (waste-) water management are at the root of many other problems, amongst them a lack of water and nutrients in agriculture, insufficient yields, and health problems and environmental contamination (SSWM). Further details can be found in the Sanitation and Water Management Toolbox, https://sswm.info.

1.4.2 Integrated Water Resources Management (IWRM)

An integrated cross-sectoral approach for water resource management is strongly needed to curb the effects of climate change at basin-scale. IWRM is defined by the Global Water Partnership (GWP) - an international network created to foster an IWRM approach - as "a process which promotes the coordinated development and management of water, land and related resources in order to maximise economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." It is a long-term process involving local communities, individuals and institutions in the management of water (and sanitation) systems and the coordination between the different sectors (health, environment, land planning) and partners (public, ministers and private companies).

There is a wealth of evidence that IWRM can play an important role in supporting households and communities to mitigate the effects of climate change and adapt to it. For policy-making and planning, applying an integrated approach requires that water development and management take into account the various uses of water and the range of people's water needs.

Figure 1.5: Climate risks are cross-cutting (Image credit: adelphi)



IWRM offers various tools and instruments that deal with access to water and protecting the integrity of the ecosystem, thus safeguarding water quality for future generations. In this way, IWRM can assist communities to adapt to changing climatic conditions that limit water availability or may lead to excessive floods or droughts (Cap-Net, 2009). Moreover, IWRM makes it easier to respond to changes in water availability and pollution. Risks can be better identified and mitigated in the process of basin planning. When action is needed, stakeholder participation helps to mobilize communities and generate action. Water users can be stimulated to use the resource sustainably in the face of climate-driven changing water conditions.

1.5 International frameworks

1.5.1 IWRM as a tool for sustainable development

The International Conference on Water and the Environment (ICWE) in Dublin in January 1992, gave rise to four principles that have been the basis for much of the subsequent water-sector reform: 1) Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment; 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 the provision, management and safeguarding of water; and 4) Water has an economic value in all its competing uses and should be recognized as an economic good as well as a social good.

In commending the Dublin Statement to the world leaders assembled at the United Nations Conference on Environment and Development (UNCED) for Agenda 21 in Rio de Janeiro in June 1992, the Rio Declaration on Environment and Development first introduced and defined the concept of IWRM as the following: Water resources must be protected, taking into account the functioning of aquatic ecosystems and the perennial nature of the resource; in developing and using water resources, priority has to be given to the satisfaction of basic needs and the safeguarding of ecosystems; and IWRM should be carried out at the level of the catchment basin or sub-basin.

The United Nations Economic Commission for Europe (UNECE) Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) was adopted in Helsinki in 1992 and entered into force in 1996. The Water Convention strengthens transboundary water cooperation and measures for the ecologically sound management and protection of transboundary surface waters and groundwaters. The Water Convention fosters the implementation of IWRM, in particular the basin approach. The signatories to the Protocol on Water and Health at the Water Convention agreed to promote international cooperation to establish joint or coordinated systems for surveillance and early warning systems, contingency plans, and responses to outbreaks and incidents of water-related diseases and significant threats of such outbreaks. According to Article 5, "Water resources should, as far as possible, be managed in an integrated manner on the basis of catchment areas, with the aims of linking social and economic development to the protection of natural ecosystems and of relating water-resource management to regulatory measures concerning other environmental mediums. Such an integrated approach should apply across the whole of a catchment area."

1.5.2 IWRM to support SDG 6

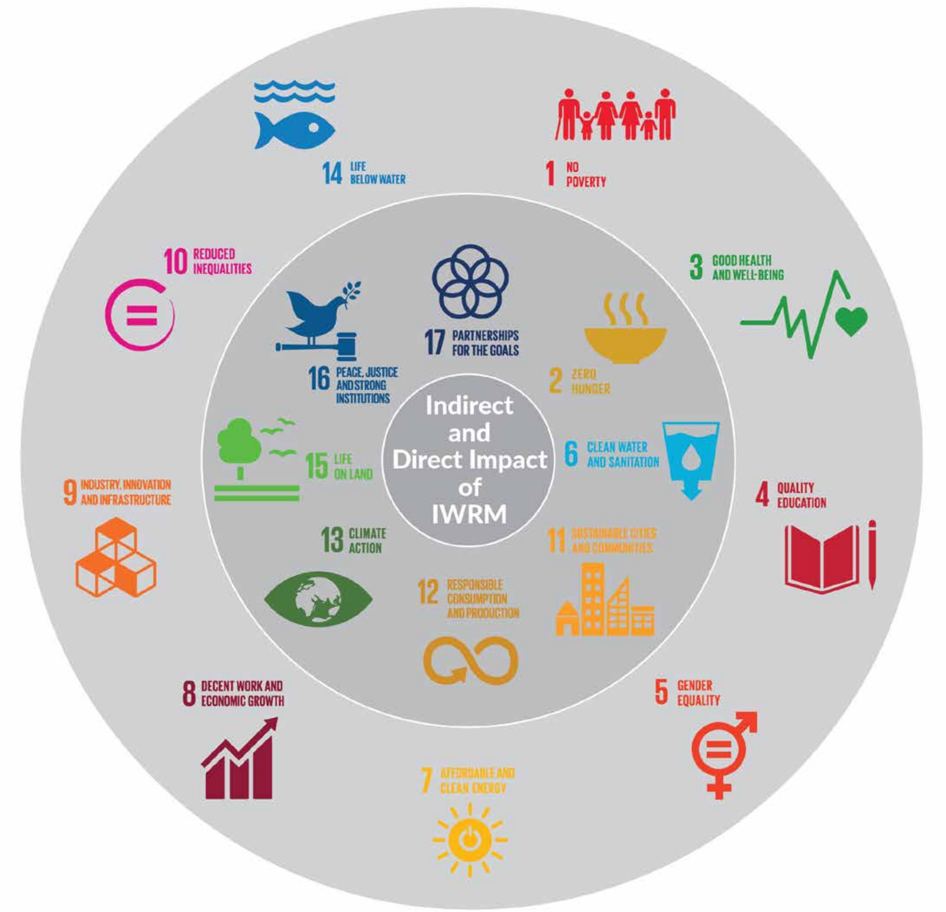
The adoption of Sustainable Development Goals (SDGs; Figure 1.6) by all member States of the United Nations (UN) in 2015, dedicated a goal to water and sanitation (SDG 6: "Ensure[s] availability and sustainable management of water and sanitation for all") with eight targets, not only focusing on drinking water, sanitation and hygiene; but also on IWRM. Target 6.5 "By 2030, implement IWRM at all levels, including through transboundary cooperation as appropriate" builds on agreements such as Agenda 21 and the Johannesburg Plan of Implementation (2002) by moving forward from planning to implementation. The second component of transboundary cooperation builds on the Water Convention. The target is specific, measurable and action-oriented. It is a foundation for all other water targets, including the 'means of implementation' Targets 6.a and 6.b, as well as many targets of the other goals.

IWRM can foster more efficient and sustainable use of water resources to achieve the SDGs by providing a framework for addressing many of the linkages, and by balancing the needs of different sectors and stakeholders (Figure 1.6). According to UN-Water (2016), many of the SDGs' targets related to social and economic development both depend on and support a sustainable, reliable water supply of adequate quality and quantity. Examples include sustainable food production systems (Target 2.4), decoupling economic growth from environmental degradation (Target 8.4), sustainable infrastructure and industry (Target 9.4), reducing the per capita environmental impact of cities (Target 11.6), and sustainable consumption and production (Target 12.1–12.8). Nonetheless, there are also some targets related to development, such as those to double agricultural productivity (Target 2.3), ensure energy for all (Target 7.1), or sustain economic growth (Target 8.1); which could potentially lead to negative impacts on water resources and water-related ecosystems, unless linkages are understood and correctly managed.

It is therefore critical that the targets within each SDG are implemented in an integrated fashion; whereas IWRM (Target 6.5) can provide adapted frameworks for addressing many of the linkages by balancing the needs of different sectors and stakeholders.

For the same reasons, some climate change adaptation/mitigation options consistent with 1.5 °C pathways are associated with multiple synergies but also potential trade-offs across the SDGs (IPCC, 2018). For example, if poorly designed or implemented, adaptation projects in a range of sectors can increase GHG emissions and water use, increase gender and social inequality, undermine health conditions, and encroach on natural ecosystems. Some 1.5 °C pathways show potential trade-offs with mitigation of SDGs 1 (poverty), 2 (hunger), 6 (water) and 7 (energy access), if not carefully managed (IPCC, 2018).

Figure 1.6: IWRM can provide adapted frameworks to achieve the SDGs



1.6 IWRM as a tool for justice

1.6.1 Human right to water

According to the United Nations Development Programme (UNDP), the Human Rights-based Approach aims to apply the rules and standards defined in international law of human rights to development-related policies and practices. It is based on the finding that human development is established on the application of social, economic, civil, political and cultural rights, while contributing to it. It admits as guiding principles of universality, the obligation of accountability and participation. All programmes of development cooperation, policies and technical assistance should further the realization of human rights, including those related to SDGs implementation, climate change adaptation/mitigation and water resource management.

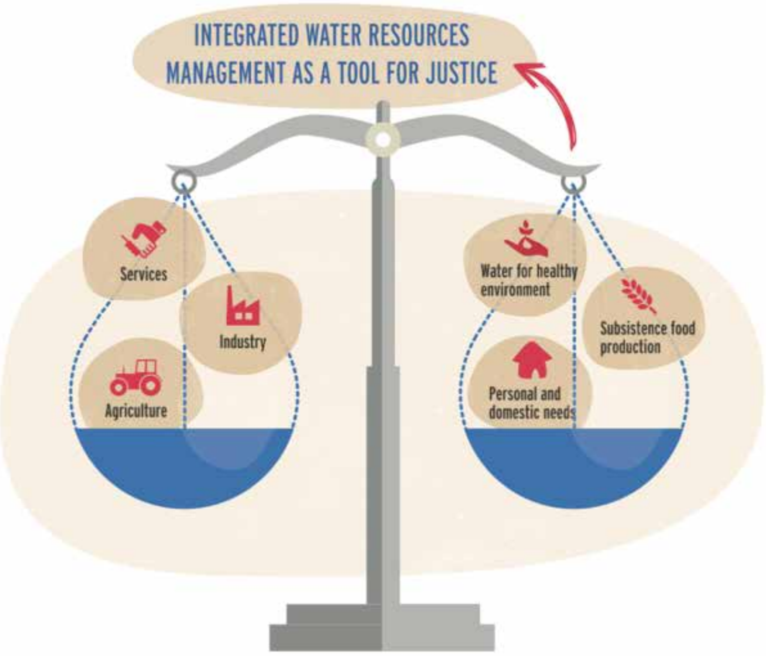
IWRM is a good example of soft law, because its key principles are not derived from international law but from an international conference at the ministerial level - ICWE -, which took place in Dublin in 1992. Additionally, these principles have found their way into the legal and policy frameworks of an increasing number of national governments over time (Cap-Net, 2016). However, since 2010, when both water and sanitation became officially recognized as human rights under international law (UNGA, 2010), the human rights system offers a moral and legal framework that is accepted almost everywhere. It sets minimum standards for governance in different areas of work - such as water management - and it defines the rights and obligations of different categories of institutions (Figure 1.7). Moreover, legally speaking, in most cases, human rights have a higher status than water laws and water rights.

1.6.2 Human rights-based approach to IWRM

Since water has been recognized as a human right (Box 1.1), the human rights system offers opportunities to streamline global and national water governance, and to provide coherence, both in terms of environmental sustainability and in terms of human development. As explained in detail in Cap-Net (2017), this has concrete implications for IWRM implementation because IWRM and human rights are interconnected. IWRM is a cornerstone of water governance, and water governance is, in turn, essential for the realization of human rights (Cap-Net, 2017; Figure 1.7).

Developing water resources infrastructure in the public interest first consists of the progressive realization of water-related human rights -

Figure 1.7: IWRM as a tool for justice and human rights (Cap-Net, 2017)



focusing on the obligation to ensure that a minimum package of rights is enjoyed by all without discrimination. Second, it consists of the allocation of water, in addition to human rights, and guarantees the interests of sustainable economic, social and cultural development. Both aspects require intensive public consultation in order to absorb the water-related aspirations of citizens into the overall catchment-management plan. The main difference between the two is that the first category is non-negotiable and requires priority action, whereas the second category is negotiable and has a secondary priority within the overall catchment-management plan. In a human rights-based approach to IWRM, a quantity of water is therefore reserved for the realization of human rights before standard water licensing can proceed. It is a two-tier process in which minimum protection levels for all are offered before planning for the satisfaction of longer-term ambitions (Cap-Net, 2017; Figure 1.7).

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BOX 1.1

– Human Rights to Water and Sanitation (HRWS)

In 2002, General Comment No. 15 on the human right to water was adopted by the United Nations Committee on Economic, Social and Cultural Rights. This comment explains that the right is implicit in Articles 11 and 12 of the International Covenant on Economic, Social and Cultural Rights (ICESCR), which lays down the right to an adequate standard of living and the right to health. In July 2010, UNGA reaffirmed the recognition of the right to safe and clean drinking water and sanitation “as a human right that is essential for the full enjoyment of life and all human rights.” This was further emphasized by Resolution 15/9 of the Human Rights Council in September 2010.

In addition to contributing to human health and well-being, such a human right is closely related to ecosystem maintenance and management of water resources. In fact, adequately addressing the latter issues is instrumental to the realization of the human right to safe drinking water and sanitation. Pollution, water scarcity and climate catastrophes are some of the issues that may affect provision of drinking water. Adequate sanitation is also fundamental, as it helps to provide a healthy environment in addition to protecting surface or groundwater from pathogenic bacteria associated with human fecal pollution. Therefore, water-related issues may be addressed in relation to different topics, such as human rights, disaster-risk reduction, business, climate change, etc., all of which are framed to a certain extent by international or national laws.

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Photo: Bill Wegener

2 MODULE 2. DRIVERS AND IMPACTS OF CLIMATE CHANGE ON WATER-USE SECTORS

Photo: Thomas Millot

Goal

The objective of this chapter is to provide an update of the key assessment findings of the Fifth Assessment Report (AR5) of IPCC, as well as to highlight the observed and forecast impacts of climate variability and change on the hydrological cycle, water resource management and human societies.

2.1 Understanding drivers and the physical science basis of climate change

2.1.1 Natural and human-induced climate changes

Natural climate cycles and greenhouse gas variations

Earth's natural greenhouse effect, which results in the Earth's temperature being warmer than if it was heated only by direct sunlight, is due to GHGs such as water vapour, methane and carbon dioxide (CO_2) which are absorbing a part of the radiant energy of the sun. This process is critical to supporting life, but human activities - primarily the burning of fossil fuels and clearing of forests - have intensified the natural greenhouse effect, causing global warming since industrial times.

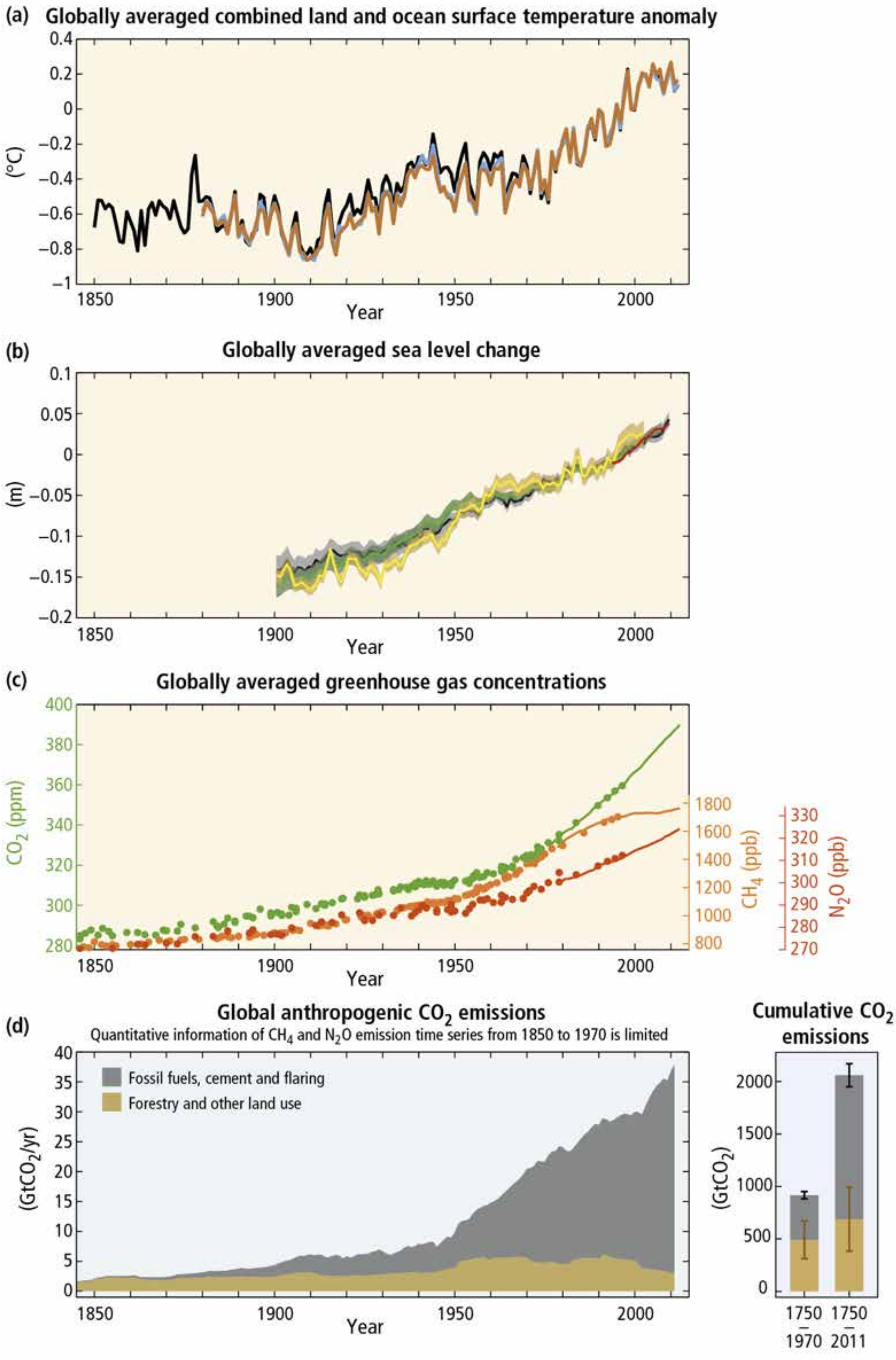
According to the Antarctic ice-core records of CO_2 concentration that now extend back 800,000 years at Dome C (Antarctica), atmospheric CO_2 levels have fluctuated between 170 and 300 parts per million (ppm) over the last 800,000 years; i.e. during the last 800,000 years and up to the industrial revolution and the massive combustion of fossil carbon, atmospheric CO_2 concentration remained below 300 ppm (Lüthi et al., 2009). There is a general agreement among the scientific community that the reconstructed cyclic variations of atmospheric CO_2 concentration correspond with the conditions of glacial and interglacial periods caused by the long-term variations of the earth's orbit around the sun (i.e. the Milankovitch cycles); which are influencing the amount of solar radiation hitting different latitudes and seasonal patterns. However, in the past two centuries, human activities have seriously altered the global carbon cycle due to CO_2 emissions in the atmosphere, exceeding natural fluctuations and the natural process by which carbon sinks can remove CO_2 from the atmosphere; i.e. the carbon sequestration in a natural reservoir (e.g. oceans, forests or swamps) that accumulates and stores some carbon-containing chemical compound for an indefinite period (see Laffoley et al., 2014).

Anthropogenic increase in CO_2 and global warming

In 2015 and for the first time in human history, the average concentration of CO_2 measured in the atmosphere at Mauna Loa Observatory (Hawaii) exceeded the symbolic figure of 400 ppm, and the atmospheric CO_2 reached 408 ppm in May 2016. Fossil-fuel combustion (oil, gas, coal) and deforestation - which releases the carbon stored in forests and particularly in tropical soils - has resulted in an increase of more than 120 ppm of CO_2 concentration in the atmosphere since pre-industrial times, of which half is since 1980 (Figure 2.1).

It is now accepted by the scientific climate community (i.e. IPCC) that CO_2 emitted by industrial activities is the main cause of global warming, although other human activities - such as livestock and rice cultivation - also release CO_2 and other GHGs - such as methane, which has an impact on the greenhouse effect 25 times greater than CO_2.

Figure 2.1: Observations (**panels a, b, c**) and emissions (**panel d**) of a changing global climate system. (**a**) Annually and globally averaged combined land and ocean surface temperature anomalies relative to the average for the period 1986 to 2005. Colours indicate different data sets. (**b**) Annually and globally averaged sea-level change relative to the average for the period 1986 to 2005 in the longest-running data set. Colours indicate different data sets. (**c**) Atmospheric concentrations of GHGs CO_2 (green), methane (CH_4, orange) and nitrous oxide (N_2O, red) determined from ice core data (dots) and from direct atmospheric measurements (lines). (**d**) Global anthropogenic CO_2 emissions from forestry and other land use as well as from burning of fossil fuel, cement production and flaring. Cumulative emissions of CO_2 from these sources and their uncertainties are shown as bars and whiskers, respectively, on the right-hand side. The global effects of the accumulation of CH_4 and N_2O emissions are shown in **panel c** (IPCC, 2014).



Leading scientists and economists agree that it is essential and urgent to stabilize and subsequently reduce the atmospheric CO_2 concentration, and UNFCCC set the limit at Cancun in 2010 of 450 ppm of CO_2 to commit to **a maximum temperature rise of 2 °C** above pre-industrial levels, and to consider lowering that maximum to 1.5 °C in the near future. This action is indeed essential in order to maintain options for successful adaptation measures at globally acceptable economic, social and environmental costs. However, despite the global mobilization of scientists, civil society and policy makers during the Climate Change Conference in Paris (COP 21) in December 2015, global warming may exceed 1.5 °C during the 21st century in many regions - the average global temperature for 2015 on land and ocean surfaces being already about 0.90 °C above the 20th-century average. This very abrupt warming - in comparison to past glacial/interglacial climate changes occurring naturally - therefore represents a major threat to biodiversity and to the survival of our human societies as we know them today, because it can generate considerable and irreversible effects that may locally exceed the adaptive capacity of many systems to survive (IPCC, 2014).

2.1.2 The effects of global warming on the climate system

According to IPCC AR5 Report, the evidence of human influence on the climate system has grown since the previous IPCC Fourth Assessment Report (AR4): Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, and in global mean sea-level rise; and it is *extremely likely* to have been the dominant cause of the observed warming since the mid-20th century. In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans (Figure 2.1). Impacts are due to observed climate change, irrespective of its cause, indicating the sensitivity of natural and human systems to changing climate.

Atmosphere

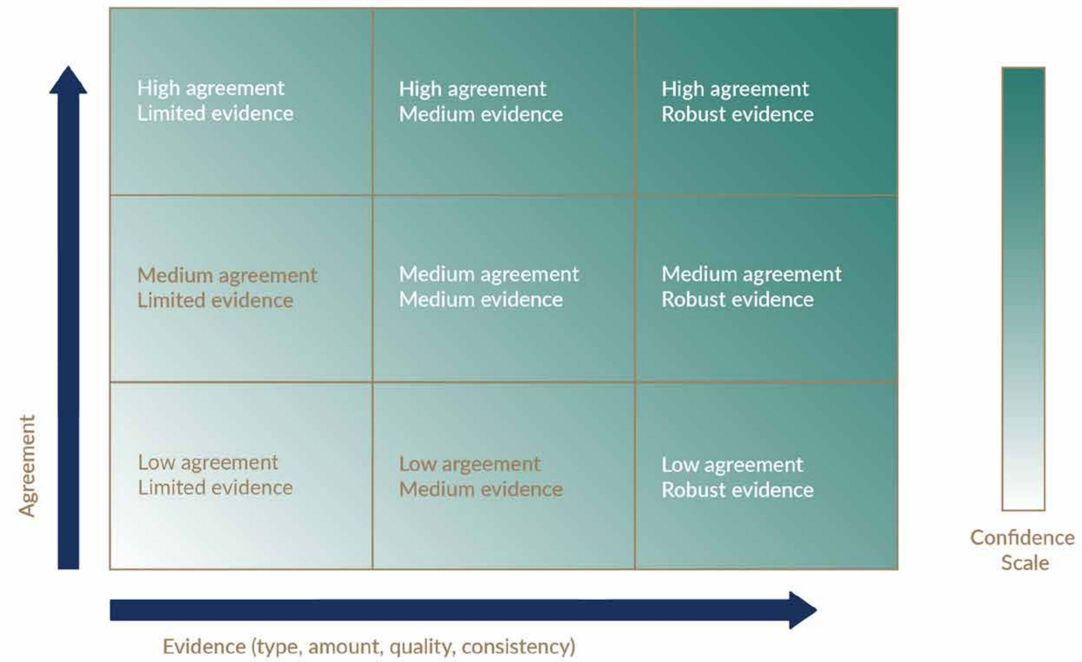
Each of the last three decades has been successively warmer at the earth's surface than any preceding decade since 1850. The globally averaged combined land and ocean surface temperature data, as calculated by a linear trend, show a warming of 0.85 °C during the period 1880 to 2012 (Figure 2.1). The total

> **It is *extremely likely* that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in GHG concentrations and other anthropogenic forcings.**

BOX 2.1

The importance of consistent and transparent treatment of uncertainties is clearly recognized by IPCC in preparing its assessments of climate change.
A level of confidence is expressed using five qualifiers: 'very low', 'low', 'medium', 'high', and 'very high'. It synthesizes the author teams' judgements about the validity of findings as determined through evaluation of evidence and agreement. Figure 2.2 depicts summary statements for evidence and agreement, and their relationship to confidence.

Figure 2.2: Summary statements for evidence and agreement, and their relationship to confidence



Likelihood, as defined in Table 2.1, provides calibrated language for describing quantified uncertainty. It can be used to express a probabilistic estimate of the occurrence of a single event or of an outcome (e.g. a climate parameter, observed trend, or projected change within a given range). Likelihood may be based on statistical or modelling analyses, elicitation of expert views, or other quantitative analyses.

Table 2.1: Likelihood Scale. Source: IPCC, 2010. https://www.ipcc.ch/report/ar4/wg1/uncertainty-guidance-note-for-the-fourth-assessment-report/

Term*	Likelihood of the Outcome
Virtually certain	99-100% probability
Very likely	90-100% probability
Likely	66-100% probability
About as likely as not	33-66% probability
Unlikely	0-33% probability
Very unlikely	0-10% probability
Exceptionally unlikely	0-1% probability

* Additional terms that were used in limited circumstances in AR4 (*extremely likely* - 95-100% probability, *more likely than not* - >50-100% probability, and *extremely unlikely* - 0-5% probability) may also be used in AR5 when appropriate.

increase between the average of the 1850–1900 period and the 2003–2012 period is 0.78 °C. In addition to robust multi-decadal warming, the globally averaged surface temperature exhibits substantial decadal and inter-annual variability due to natural climate variability. It is *virtually* certain that globally the troposphere has warmed and the lower stratosphere has cooled since the mid-20th century. *Confidence* in precipitation change averaged over global land areas since 1901 is *low* prior to 1951 and *medium* afterwards. Averaged over the mid-latitude land areas of the Northern Hemisphere, precipitation has *likely* increased since 1901 (*medium confidence* before and *high confidence* after 1951).

Ocean

Ocean warming dominates the increase in energy stored in the climate system, accounting for more than 90 percent of the energy accumulated between 1971 and 2010 (*high confidence*) with only about 1 percent stored in the atmosphere. On a global scale, the ocean warming is greatest near the surface, and the upper 75 m warmed by 0.11 °C per decade over the period 1971 to 2010. It is *very likely* that regions of high surface salinity, where evaporation dominates, have become more saline, while regions of low salinity, where precipitation dominates, have become fresher since the 1950s. These regional trends in ocean salinity provide indirect evidence of changes in evaporation and precipitation over the oceans and thus of changes in the global water cycle (*medium confidence*). There is no observational evidence of a long-term trend in the Atlantic Meridional Overturning Circulation (AMOC).

Since the beginning of the industrial era, oceanic uptake of CO_2 has resulted in acidification of the ocean; the pH of ocean surface water has decreased by 0.1 (*high confidence*), corresponding to a 26 percent increase in acidity. Changes in deep-sea chemistry and circulation can lead to significant differences in carbonate preservation and accumulation in oceanic sediments (i.e. the calcification process that captures carbon into the ocean system), but a recent overriding cause of change is ocean acidification combined with increasing seawater temperatures arising from climate change. These two impacts are expected to have a pronounced effect on the efficiency of the ocean carbon pumps. The capacity of the ocean water column to act as a sink for atmospheric carbon is therefore predicted to weaken in the future, and there is evidence that it may have already started (Doney et al., 2009).

Cryosphere

Over the last two decades, the Greenland and Antarctic ice sheets have been losing mass (*high confidence*). Glaciers have continued to shrink almost worldwide (*high confidence*). Northern Hemisphere spring snow cover has continued to decrease in extent (*high confidence*). There is *high confidence* that there are strong regional differences in the trend in Antarctic sea ice extent, with a *very likely* increase in total extent. Glaciers have lost mass and contributed to sea-level rise throughout the 20th century. The rate of ice mass loss from the Greenland ice sheet has very likely substantially increased over the period 1992 to 2011, resulting in a larger mass loss from 2002 to 2011 than from 1992 to 2011. The rate of ice mass loss from the Antarctic ice sheet, mainly from the northern Antarctic Peninsula and the Amundsen Sea sector of West Antarctica, is also *likely* larger from 2002 to 2011.

The annual mean Arctic sea ice extent decreased over the period 1979 (when satellite observations commenced) to 2012. The rate of decrease was *very likely* in the range 3.5 to 4.1 percent per decade. Arctic sea ice extent has decreased in every season and in every successive decade since 1979, with the most rapid decrease in decadal mean extent in summer (*high confidence*). For the summer sea ice minimum, the decrease was *very likely* in the range of 9.4 to 13.6 percent per decade (range of 0.73 to 1.07 million km^2 per decade). It is *very likely* that the annual mean Antarctic sea ice extent increased in the range of 1.2 to 1.8 percent per decade (range of 0.13 to 0.20 million km^2 per decade) between 1979 and 2012. However, there is *high confidence* that there are strong regional differences in Antarctica, with extent increasing in some regions and decreasing in others. There is *very high confidence* that the extent of Northern Hemisphere snow cover has decreased since the mid-20th century by 1.6 percent per decade for March and April, and 11.7 percent per decade for June, over the 1967 to 2012 period. There is *high confidence* that permafrost temperatures have increased in most regions of the Northern Hemisphere since the early 1980s, with reductions in thickness and areal extent in some regions. The increase in permafrost temperatures has occurred in response to increased surface temperature and changing snow cover.

Sea level

Over the period 1901 to 2010, global mean sea level rose by 0.19 m (Figure 2.1). The rate of sea-level rise since the mid-19th century has been higher than the mean rate during the previous two millennia (*high confidence*). It is *very likely* that the mean rate of global averaged sea-level rise was 1.7 mm/yr between 1901 and 2010, and 3.2 mm/yr between 1993 and 2010. Tide gauge and satellite altimeter data are consistent regarding the higher rate during the latter period. It is *likely* that similarly high rates occurred between 1920 and 1950. Since the early 1970s, glacier mass loss and ocean thermal expansion from warming together explain about 75 percent of the observed global mean sea-level rise (*high confidence*). Over the period 1993 to 2010, global mean sea-level rise is, with *high confidence*, consistent with the sum of the observed contributions from ocean thermal expansion, due to warming, from changes in glaciers, the Greenland ice sheet, the Antarctic ice sheet and land water storage.

Rates of sea-level rise over broad regions can be several times larger or smaller than the global mean sea-level rise for periods of several decades, due to fluctuations in ocean circulation. Since 1993, the regional rates for the Western Pacific are up to three times higher than the global mean, while those for much of the Eastern Pacific are near zero or negative. There is *very high confidence* that maximum global mean sea level during the last interglacial period (129,000 to 116,000 years ago) was, for several thousand years, at least 5 m higher than present, and *high confidence* that it did not exceed 10 m above present. During the last interglacial period, the Greenland ice sheet *very likely* contributed between 1.4 and 4.3 m to the higher global mean sea level, implying with *medium confidence* an additional contribution from the Antarctic ice sheet. This change in sea level occurred in the context of different orbital forcing and with high-latitude surface temperature, averaged over several thousand years, at least 2 °C warmer than at present (*high confidence*).

2.2 Understanding observed and projected impacts of climate variability and change on water resources

Evidence of observed climate change impacts is strongest and most comprehensive for natural systems. In many regions, changing precipitation or melting snow and ice are altering hydrological systems, affecting water resources in terms of quantity and quality (*medium confidence*). Many terrestrial, freshwater and marine species have shifted their geographic ranges, seasonal activities, migration patterns, abundances and species interactions in response to ongoing climate change (*high confidence*). Some impacts on human systems have also been attributed to climate change, with a major or minor contribution of climate change distinguishable from other influences (Figure 2.1). Assessment of many studies, covering a wide range of regions and crops, shows that negative impacts of climate change on crop yields have been more common than positive impacts, especially in high-latitude regions (*high confidence*).

2.2.1 Increasing temperature and changing precipitation patterns

Rising global average temperature is associated with widespread changes in weather patterns. Surface temperature is projected to rise during the 21st century under all assessed emission scenarios. The global mean surface temperature change for the period 2016–2035 relative to 1986–2005 will *likely* be in the range 0.3 °C to 0.7 °C (*medium confidence*). It is *very likely* that heatwaves will occur more often and last longer, and that extreme precipitation events will become more intense and frequent in many regions (IPCC, 2014).

Changes in precipitation in a warming world will not be uniform. The high latitudes and the equatorial Pacific are *likely* to experience an increase in annual mean precipitation by the end of this century. In many mid-latitude and subtropical dry regions, mean precipitation will *likely* decrease, while in many mid-latitude wet regions, mean precipitation will *likely* increase. Extreme precipitation events over most mid-latitude land masses and over wet tropical regions will *very likely* become more intense and more frequent as global mean surface temperature increases. Globally, it is *likely* that the area encompassed by monsoon systems will increase; monsoon precipitation is *likely* to intensify, and El Niño-Southern Oscillation (ENSO)-related precipitation variability on regional scales will *likely* intensify.

2.2.2 Extreme weather phenomena and increasing demand for water supply

According to IPCC (2014), changes in many extreme weather and climate events have been observed since about 1950. Some of these changes have been linked to human influences, including a decrease in cold temperature extremes, an increase in warm temperature extremes, an increase in extreme high sea levels and an increase in the number of heavy precipitation events in a number of regions. It is *likely* that the frequency of heatwaves has increased in large parts of Europe, Asia and Australia, and that human influence has more than doubled the probability of occurrence of heatwaves in some locations. There is *medium confidence* that the observed warming has increased heat-related human mortality and decreased cold-related human mortality in some regions. There are *likely* more land regions where the number of heavy precipitation events has increased than where it has decreased. There is *low confidence* that anthropogenic climate change has affected the frequency and magnitude of fluvial floods on a global scale. Impacts from recent climate-related extremes, such as heatwaves, droughts, floods, cyclones and wildfires, reveal significant vulnerability and exposure of some ecosystems and many human systems to current climate variability (*very high confidence*). Direct and insured losses from weather-related disasters have increased substantially in recent decades, both globally and regionally.

The increase in extreme weather phenomena such as heatwaves, floods and fluctuating rates of precipitation, all of which are associated with climate variability and change (and threaten food security), is occurring in a period of other global changes which impact the water cycle. Projections are that the world population will reach 9.1 billion in 2050 and that 2.4 billion of that population will live in sub-Saharan Africa (UN DESA, 2013). A very high demographic increase and rural exodus strengthen urbanization, while changing lifestyles place a very high demand on direct water use (drinking water, hygiene) and an even higher demand on indirect use (water for consumer services and goods).

UN Photo: Kibae Park

Humanity must therefore compete with an increased demand for fresh water for household and agricultural use - the latter accounting for approximately 70 percent of the water used worldwide - as well as for industrial use, the energy sector being the second largest water consumer. Worldwide, projections are for a 55 percent demand increase of water between 2000 and 2050 (OECD, 2012). This increase will mainly be in manufacturing (+400 percent), electricity production (140 percent) and household use (130 percent). Given OECD forecasts and these competing demands, it will hardly be possible to increase the volumes of water required for irrigation, hence the importance of using waste water in agriculture.

2.2.3 Rising sea levels, submersion and salinization

It is *very likely* that AMOC will weaken during the 21st century. The ocean will continue to warm and acidify, and global mean sea level to rise. The rise in sea levels as a result of global warming (Figure 2.1) will increase coastal erosion, threatening many coastal zones and megacities. According to UN Environment, half of the world's population lives less than 60 km from the sea and three-fourths of all cities are located on the coast. The threat is not only physical (deaths, injuries, illnesses, disruption of the means of livelihood), but also financial and political. It concerns low-elevation coastal zones and low-lying small islands – particularly susceptible to coastal flooding and rising sea levels (IPCC, 2014).

Global warming increases the risk of maritime submersion (temporary inundation of coastal zones) because of the combined effects of rising sea levels and the severity of extreme climate events. These devastating events cause immense human, material and environmental damage. They can damage sanitation infrastructures, leading to the overflow of septic tanks and the treatment basins of wastewater treatment plants, contaminating local potable water and regional freshwater resources (e.g. river or groundwater diffuse pollution). The projected increase in the intensity of tropical cyclones, exacerbated by sea-level rise and the degradation of ecosystems that provide protection from storms and flooding, will pose a direct threat to human lives and coastal settlements. Without adaptation, IPCC AR5 projects with *high confidence* that "hundreds of millions of people will be affected by coastal flooding and will be displaced due to land loss by year 2100." Coastal communities will also be adversely affected by the more gradual degradation of land, soils, freshwater resources, and coastal and estuarine ecosystems

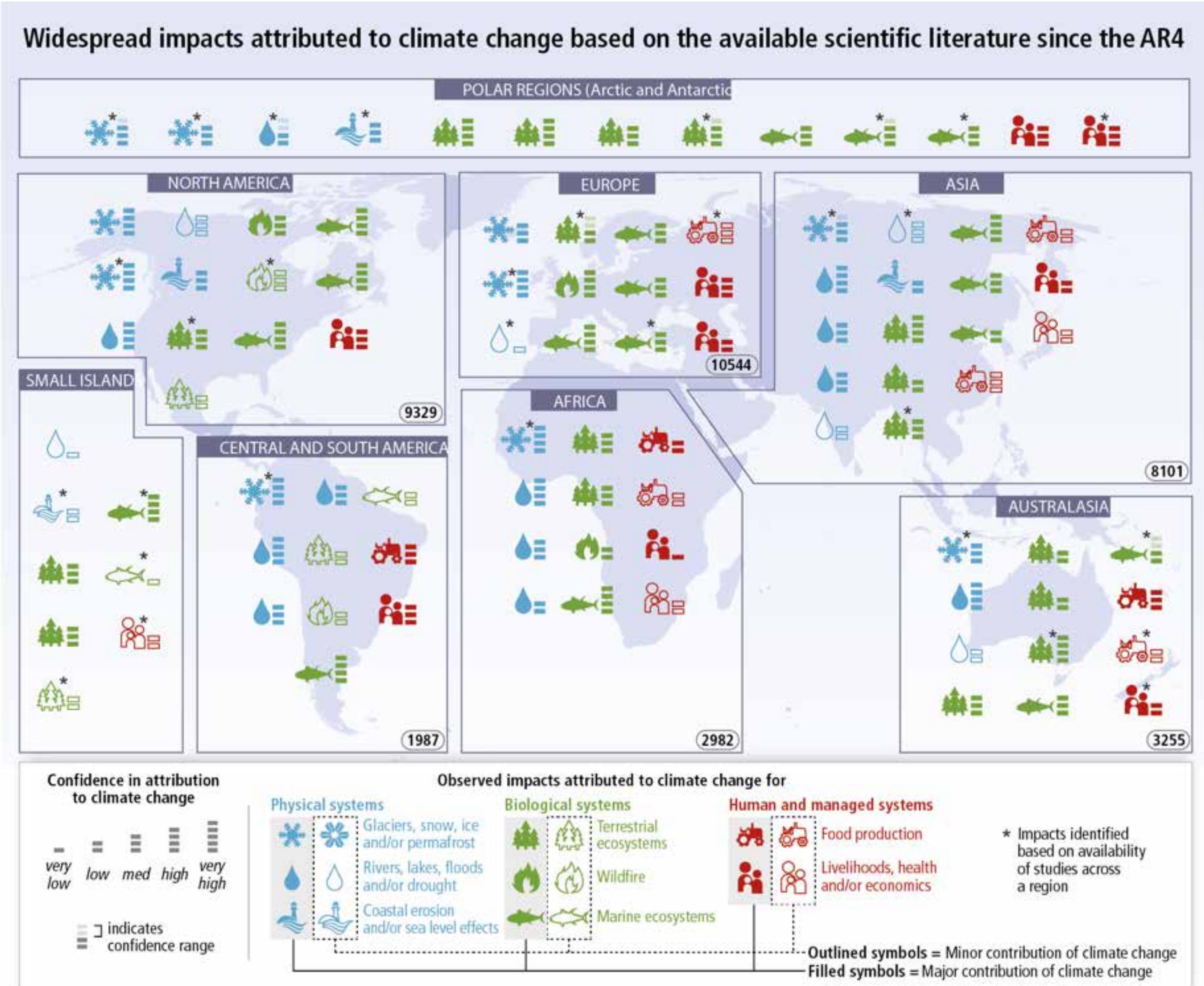
Salinization is the accumulation of water-soluble salts in the soil or water table to a level that impacts agricultural production (reducing soil permeability), environmental health and economic welfare. Surface salinization can result from sea-level rise, which contributes to saltwater inundation of freshwater resources, but also from unsuitable irrigation practices and from inadequate drainage.

2.3 Sectors and users

Climate change will amplify existing risks and create new risks for natural and human systems. Climate change will significantly reduce surface-water and groundwater resources in most dry subtropical regions, thus intensifying competition for water among agriculture, ecosystems, settlements, industry and energy production, and affecting regional water, energy and food security. Risks are unevenly distributed and are generally greater for disadvantaged people and communities in countries at all levels of development (IPCC, 2014). In fact, water is the first primary resource impacted by climate change, a phenomenon which will increase the risks related to its distribution and availability. Reduction in the water resources of many regions, due in part to climate variability and change, can have widespread consequences for human activity in terms of access to potable water, and therefore to health, food security, agriculture, economic development and social progress.

Without fundamental reforms and significant improvements in water management (e.g. wastewater reuse and recycling), the situation could intensify by 2050, since available water supplies are diminishing because of human activity, and they could also become more unreliable because of climate change. Projections are that in 2030 the world will be confronted by a general water deficit of 40 percent if the situation remains unchanged (2030 WRG). According to

Figure 2.3: Map showing that there are substantial impacts in recent decades now attributed to climate change. Symbols indicate categories of attributed impacts, the relative contribution of climate change (major or minor) to the observed impact, and confidence in attribution. Numbers in ovals indicate regional totals of climate change publications from 2001 to 2010, based on the Scopus bibliographic database for publications in English with individual countries mentioned in title, abstract or key words (as of July 2011). These numbers provide an overall measure of the available scientific literature on climate change across regions; they do not indicate the number of publications supporting attribution of climate change impacts in each region. Studies for polar regions and small islands are grouped with neighbouring continental regions (IPCC, 2014).



OECD's baseline scenario on the future of the environment, by 2050, 3.9 billion people (over 40 percent of the world population) will probably be living in water catchment areas with high water stress (OECD, 2012).

2.3.1 Regional impacts on plant production

According to IPCC (2014), climate change has affected the natural and human systems of all continents and oceans (Figure 2.3). In many regions, changes in the rainfall patterns and/or the melting of snow and ice disrupt water systems and affect the quality and quantity of the supply.

Glaciers continue to shrink almost worldwide because of climate change, affecting water flow and downstream water reserves. Global warming also leads to melting of permanently frozen ground (permafrost) in high latitudes as well as in high altitudes.

Climate change has negatively affected the yield of wheat and corn cultivation in many regions and on an international scale. The impacts observed in rice and soya cultivation are fewer in the major rice and soya producing regions and have more to do with the means of production related to food security than with access or other food security components (Figure 2.1). In fact, several cases of sudden increases in the price of food and grain followed extreme climate events in the main producing areas, which suggests that prevailing markets are sensitive to such events.

Recent extreme weather events, such as heatwaves, droughts, floods, hurricanes and wildfires, highlight the immense vulnerability of certain ecosystems and human systems to them. The impacts of such events include damage to ecosystems, disruption of food production and water supply, and damage to human infrastructures and institutions. The impacts of climate change are generally water related (drought or flooding). The occurrence of these natural phenomena and of water-related crises may generally threaten food security and furthermore increase the risk of conflict and epidemics.

2.3.2 Climate catastrophes and reduced water quality

The impacts of extreme climate events additionally affect human well-being (destruction of housing, and death). In urban areas, climate change is projected to increase risks for people, assets, economies and ecosystems, including risks from heat stress, storms and extreme precipitation, inland and coastal flooding, landslides, air pollution, drought, water scarcity, sea-level rise and storm surges (*very high confidence*).

Rural areas are expected to experience major impacts on water availability and supply, food security, infrastructure and agricultural incomes, including shifts in the production areas of food and non-food crops around the world (*high confidence*). By extension, this can lead to population displacements (climate refugees), which can lead to disputes over the use of land and water.

The high vulnerability of our societies to climate catastrophes (e.g. tornados and landslides) can also be associated in even greater measure to natural disasters such as earthquakes, tsunamis and volcanic eruptions, which can lead to the risk of industrial accidents that could jeopardize the water supply; because of the vulnerability of potable water systems and sanitation systems in relation to weather catastrophes which can induce widespread diffuse pollution from industrial and domestic sources.

2.3.3 Ecosystem services and livelihoods

Human societies benefit in numerous ways from ecosystem services. These can be grouped into

Photo: Marcus Kauffman

four broad categories: *provisioning*, such as the production of food and water; *regulating*, such as the control of climate and disease; *supporting*, such as nutrient cycles and crop pollination; and *cultural*, such as spiritual and recreational benefits. Risks of harmful impacts on ecosystems (services) and human systems increase with the rates and magnitudes of warming, ocean acidification, sea-level rise and other dimensions of climate change (*high confidence*, IPCC, 2014). A large fraction of terrestrial, freshwater and marine species faces increased extinction risk due to climate change during and beyond the 21st century, especially as climate change interacts with other stressors (*high confidence*). Global marine species redistribution and marine biodiversity reduction in sensitive regions, under climate change, will challenge the sustained provision of fisheries productivity and other ecosystem services, especially at low latitudes (*high confidence*). Marine ecosystems, especially coral reefs and polar ecosystems, are at risk from ocean acidification (*medium to high confidence*). Carbon stored in the terrestrial biosphere is susceptible to loss to the atmosphere as a result of climate change, deforestation and ecosystem degradation (*high confidence*). Coastal systems and low-lying areas will increasingly experience submergence, flooding and erosion throughout the 21st century and beyond, due to sea-level rise (*very high confidence*).

The proportions of the global population that will experience water scarcity and be affected by major river floods are projected to increase with the level of warming in the 21st century (*robust evidence, high agreement*). Climate change throughout the 21st century is projected to reduce renewable surface-water and groundwater resources in the driest subtropical regions (*robust evidence, high agreement*), intensifying competition for water among sectors (*limited evidence, medium agreement*). All aspects of food security are potentially affected by climate change, including food production, access, use and price stability (*high confidence*). Until mid-century, projected climate change will impact human health mainly by exacerbating health problems that already exist (*very high confidence*).

2.3.4 Human societies and human rights

From a poverty perspective, climate change impacts are projected to slow down economic growth, make poverty reduction more difficult, further erode food security, and prolong existing poverty traps and create new ones, the latter particularly in urban areas and emerging hotspots of hunger (*medium confidence*). Climate change is projected to increase displacement of people (*medium evidence, high agreement*). Climate change can indirectly increase risks of violent conflict by amplifying well-documented drivers of these conflicts, such as poverty and economic shocks (*medium confidence*) (IPCC, 2014).

Climate change poses an enormous threat to the lives and well-being of individuals and communities across the world. The observed and predicted climatic changes will adversely affect millions of people and the ecosystems, natural resources and physical infrastructure upon which they depend. These harmful impacts include sudden-onset events that pose a direct threat to human lives and safety, as well as more gradual forms of environmental degradation that will undermine access to clean water, food and other key resources that support human life. Therefore, climate change will have a profound effect on the enjoyment of human rights for billions of people, including on HRWS (Box 1.1).

According to a recent UN Environment report on climate change and human rights, the impacts of climate change on freshwater resources, ecosystems and human settlements are already undermining access to clean water, food, shelter and other basic human needs; interfering with livelihoods; and displacing people from their homes. Even if the global temperature remains within the international goal of 2 °C of global warming, these impacts will expand dramatically in the coming decades (UN Environment, 2015). As also highlighted in COP 21 - Paris Agreement - these impacts constitute a serious interference with the exercise of fundamental human rights, such as the rights to life, health, water, food, housing and an adequate standard of living. Moreover, mitigation, adaptation and geoengineering measures can also adversely affect the exercise of human rights. Some hydroelectric and biofuel projects have, for instance, resulted in human rights violations with the displacement of local/indigenous peoples, the destruction of local ecosystems and livelihoods, food shortages and price shocks, or additional water stress and scarcity. There is eventually a high risk of human rights violations resulting from the implementation of resettlement programmes for those who are displaced or at risk of displacement due to climate change and variability (e.g. sea-level rise and extreme events such as flood and droughts) and a corresponding need to ensure that such programmes are undertaken with adequate input and consent from those who are relocated; whereas climate change will likely have a devastating effect on many of the ecosystems that indigenous peoples rely on for their livelihoods and cultural identity (UN Environment, 2015).

Summary

Recent anthropogenic emissions of GHGs - and especially CO^2 emissions from industry - are causing changes in the climate which will have widespread impacts on water resources on all continents for centuries. A better understanding of the physical science basis of climate change can be used by the water sector to develop local/regional adaptation and mitigation complementary strategies, based on innovative technical approaches to sustainable water management solutions.

Suggested reading

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Photo: Ant Rozetsky

3 MODULE 3. STRATEGY DEVELOPMENT AND PLANNING FOR ADAPTATION

Photo: NASA

Goal

The aim of this module is to familiarize participants with the basic principles and steps of adaptation planning. The content provides a basic introduction to adaptation, and briefly explores links between mitigation and adaptation action. Institutional frameworks guiding global adaptation actions are explained. The module also covers the various national and local-level actions to consider when planning for adaptation.

3.1 Introduction

2015 was the warmest year on record with temperatures about 1 °C above pre-industrial levels.[1] Each month of the first half of 2016 broke further records: The average temperature for the full six-month period was 1.3 °C higher than the average in the late 19th century. This was partly due to the extremely strong El Niño event in 2015-2016 which was among the strongest El Niños on record.[2]

The increasing temperatures put marine ecosystems under further stress, with coral reefs bleaching at record rates. Since 2014 the world has been experiencing one of its longest coral-bleaching events. Scientists estimate that 35 percent of corals on the northern and central Great Barrier Reef are dying or are already dead, and 80 percent of corals in Kiribati have died due to mass bleaching. The global average sea level from January to November 2015 was the highest ever recorded by satellites.[3]

Meanwhile, the number of category 4 and 5 storms striking land has doubled. All impacts are due to ocean-surface warming related to human-caused climate change. According to WMO, 2015 also saw some of the most intense tropical cyclones ever recorded, with Pam, a category 5 storm, making landfall near Vanuatu, Mexico, and hurricane Patricia reaching a peak intensity of 346 km per hour — the strongest storm ever to emerge in either the Eastern Pacific or the Atlantic basin. A very rare cyclone, Chapala, also churned ashore in Yemen. This event was immediately followed by a similar cyclone - Megh.

The increase in extreme events was identified as a new challenge for water managers in Agenda 21, UNCED (the Earth Summit) in Rio de Janeiro (1992). The need to address climate change and increasing climate variability is a key issue in the global water debate.

According to António Guterres, the UN Secretary-General, the actions to cope with climate change require urgent and far more ambitious action to cut emissions by half by 2030 and reach net zero emissions by 2050. "Specifically, we need to end deforestation and plant billions of trees; drastically reduce the use of fossil fuels and phase out coal by 2050; ramp up installation of wind and solar power; invest in climate-friendly sustainable agriculture; and consider new technologies such as carbon capture and storage. The coming period is critical. We must meet the Paris commitments to bend the emissions curve by 2020."[4]

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[1] World Meteorological Organization, 2016. WMO Statement on the Status of the Global Climate in 2015, http://library.wmo.int/pmb_ged/wmo_1167_en.pdf (accessed November 2016).

[2] NOAA Earth System Research Laboratory 2016. 'Unprecedented effort launched to discover how El Niño affects weather', 5 February 2016, http://www.esrl.noaa.gov/psd/news/2016/020516.html (accessed November 2016).

[3] 'Towards a Global Resilience Agenda Action on Climate Fragility Risks', p. 8, https://www.climate-diplomacy.org/publications/towards-global-resilience-agenda-action-climate-fragility-risks (accessed November 2016).

[4] 8 October 2018. Statement by the Secretary-General on the IPCC Special Report Global Warming of 1.5 °C.

IWRM should form the encompassing paradigm for coping with natural climate variability, and the prerequisite for adapting to the consequences of global warming and associated climate change under conditions of uncertainty. Management of land and water resources presents the major input in addressing all development priorities; therefore, IWRM planning processes must incorporate a dimension on climate change adaptation. The following sections provide elements of guidance available from a range of key international institutions engaged in the adaptation debate. Furthermore, various adaptation strategies are explored.

3.2 Adaptation to climate change

Adaptation refers to adjustments in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices and structures to minimize potential damages, or to benefit from opportunities associated with climate change.

'Enabling conditions' are the conditions that affect the feasibility of adaptation and mitigation options, and can accelerate and scale up systemic transitions that would limit temperature increase to 1.5 °C and enhance capacities of systems and societies to adapt, while achieving sustainable development, eradicating poverty and reducing inequalities. Enabling conditions include finance, technological innovation, strengthening policy instruments, institutional capacity, multilevel governance, and changes in human behaviour and lifestyles. They also incorporate inclusive processes and attention to power asymmetries and unequal opportunities.[5]

The diverse strategies and measures that are available and appropriate for addressing adaptation include a wide range of actions that can be categorized as structural, institutional, ecological or behavioural. Some actions to develop adaptative capacity are described in 3.2.1.

[5] IPCC, 2018. Annex I: Glossary (R. Matthews [ed.]). In: Global warming of 1.5 °C. An IPCC Special Report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global GHG pathways, in the context of strengthening the global response to the threat of climate change, sustainable development and efforts to eradicate poverty.

3.2.1 Elements of adaptation

Adaptation activities span five general components:

- Observation of climatic and non-climatic variables;
- Assessment of climate impacts and vulnerability;
- Planning;
- Implementation; and
- Monitoring and evaluation of adaptation actions.

Adaptation to the impacts of climate change may be undertaken across various regions and sectors, and at various levels.[6] An important component of the strategy is to engage stakeholders of national, regional, multilateral and international organizations, the public and private sectors, civil society and other relevant actors.

In adaptation actions there is more focus on the water sector, biodiversity, forestry, agriculture, infrastructure and human settlements, while in mitigation the majority of the action is developed in forestry, energy and transport.[7]

Any adaptation action promoted has impact in the other areas and sectors that have to be considered. For example, improvements in irrigation efficiency would need to be supplemented with ancillary activities, such as shifting to crops that require less water, and improving soil and moisture conservation (Fader et al., 2016; Hong & Yabe, 2017; Sikka et al., 2018). Currently, the feasibility of improving irrigation efficiency is constrained by issues of replicability across scale and sustainability over time (Burney & Naylor, 2012), institutional barriers and inadequate market linkages (Pittock et al., 2017).[8]

[6] https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/what-do-adaptation-to-climate-change-and-climate-resilience-mean

[7] Medidas de Adaptación y mitigación frente al cambio climático en América Latina y el Caribe: Una revisión general Luis Sánchez Orlando Reyes, Unidad de Cambio Climático de la División de Desarrollo Sostenible y Asentamientos Humanos de la Comisión Económica para América Latina y el Caribe (CEPAL).

[8] Schultz, L., Steg, T., Sugiyama et al., 2018. Strengthening and implementing the global response. In: Global warming of 1.5 °C. An IPCC Special Report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global GHG emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development and efforts to eradicate poverty, Chapter 4.

Figure 3.1: Elements of adaptation

The implementation of IWRM would need to take into consideration pre-existing social, economic, historical and cultural contexts (Merrey, 2009; Mehta et al., 2014). IWRM promotes coordinating groundwater, surface-water abstractions, flood management, energy production, navigation and water quality, among other aspects, working at basin level.

3.2.2 Adaptation and mitigation

Climate change adaptation and mitigation efforts must be applied as complementary – not exclusive options. The reasons for this lie in the recognition that even if the global community successfully manages to mitigate climate change by reducing GHG emissions, the climate is still expected to warm for several decades, with all the projected implications for the water cycle. Therefore, mitigation is not enough. Yet adaptation alone is also not a sufficient answer to the problem, as adaptation options have limits, especially if certain levels of warming are exceeded. Figure 3.2 illustrates this complementary approach and its net benefit for various degrees of warming.

3.3 Climate change adaptation: The institutional framework

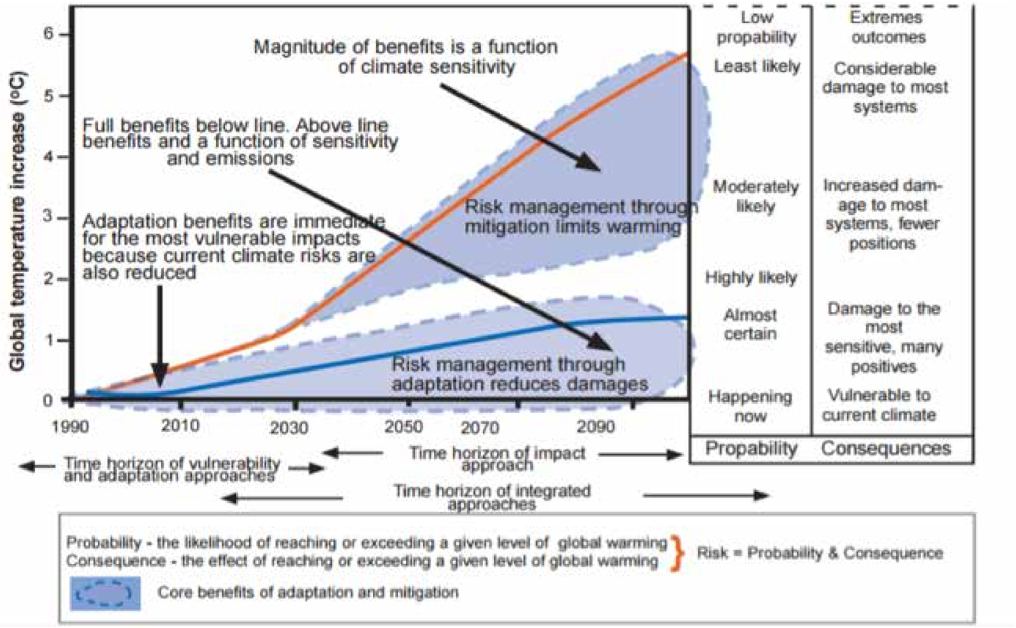
There is growing recognition that climate change adaptation strategy requires actions that consider many sectors, including: water, energy, agriculture, transportation, housing and others. These challenges indicate that it is necessary to focus on the key interactions between the various stakeholders to improve adaptation activities at national, intergovernmental and transnational levels, through sharing knowledge, best practices, recognizing successful actions, and improving transparency and accountability.[9] International institutions working on climate governance, such as UNFCCC and the Paris Agreement, help set the overall global strategy in adapting to climate change.

3.3.1 Guidance from UNFCCC

UNFCCC addresses adaptation through Article 4 by calling on Parties to “formulate, implement, publish and regularly update national and, where appropriate, regional programmes containing

[9] T. Hale and L. Chambers, ‘Design Considerations for a Registry of Sub- and Non-State Actions in the UN Framework Convention on Climate Change’, Oxford (2014).

Figure 3.2: Risk management through adaptation and mitigation (adapted from source: IPCC, 2007a, Figure 2.1)



measures to mitigate climate change [...] and measures to facilitate adequate adaptation to climate change" (UNFCCC, 1994). A series of programmatic elements on adaptation planning have been developed under UNFCCC with inputs from various UN organizations and other international mechanisms. These processes play an essential role in promoting the climate change adaptation agenda and have the potential to inspire adaptation actions in the water sector.

3.3.2 Paris Agreement

At the Paris Agreement climate conference (COP 21 in 2015), the participants agreed to place emphasis on bottom-up action: Parties agree, "to uphold and promote regional and international cooperation in order to mobilize stronger and more ambitious climate action by all Parties and non-Party stakeholders, including civil society, the private sector, financial institutions, cities and other subnational authorities, local communities and indigenous peoples."[10] The Paris Agreement requires all Parties to put forward their best efforts through Nationally Determined Contributions (NDCs) and to strengthen these efforts in the years ahead. Following the adoption of the Paris Agreement, the States commit to the development of national-level plans such as NDCs, to set a baseline for emissions, to regularly report on their emissions and on their implementation efforts to reduce these emissions.[11]

3.4 Planning for adaptation

Examples of strategies for adaptation actions in the water sector:

- IWRM at basin level
- Land management
- Changes in use and efficiency patterns
- Water recycling
- Improvements in irrigation techniques
- Improvements in infrastructure in water management
- Increase of dryland agriculture
- Improvement of water storage and conservation techniques
- Improvement of sustainable groundwater extraction techniques
- Water leakage reduction
- Rainwater collection
- Water transfer
- Risk management related to precipitation
- Water assignment by sector
- Desalinization

In this section, we cover some existing tools and processes, at national and local levels, to consider when developing a strategy for climate change adaptation in the water sector.

[10] Preamble, Decision 1/COP 21.

[11] Paris Agreement, http://unfccc.int/paris_agreement/items/9485.php

3.4.1 National Adaptation Programmes of Action (NAPA)

NAPAs provide a process for LDCs to identify priority activities that respond to their urgent and immediate needs with regard to adaptation to climate change. The rationale for NAPAs rests on the limited ability of LDCs to adapt to the adverse effects of climate change. In order to address the urgent adaptation needs of LDCs, a new approach was needed that would focus on enhancing adaptive capacity to climate variability, which would help to address the adverse effects of climate change. NAPAs take into account existing coping strategies at the grass-roots level, and build upon them to identify priority activities, rather than focusing on scenario-based modelling to assess future vulnerability and long-term policy at state level.

The steps for the preparation of NAPAs include:

- 1. Synthesis of available information;
- 2. Participatory assessment of vulnerability to current climate variability and extreme events, and of areas where risks would increase due to climate change;
- 3. Identification of key adaptation measures as well as criteria for prioritizing activities; and
- 4. Selection of a prioritized shortlist of activities.

The development of a NAPA also includes short profiles of projects and/or activities intended to address urgent and immediate adaptation needs of LDC Parties. NAPA is an important resource as it lays out the national-level strategy towards adaptation which can provide water managers with an important reference when designing their own projects.

3.4.2 Climate risk screening

Climate risk screening is an integral part of efforts to ascertain current and future vulnerabilities and risks related to climate change. It is a prerequisite for identifying and designing adaptation measures, and an important element in the process of integrating, or mainstreaming, climate change adaptation into development projects, planning and policy processes.[12]

There are different tools to be used at national or local levels, in programmes, policy or plans. Some of the climate risk screening and assessment tools were listed by UN Environment and CC DARE (Climate Change Adaptation and Development Initiative). See Table 3.1 for a list of tools.

[12] 'Climate Risk Screening Tools and Their Application: A guide to the Guidance', UN Environment Risoe Centre, September 2011, p. 5, http://orbit.dtu.dk/files/6238714/Climate%20Risk%20Screening%20Tools.pdf

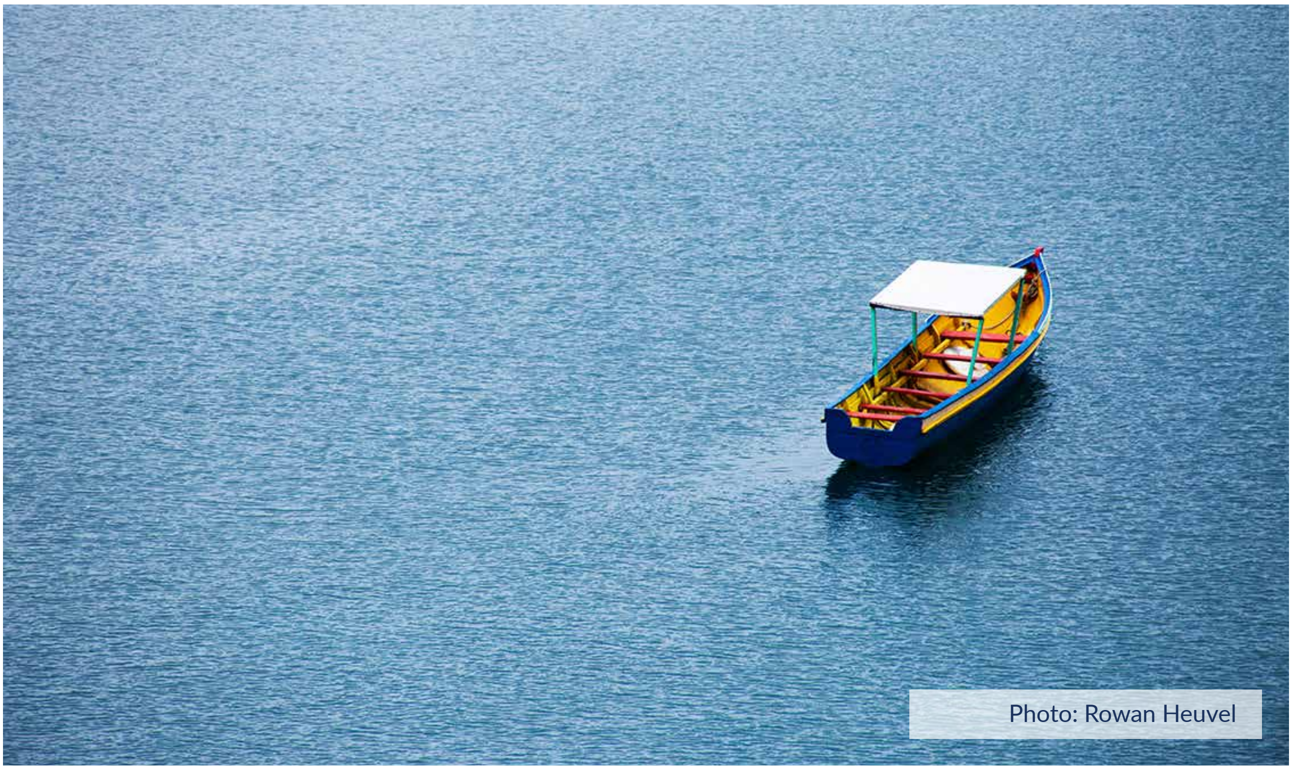


Photo: Rowan Heuvel

Table 3.1: Overview of available climate risk screening and assessment tools (in alphabetical order) Source: Trærup & Olhoff

Climate risk screening tools	Organization/ Institution	Target audience	Approach	Summary
Assessment and Design for Adaptation to Climate Change – A Prototype Tool (ADAPT)	World Bank	Policy makers, development project planners and managers	Software-based approach integrating climate databases and expert assessments	Carries out risk through a 5-lev to minimize risk resources. The biodiversity.
Adaptation Wizard	UK Climate Impacts Programme	Planners and managers, UK	User-friendly info and structuring computer-based tool following a risk-based approach	5-step process identify options developing cou of real use for c
Climate Change Adaptation through Integrated Risk Assessment (CCAIRR)	Asian Development Bank	Development project planners and managers	Risk and case study-based approach	The approach c Capacity assess knowledge data mainstreaming,
Climate change and Environmental Degradation Risk and Adaptation assessment (CEDRA)	Tearfund	Development project planners and managers	Participatory process for multi-stakeholder consultations	The tool assists may pose a risk the decisions to
Climate-FIRST (Climate Framework Integrating Risk Screening Tool)	Asian Development Bank	Development project planners/ managers	Risk assessment	Climate-risk scr projects/progra
Climate Risk Impacts on Sectors and Programmes (CRISP)	Department for International Development (DFID)	Policy makers, project/ programme managers	Sector-based climate risk assessment methodology	Structuring fran screening of DF impacts at the s
Climate-proofing for Development	GIZ	Programmes and programme managers	Process-based tool	The tool enable programmes, ar by climate chan these changes.

(2011)

	Level	Costing exercise included	Link/References
analysis at the planning and design stage, el flag classification and proposes options ks + guides project designers to appropriate focus thus far is on agriculture, irrigation and	Project	No	http://sdwebx.worldbank.org/climateportal/
to assess vulnerability to climate change and s to address key climate risks. Needs to take ntry context into consideration in order to be developing countries.	Organization	Yes	www.ukcip.org.uk/index.php?option=com_content&task=view&id=147&Itemid=297
omprises 5 main components: sment and strengthening, review of a and tools, Rapid Risk Assessment, and monitoring and evaluation.	Programme	Yes	https://www.adb.org/sites/default/files/publication/28796/climate-proofing.pdf
s to prioritize which environmental hazards to existing project locations, and supports adapt projects or start new ones.	Project	No	https://learn.tearfund.org/~/media/files/tilz/topics/environmental_sustainability/cedra_version_2/01cedra_book_and_forms/cedra_main_document.pdf?la=en
reening software tool for rapid assessment of mmes risk potential.	Project & programme	N/A	Not yet available
mework developed for the portfolio FID activities in Kenya. Assesses climate sector level.	Programme & sector	Yes	Not available
es an analysis of policies, projects and nd identifies risks and opportunities posed ge, and helps to identify measures to tackle	National, sectoral, project and local	Yes	http://www.gtz.de/en/themen/umwelt-infrastruktur/umweltpolitik/31288.htm

Successful examples:

In the case of Mali, they applied the Climate Proofing for Development tool to identify adaptation options in agriculture. This determined measures such as promotion of efficient water use, erosion control, diversification, and preparation to evade pests and diseases in agriculture and livestock, among others.

In the case of Togo, they used a climate risk screening tool to identify the most vulnerable crops; built strategies to reduce the amount of soil washed away by floods; and promoted the practice of farming and market gardening in the dry season, which provides additional income to women's groups and youth. Additionally, water reservoirs were rehabilitated to reduce rural poverty.[13]

3.4.3 Carbon-neutral and green measures

Carbon neutrality refers to actions that promote net zero carbon emissions by matching a measured quantity of carbon released with an equivalent amount sequestered or offset, or by buying enough carbon credits to make up the difference.[14] It is used in the context of carbon dioxide-releasing processes associated with transportation, energy production and industrial processes such as production of carbon-neutral fuel.

Carbon neutrality projects play an important role in the creation of sustainable supply chains and include other GHGs measured in terms of their carbon dioxide equivalence (CO_2e) - the impact a GHG has on the atmosphere expressed in the equivalent amount of CO_2. The other GHGs regulated by the Kyoto Protocol are: methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulphur hexafluoride (SF_6). UN proposes a focus on good practices across different sectors and their ability to stimulate economic activity and development, while reducing emissions.[15]

There is no single solution but multiples strategies: The International Energy Agency reports (2016) that end-use fuel and electricity efficiency could save 6.8 gigatonnes of CO_2, and power generation efficiency and fossil-fuel switching could save another 0.3 gigatonnes of CO_2 by 2030. Countries and other actors are already applying policies that are beneficial to both sustainable development and climate mitigation. About half the countries in the world have national policies for promoting more efficient use of energy in buildings. About half are working on improving the efficiency of appliances and lighting. Other national policies and measures are promoting electricity generation with renewable energy, reducing transport demand and shifting transport modes, reducing process-related emissions from industry, and advancing sustainable agriculture.

Successful examples:

Costa Rica aims to be fully carbon-neutral by 2021. In 2004, 46.7 percent of Costa Rica's primary energy came from renewable sources. By 2006, 94 percent of its electricity was generated from hydroelectric power, wind farms and geothermal energy.[16] A 3.5 percent tax on gasoline in the country is used for payments to compensate landowners for growing trees and protecting forests, and its government is making further plans for reducing emissions from transport, farming and industry. Costa Rica also ran on 100 percent renewable energy for more than 150 days, starting in June 2016, demonstrating that life without fossil fuels is possible - for small countries, at least. The country has been powered on a mix of hydro, geothermal, wind and solar energy, with hydro power providing about 80.27 percent of the total electricity for the month of August. Geothermal plants contributed roughly 12.62 percent of electricity generation in August, while wind turbines provided 7.1 percent, and solar 0.01 percent. As in 2015, when Costa Rica managed to power itself for a total of 299 days

[13] CC DARE initiative, UN Environment and UNDP, Success Stories http://www.adaptationlearning.net/sites/default/files/resource-files/CC%20DARE_Country%20Project%20progress%20and%20Overview_2_2.pdf

[14] Projects which sell carbon credits include wind farms which displace fossil fuel, household device projects which reduce fuel requirements for cooking stoves and boiling water in low-income households, forest protection from illegal logging, methane capture from landfill gas and agriculture, reforestation for smallholder farmers, and run-of-river hydropower and geothermal energy. To demonstrate the capture requires third-party standards such as the Verified Carbon Standard (VCS), Gold Standard, Climate Action Registry (CAR), American Carbon Registry (ACR) and the Clean Development Mechanism (CDM), to validate and verify their claims.

[15] UN Environment News Centre, https://www.unenvironment.org/news-and-stories/press-release/united-nations-agencies-funds-and-programmes-make-progress-towards

[16] UN Environment Climate Neutral Network: Costa Rica, retrieved on 20 December 2018.

without burning oil, coal or natural gas, 2016's milestone was helped by heavy rainfalls at the country's four hydroelectric power facilities.

UN programmes and agencies also rose to the challenge of becoming carbon-neutral; at the end of 2015, 18 UN system organizations reported having an Emission Reduction Strategy, and at least nine are either implementing an environmental management system or reached the highest standards in building management. As many as 21 organizations have gone further and have become climate-neutral through the purchase of carbon credits, with one further agency offsetting from its headquarters.[17]

UN's inventory accounts for six GHGs (CO_2, CH_4, N_20, HFCs, PFCs and SF_6) that are covered by the Kyoto Protocol. Hydrochlorofluorocarbons (HCFCs) are not covered by Kyoto but are governed by the Montreal Protocol and are reported under the 'optional emissions' category. GHG emissions are reported separately for each gas, both in terms of their mass and as an aggregate using the common comparable unit of CO_2e, based on the global warming potential of each gas. The reductions have come about through increased efficiencies in the use of fuel, electricity, water and consumables; a new car-pooling system is just one example. Also, travelling was reduced with an interactive remote meeting system that avoided travelling 38 million km. This has resulted in savings of 24 million kg of CO_2.

FAO Latin America reduced paper usage by 47 percent between 2011 and 2013 by changing the print preferences in all computers, and is now recycling 350 kg of glass, paper, cardboard, Tetra Pak, cans and plastic bottles per month.[18]

The **City of Adelaide**[19] decreased carbon emissions by 20 percent between 2007 and 2013. This reduction occurred over a period when economic growth was significant. This is a highly noteworthy example of the decoupling of economic growth from carbon emissions, demonstrating that deep cuts to emissions can be made without forgoing economic growth. Analysis indicates that the 20 percent reduction in carbon emissions could largely be attributed to decarbonization or 'greening' of the city's electricity supply due to large-scale wind projects and widespread rooftop solar photovoltaic; and significant energy efficiency improvements in new and existing commercial buildings. Most of a city's carbon emissions are from mains electricity and transport. The built environment and transport sectors will be paramount in efforts to achieve deep cuts in city emissions.

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[17] *Moving Towards a Climate Neutral UN: The UN System's Footprint and Efforts to Reduce It, 2015 Edition*, http://www.greeningtheblue.org/sites/default/files/MTCNUN-24.11.15-sequential.pdf

[18] *Moving Towards a Climate Neutral UN: The UN System's Footprint and Efforts to Reduce It, 2013 Edition*, p. 7, http://www.greeningtheblue.org/sites/default/files/sequential6.3.14.pdf

[19] *Carbon Neutral Strategy 2015–2025 Adelaide, South Australia*, p. 6, https://www.adelaidecitycouncil.com/assets/Policies-Papers/docs/STRATEGY-carbon-neutral-2015-25.pdf

4 MODULE 4. TECHNOLOGIES FOR ADDRESSING ADAPTATION CHALLENGES

Photo: Anna Jimenez Calaf

4.1 Introduction

Even if the release of anthropogenic GHGs could be greatly reduced, there is still the need to adapt to the impacts of climate change, and it will take considerable time before the results of mitigation interventions will be visible. Water managers have to deal with changes in the hydrological cycle and related uncertainties today and in the near future. It is generally accepted that improving water management today will help us to adapt tomorrow, and there are many actions that can be taken to prepare for a more variable climate.

Following the adaptation planning approach of the Mekong River Commission Climate Change Adaptation Initiative (MRC CCAI, 2011), section 4.2 will focus on how to assess vulnerability as a basis for developing an adaptation strategy. Adaptation responses and concrete technologies for adaptation will be covered in section 4.3, and methods on how to prioritize viable adaptation technologies in section 4.4. The content of sections 4.3 and 4.4 draws strongly from the publication *Climate Change Adaptation Technologies for Water* (UN Environment, 2016).

4.2 Vulnerability

Vulnerability can be seen as a function of exposure, sensitivity and adaptive capacity. Therefore, addressing each of these components will help to build resilience to climate change (Box 4.1).

As an example, MRC CCAI adaptation planning approach, covers the following key components (Figure 4.1).

BOX 4.1

Exposure, sensibility and adaptive capacity

Exercise to define exposure, sensitivity and adaptive capacity: see Facilitators Guide

Exposure

The extent to which something is faced with climate stress

Sensitivity

The degree to which a system can be affected, negatively or positively, by changes in climate

Adaptive capacity

Ability to adjust to climate change to minimize damage, take advantage of opportunities, or cope with consequences

4.2.1 Scoping

The purpose of the scoping phase is to identify the main problems (e.g. which areas, communities, sectors), the objectives, the potential stakeholders, etc. This is the initial stage in the planning process, and should assist the adaptation planners in selecting relevant sites and in gaining a proper understanding of the actual situation.

4.2.2 Vulnerability assessment

A vulnerability assessment is carried out to assess not only the current risks and vulnerability (who are most vulnerable, where are they located, and what risks do they face?), but also to assess future risks and vulnerabilities. For the latter it is necessary to formulate a plausible future including climate predictions and socio-economic developments.

Figure 4.2 shows examples of two matrices to quantify risk (based on exposure and sensitivity) and vulnerability (based on risk and adaptive capacity) on a relative scale.

4.2.3 Identification of adaptation options and development of an adaptation strategy

In identifying adaptation options and developing an adaptation strategy, first a longlist of feasible actions has to be made. These actions should address the most vulnerable systems and should aim at reaching, or maintaining, an acceptable level of functioning under climate change. In the next step, preferred options can be selected for implementation based on previously agreed criteria. Criteria to be considered include the level of damage/benefits to be gained, 'no-regret' options, contribution to SDG achievement, cost-

Figure 4.1: Adaptation planning approach in the Climate Change and Adaptation Initiative of the Mekong River Commission (MRC CCAI, 2011)

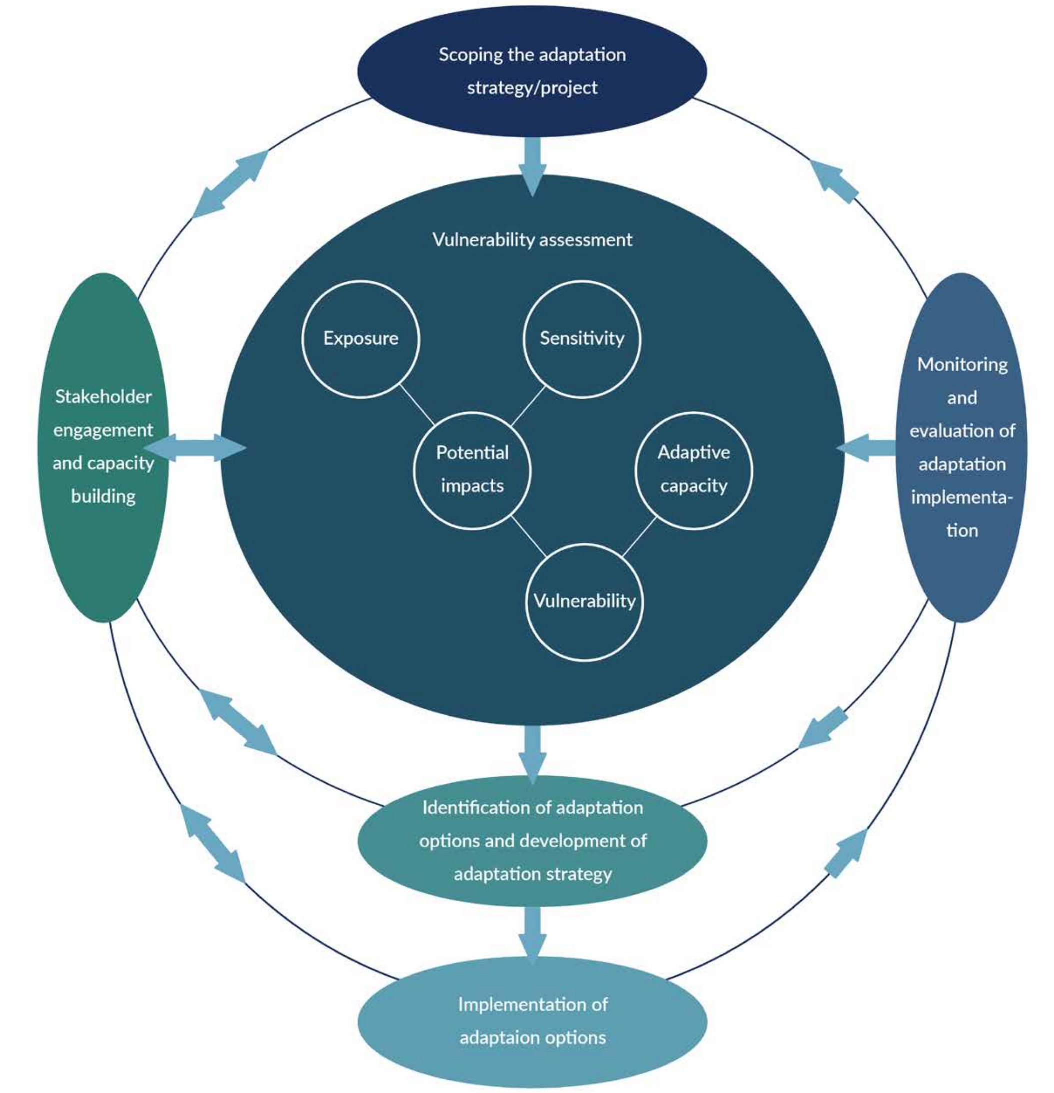
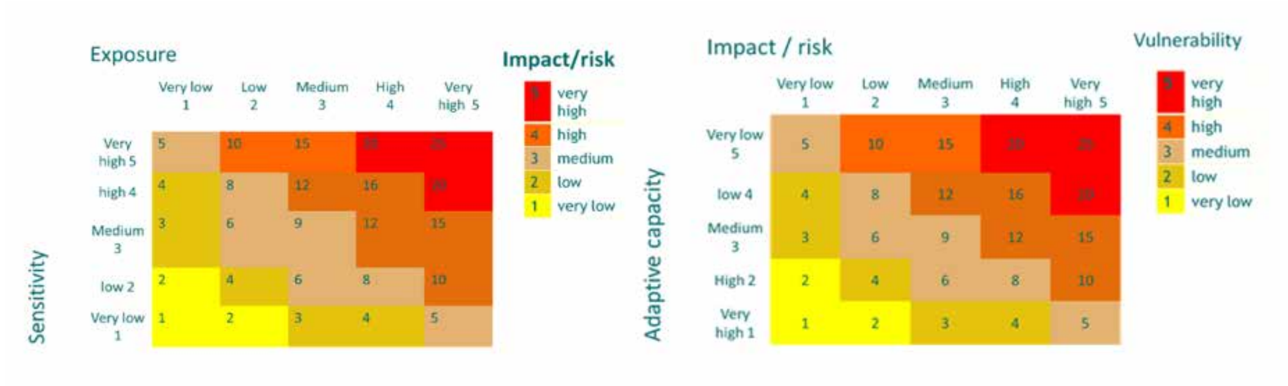


Figure 4.2: Examples of risk and vulnerability matrices



effectiveness and synergies between policies (e.g. contribution to mitigation of GHG emissions). This will result in a ranked list of adaptation options, which forms the basis of a cohesive strategy document.

4.2.4 Implementation of adaptation options

Finally, the adaptation plan needs to be implemented with the support of the stakeholders. This will be worked out in more detail in the context of IWRM in Chapter 5.

4.2.5 Cross-cutting components

Additional cross-cutting components include stakeholder engagement and capacity-building, and monitoring and evaluation. Needless to say, active involvement of all stakeholders is critical in developing and implementing an effective strategy and selected measure. Often, there is also a need to develop capacity by training stakeholders, ranging from local communities to policy makers. Finally, as in any planning process, all steps need to be monitored and evaluated for their (cost) effectiveness and impact (positive as well as negative).

4.3 Adaptation responses and technologies

Adaptation to climate change refers to the process of adjustment to actual or expected climate and its effects (IPCC Working Group II AR5, 2014). In human systems this means minimizing or preventing harm, or, on the other hand, exploiting potential benefits. In natural systems, human interventions can be used to facilitate adjustment to climate impacts (Figure 4.3).

Ask the participants to come up with examples. Discuss feasibility, sustainability, social and financial implications.

Adaptation differs from mitigation, which focuses on reducing the causes of climate change, e.g. limiting the release of GHGs by reducing sources and/or enhancing sinks. In spite of the fact that mitigation should lead to a more sustainable solution to the problems, adaptation to climate change is inevitable. This is mainly because it will take considerable time to see possible impacts of mitigation measures. Measures taken today will be effective long afterwards, while society is already confronted with changes in the hydrological cycle, mainly in the form of longer drought periods and more intensive precipitation events.

Another complication when dealing with adaptation is uncertainty, with its varied sources. First, it is not only the climate that is changing. Societies also face social and economic changes due to growing populations, migration, urbanization, economic developments, etc. Second, there are many steps in predicting impacts on the basis of (uncertain) emission scenarios, each with its own range of variation.

As discussed in Chapter 1, water challenges related to climate variability can be considered under six broad themes as illustrated in Figure 1.4: 1) climate risks; 2) too little water; 3) too much water; 4) water pollution; 5) sea-level rise; and 6) disaster preparedness. Within each of these themes, a number of key adaptation response types for tackling risk and uncertainty in the water sector is available (cf. Figure 3.1).

Figure 4.3: Climate change adaptation challenges and response options related to water resources

4.3.1 Climate risks

- Hazard and risk assessments with the view to establishing linkages between regional climate change and its impacts at a local level, identifying the specific risks to the water resource sector that need to be addressed and included in planning:
  This includes the impacts on water resource availability and quality, but also identification of locations and communities particularly vulnerable to extreme events, such as floods and droughts.
- Vulnerability assessments look at the interaction between the climate change impacts and the qualities of the area, economic activity, ecosystem or community in question:
  Vulnerability is a function of the potential impacts of climate change (exposure), of the characteristics of the system (sensitivity to the changes) and the ability of the system to deal with the impacts (adaptive capacity) (GIZ, 2014). This also means that vulnerability is a less static element, and it can change over time, and be reduced, by implementing appropriate adaptation response measures.

4.3.2 Too little water

- Improvements in water allocation aiming at sharing existing resources among the users and uses in a way that is equitable and ensures maximum benefit for all, including the environment:
  An important precondition for efficient water allocation arrangements is an overall understanding of inputs and abstractions within the entire river basin or waterbody in question; including the quantification of availability and demand for various users, as well as the value that various uses create

for society. Based on this information, decisions for optimal allocation can be made. Stakeholder dialogues should form an important part of all water allocation projects, given that often compromises have to be negotiated among competing uses.

- Water augmentation seeking to increase the available supply of fresh water through active recharge or protection or water recharge areas:
  Natural recharge of groundwater takes place when surface water from rain or surface stream flow is able to percolate through soil and vegetation to reach the water table. In recent decades, urban development and other land conversion activities have reduced the extent of permeable surfaces for groundwater recharge, due to buildings, asphalt and other hard constructions that do not allow the water to percolate through soil. Water augmentation aims to restore the opportunities for increased water capture and infiltration by creating green spaces for improved natural recharge from rainfall. Another option for increased augmentation can be managed recharge, such as water injection in existing aquifers.
- Water storage to sustain agricultural and other socio-economic activities even during the dry season:
  Some areas may experience decline in precipitation, while in others, even with an overall increase, rain may fall over shorter and more intense periods, extending the periods of dry spells.
- Water efficiency and demand management measures aiming at reducing inefficient use and waste of fresh water and better oversight of water use:
  This may involve improving the use efficiency through better technologies, and increasing incentives for water savings or regulatory requirements that set standards for acceptable water-use limits. Successful implementation of these relatively low-cost measures requires a high level of engagement from relevant stakeholders, including the general public; awareness-raising and education plays an important role in successful implementation of such approaches.
- Alternative sources of fresh water may be required to augment water supply and demand measures in addition to surface and groundwater utilization:
  The alternative water sources seeing rapidly developing application include desalination of seawater and re-use of waste water, although other options are also available.

4.3.3 Too much water

- Riverine flood protection aiming at minimizing the impacts of potential flooding events.
- Urban stormwater management to collect abrupt increase of run-off water.
- Glacier lake burst prevention by controlling lake drainage.

4.3.4 Water pollution

- Limiting nutrient leakage through improvements in land management and agriculture practices (i.e. reducing diffuse organic pollution).
- Limiting saltwater intrusion from increasing abstractions of groundwater in coastal areas and exacerbated by sea-level rise (i.e. preserving groundwater resources).
- Mitigating pollution at source through management systems and policy measures, water treatment and water safety planning (i.e. reducing point source pollution).
- Flood-proofing for water quality through improved stormwater management, securing wells from flooding and preventing contamination from latrines.
- Improved water treatment capacity.

4.3.5 Sea-level rise

- Limiting saltwater intrusion.
- Built infrastructure for shoreline protection.
- Green infrastructure for shoreline protection.
- Accommodation and management.

4.3.6 Disaster preparedness

- Early warning systems in place and operational, alerting communities at risk and initiating disaster response procedures.
- Implementation of disaster response technologies to ensure that exposed communities understand and follow evacuation or other procedures in the event of a natural disaster. On a national level, it is also crucial that responsible institutions are well coordinated and their respective responsibilities in the event of disaster are clearly divided and understood.

Following these six different adaptation responses, Tables 4.1-4.6 present an overview of possible technologies that support adaptation to the impacts of climate change in the context of IWRM.

Table 4.1: Technologies supporting key adaption responses to climate variability. Overarching theme: Climate risks

Adaptation response	Technologies	Description
Hazard and risk assessment	Downscaling of climate model projections	Methods of estimating local-scale impacts of climate change based on information derived from Regional and Global Climate Models. Fundamental in modelling and understanding future climate impacts on water resources.
	Disaster risk assessment using LiDAR	Disaster risk assessment and mapping using remote-sensing-based Light Detection and Ranging (LiDAR) data.
	Flood hazard assessment and mapping	Identification of areas at risk to flood inundation (coastal or inland).
	Drought risk assessment and mapping	Identification and mapping of areas (or socio-economic activities) at risk to droughts.
Vulnerability assessment	Socio-economic scenarios	Modelling approaches to assess future impacts of climate change on water resources, including various socio-economic reference conditions.
	Climate change vulnerability assessments	Assessment of the extent to which the system of interest is vulnerable to changes to which climate variables.

Table 4.2: Technologies supporting key adaption responses to water scarcity. Overarching theme: Too little water

Adaptation response	Technologies	Description
Water allocation	Basin-level modelling and seasonal forecasting for water allocation	Planning instruments to help optimize water allocation among competing water uses by employing a combination of hydrological and economic models.
	Seasonal water rationing	Approach and associated technologies to control the rates of water use among the different users, based on the seasonal availability of water.
	Water re-allocation	Transfer of water-use rights between different water users based on assigned allocation (voluntary or involuntary).
Water augmentation	Rainwater harvesting for infiltration	Practices to increase rainwater uptake in soils from the soil surface, the rooting system and for recharging groundwater.
	Urban green spaces and permeable surfaces	Establishing or expanding areas covered by vegetation, to facilitate water infiltration through the soil and vegetation.
	Source water protection and watershed conservation	Development of management and policy measures to restrict overuse and pollution of water at its source, and may include regulations, compensation schemes or conservation measures in upstream watershed.
Water efficiency and demand management	Water efficiency in industry	Behavioural, operational and technological changes to increase water efficiency in industrial production.
	Improved irrigation efficiency	Practices and technologies for minimizing water use within the agricultural sector, while maintaining optimal crop productivity rates.
	Water accounting (metering)	Approach to public water resource management aimed at monitoring and eventually reducing water consumption, and associated equipment (water meters).
	Reducing system - water loss and leakages	Implementing leak detection systems, pressure control, maintaining water meters and controlling against unauthorized water use to help mitigate real and apparent losses of water (non-revenue water).

Water efficiency and demand management	Public water conservation campaigns	Public educational and awareness campaigns on the benefits of water conservation, and the different ways of conserving water.
	Progressive pricing	An economic instrument to manage water demand and help reduce excessive water consumption, by increasing water price rates per unit of volume, as the volume of water used increases.
	Hydrological zoning	Management method to protect local water sources from risks of over-abstraction, land salinization, groundwater pollution and waterlogging, by managing land-use activities based on assigned hydrological zones.
	Water licensing and permits	Approach to demand management requiring private landowners or potential water users to apply for (or purchase) a licence or permit for water use or any watershed-affecting activities (e.g. construction, diversion, artificial recharge).
	Water savings requirements in building codes	Building codes requiring installation of modern, water-efficient technologies, i.e. water pressure control, faucet aerators, leak detectors, water-saving toilets, etc. to maximize use efficiency, or requiring installation of internal water recycling systems, or the establishment of infrastructure to provide alternative water sources (e.g. rainwater-harvesting tanks).
Water storage	Surface reservoirs	Building structures for water storage (reservoirs, dams, etc.), or increasing storage capacity of existing built structures.
	Multipurpose dams	Dams combining two or more functions of traditional single-purpose dams, e.g. storing and supplying water for irrigation, and flood control, power generation.
	Natural wetlands	Wetland restoration or conservation activities (or avoided degradation) for natural water storage and regulation.
	Rainwater harvesting for storage	Structures for collecting and storing rainwater.
Alternative water sources Water reuse	Seawater desalination	Technologies for removal of salt and other constituents from saline water (e.g. seawater). The two most common forms: thermal treatment and membrane processes.

Alternative water sources Water reuse	Solar water distillation	Making subpar-quality water available for potable use by using the energy from sunlight to separate fresh water from salts or other contaminants.
	Inter-basin transfers	Transfer of water from a watershed with surplus water (donor basin) to a watershed suffering from water shortage (recipient basin).
	Fog harvesting	Structures to capture water from wind-driven fog.
	Water recycling and reuse	Collecting and treating waste water for productive uses (e.g. industry and agriculture).

Table 4.3: Technologies supporting key adaption responses to flooding. Overarching theme: Too much water

Adaptation response	Technologies	Description
Riverine flood protection	Structural barriers to flooding - dams, dikes, locks and levees	Permanent, built structural barriers for flood protection (dams, dikes, locks and levees, etc.).
	Reconnecting rivers with floodplains	Removing existing barriers along the edges of the river, to allow re-establishment of its natural course over time, reconnecting to the floodplains to mitigate flood impacts and losses.
	Flow-through dams	Construction of flow-through dams (also known as perforated dams), solely for the purpose of flood control and mitigation of flood risks.
	Accommodation of flooding (flexible buildings and infrastructure)	Design measures for buildings and infrastructure to withstand and adapt to the impact of flooding, mitigating the socio-economic losses.
	Ecological river restoration	Ecological, spatial and physical management practices to revert river to (or close to) its natural state and function to mitigate flood impacts (restoration techniques include reconnecting rivers with floodplains).
	Multipurpose dams	Dams combining two or more functions of traditional single-purpose dams, e.g. storing and supplying water for irrigation, and flood control, power generation.

Riverine flood protection	Zoning and land development limitations	Management-based approaches minimizing the impacts of potential flooding events by dividing urban areas into zones with a varying degree of development restrictions depending on the level of flood risk.
Urban stormwater management	Urban green spaces (SuDS - Sustainable Drainage Systems)	Establishment of areas covered by vegetation to facilitate stormwater infiltration and filtration in urban areas.
	Permeable pavements and parking lots	Permeable asphalt, permeable concrete, concrete grid pavers, loose gravel or stone-chippings, resin-bound paving, and porous plastic 'pavement' structures designed to facilitate better water infiltration.
	Optimization of urban drainage systems	Using computer simulation models to improve real-time operation, and optimize performance of urban drainage systems, reveal deficiencies, identify high-flood-risk areas, and compute the optimal design improvement interventions.
	Bioswales	Strips of vegetated areas established with the purpose of redirecting and filtering storm water in urban areas.
Glacial lake burst prevention	Artificial lowering of glacial lakes	Reducing risk of outbursts by draining water from lakes vulnerable to overflowing, e.g. by digging a canal from the glacial lake to a nearby river.

Table 4.4: Technologies supporting key adaption responses to threats to water quality. Overarching theme: Water pollution

Adaptation response	Technologies	Description
Limiting nutrient leakage	Riparian buffers (e.g. wetlands, buffer strips)	Strips of vegetation along the banks of waterways (lakes, rivers, streams, etc.) which protect from potential pollutants stemming from adjacent land activity.
	Protected areas and land-use limitations	Legislative approaches, typically targeting agricultural activities, limiting fertilizer (typically nitrogen and phosphorus) used in land-based activities in designated areas.
	Change in land-use practices	Implementation of sustainable land-use practices to reduce nutrient leakage (e.g. improving long-term soil quality and soil/water retention capacity, improving productivity and reducing fertilizer use).

Limiting saltwater intrusion	*See Sea-level rise section in Table 4.5.*	
Mitigating pollution at source	Source-water protection	Development of management and policy measures to restrict overuse and pollution of water at its source.
	Improved point-of-use water treatment	Implementation of decentralized water treatment technologies and approaches at the point of use, e.g. physical filtration, chlorination or disinfectant powder use, solar disinfection, etc.
	Water safety plans	Comprehensive risk assessment and management plans, where all possible threats towards drinking water in the supply chain from catchment/supplier to consumer are assessed, and interventions to control the risks of water contamination are planned, implemented and monitored.
Improved stormwater management	*See Urban stormwater management section in Table 4.3.*	
Flood-proofing for water quality	Flood-proof wells	Implementing measures to secure wells from flooding, using specialized construction design and planning procedures.
	Flood-proof sanitary latrines	Construction design and planning measures to prevent water contamination from latrines, e.g. raising latrines on to an elevated land mound, lining the latrine pit with solid materials, temporary floating latrines.
Improved water treatment capacity	Advanced domestic wastewater treatment tanks	Advanced domestic wastewater treatment tanks are used to remove solids, pathogens and other impurities from waste water at the household level.
	Constructed wetlands for water treatment	Constructing wetlands to make use of the natural purification processes of vegetation, soils and microbes to remove contaminants from discharge.
	Improved efficiency of centralized water treatment systems	Improving efficiency of centralized systems may include, e.g. renovation or changing of infrastructure or installation of new equipment (sensors, aerators, automated control systems).

Table 4.5: Technologies supporting key adaption responses. Overarching theme: Sea-level rise

Adaptation response	Technologies	Description
Limiting saltwater intrusion	Drainage canals	Drainage canals are an adaptation measure when effectively used as flood management mechanisms.
	Limiting abstraction from shallow aquifers	Using better groundwater management such as scientific monitoring and assessments, improved water-use efficiency/regulations, etc., to reduce abstraction of fresh water to sustainable levels.
	Barriers to saltwater intrusion	Establishment of physical (low-permeable materials such as steel or concrete) or hydraulic barriers (such as injecting fresh water and/or pumping salt water to prevent the landward movement) to hinder saltwater intrusion.
	Increasing sustainable aquifer recharge	Adding water to an aquifer through man-made systems (e.g. recharge basins or check dams, injection wells) to increase the amount of fresh water and to control or prevent the intrusion of salt water.
	Coastal groundwater-level monitoring	Monitoring approaches and associated data infrastructure to establish an in-depth understanding of the hydraulic processes that lead to saline intrusion in coastal areas.
	Coastal surface-water monitoring	Monitoring approaches and associated data infrastructure focusing on the interactions with surface water.
Built infrastructure for shoreline protection	Revetments	Shore-parallel, sloping structures, constructed landwards of the beach to dissipate and reduce wave action at the boundary between the sea and land.
	Sea walls	Engineered structures to prevent further erosion of the shoreline, built parallel to the shore and aim to hold or prevent sliding of the soil, while providing protection from wave action.
	Land claim	Creating new land from areas that were previously below high tide.

Built infrastructure for shoreline protection	Beach nourishment	A soft engineering approach that involves artificial addition of sediment of suitable quality to a beach area that has a sediment deficit.
	Storm surge barriers/ closure dams	Storm surge barriers are movable or fixed barriers or gates which are closed when an extreme water level is forecast in order to prevent flooding. Closure dams are fixed structures that permanently close off a river mouth or estuary.
	Breakwaters	Shore-parallel structures designed to intercept and reduce incoming wave energy at the shoreline.
	Groynes	Narrow, shore-perpendicular, hard structures designed to interrupt longshore sediment transport, and help to build and stabilize the beach environment.
	Jetties	Hard structures constructed on the banks of tidal inlets and river mouths to trap a portion of the longshore sediment transport, and to stabilize the inlet and prevent siltation of the channel.
	Dikes	Predominantly earth structures designed to resist wave action and prevent or minimize overtopping.
Green infrastructure for shoreline protection	Artificial reefs	An artificial reef is a submerged (or partly exposed to tides) structure deliberately placed on the seabed to mimic functions of a natural reef, such as protecting, regenerating, concentrating and/or enhancing populations of living marine resources.
	Restoration and protection of coral and oyster reefs	Protection of existing reefs can be done through legal protection and by monitoring the reefs, minimizing any potential threats. Restoration includes structural restoration to habitat range, and biological restoration to assist growth.
	Cliff stabilization	Minimizing erosion of sloping soft rock coasts. Cliff stabilization measures may take a wide variety of forms including foot protection, regrading, smoothing, increasing vegetative cover and improving drainage.

Green infrastructure for shoreline protection	Seagrass beds	Seagrasses are submerged marine flowering plants forming extensive meadows in many shallow coastal waters worldwide. The leafy shoots provide food and shelter for many animals (including commercially important species, e.g. prawns), and their roots and rhizomes are important for oxygenating and stabilizing bottom sediments and preventing erosion.
	Coastal wetlands (including mangroves)	Sustaining the climate adaptation functions (coastal storm protection, mitigation effects of sea-level rise, erosion) through restoration or conservation of coastal wetlands, including eliminating drivers of degradation and allowing natural regeneration.
	Dune construction and rehabilitation	The restoration of natural or artificial dunes from a more impaired, to a less impaired or unimpaired state of overall function, in order to gain the greatest coastal protection benefits.
Accommodation and management	Coastal zoning	Coastal zoning is the division of coastal areas into zones, which can be assigned different purposes and user restrictions.
	Floating agricultural systems	The technology is mainly aimed at adapting to more regular or prolonged flooding. The approach employs beds of rotting vegetation, which act as compost for crop growth. These beds are able to float on the surface of the water, thus creating areas of land suitable for agriculture in waterlogged regions.
	Flood-proofing	Technologies may include elevating structures above the floodplain, employing designs and building materials, which make structures more resilient to flood damage and prevent floodwaters from entering structures in the flood zone, among other measures.
	Managed coastal realignment	Deliberate process of altering flood defences to allow flooding of a presently defended area.
	Coastal setbacks	Coastal setbacks are a prescribed distance to a coastal feature such as the line of permanent vegetation, within which all or certain types of development are prohibited.
	Fluvial sediment management	Fluvial sediment management is the holistic management of sediment supply from rivers to the coast, taking the full range of human activities at river-basin level into account.

Table 4.6: Technologies supporting key adaption responses to disasters. Overarching theme: Disaster preparedness

Adaptation response	Technologies	Description
Early warning	Flood forecasting systems	Flood forecasting systems help forecast potential flooding events before they occur by determining the risks of floods based on changes in precipitation.
	Early warning systems for floods	The main purpose of early warning systems is to use flood forecasts to issue warnings when a flood is imminent or already occurring.
	Landslide and mudflow warning systems	Landslide and mudflow warning systems produce a warning when an area is in danger of a landslide or mudflow event, improving disaster preparedness and minimizing the risks of a landslide or mudflow event.
	Decentralized community-run early warning systems	Low-cost technology for improving disaster preparedness, run by local community members. Community members use simple equipment to forecast potential natural disasters, e.g. floods, landslides and drought, and operate a communication/dissemination system to inform other local residents of any impending threats.
	Drought early warning systems	The main purpose is to warn local communities when there is the risk of a drought, improving preparedness and decreasing the potential risks associated with loss of crops and food.
Disaster response	Stacking of sandbags combined with the use of ground-improvement technology (for basic restoration and reinforcement/ restoration)	Sandbag barriers are temporary barriers that protect buildings and populations from inundation damage, and associated economic loss.
	Flood Disaster Preparedness Indices (FDPI)	FDPI can be used to assess the preparedness of a local community to tackle flood situations.
	Communication protocols	Communication protocols for disaster response lay out the framework for communication tools and communication responsibilities for the area in question. Traditional media, social media, religious centres, schools, local volunteer teams and workshops are common examples of communication tools during disaster events.

Disaster response	Flood shelters	Flood shelters are robust elevated structures that can be used as refuge by local residents during an extreme weather event.
	Social media applications for disaster response and mapping	Use of social media applications to distribute information during or following a disaster, also allowing those affected by a disaster to be in touch with disaster relief organizations, friends and family.
	National and community disaster management plans	National disaster management plans incorporate disaster risk management into national policies, and establish a framework, which clearly specifies the roles of the institutions/committees responsible in the various stages of disaster management.

4.4 Prioritization

4.4.1 Steps in prioritization

As discussed in section 4.3, for each major climate-related water challenge, there is a range of potential adaptation responses and technologies available. The task of decision makers, practitioners, managers, technology adopters and other stakeholders is to contribute to the evaluation of these technologies so that the most appropriate technology intervention (or a portfolio of interventions) for a specific climate-related water challenge is chosen. This can be a daunting task amidst the complexity of water interactions across a number of sectors, and the wide spectrum of users and stakeholders that rely on water and water ecosystem services.

In this context, a prioritization process enables a decision maker to select a technology (or a set of technologies) for implementation (Box 4.2). The process entails identifying criteria for assessment followed by evaluating the performance of technologies against these criteria. The best-performing technology (or a set of technologies) in all the chosen criteria (or at an aggregate level) is (are) selected for implementation.

4.4.2 Relevant criteria for technology selection

Criteria are the measures or parameters against which the performance of technologies is judged. They facilitate comparison among alternatives in meeting the goals of solving climate challenges. Choice of criteria for assessment can be completely driven by stakeholders or can be based on already existing independent scientific criteria.

The chosen criteria should comprehensively measure the appropriateness of technologies to address the adaptation challenge and deliver on specific adaptation objectives. If the criteria are broad, then each criterion can have sub-criteria.

The stakeholder group involved in criteria selection should first come up with a longlist of assessment criteria and sub-criteria, and then screen for comprehensiveness, double counting, redundancy and relevance to context to come up with a smaller pool to be used for assessment.

There are many potential criteria and sub-criteria relevant for assessing technologies for adaptation in the water sector. Table 4.7 gives an example of two broad criteria groups of costs and benefits. These criteria are further divided into sub-criteria and indicators to measure these sub-criteria.

4.4.3 Prioritization tools

Some common approaches for assessment, comparison and prioritization of various technologies for adaptation are:

BOX 4.2

Steps in prioritization. Adapted from UN Environment (2016)

Prioritization process

The following process can be followed by stakeholders to determine a set of prioritized technologies for implementation.

Step 1: The decision context

To identify a relevant set of prioritized technologies, the first step is to determine the objectives. In simple terms, the expected outcomes from technologies or the decision context must be clear. The decision contexts are in general the economic, environmental, social and political settings that surround the decision. For example, reducing vulnerability to drought, enhancing resilience to floods, reducing impacts from salinity are environmental decision contexts; equitable water access is within a social decision context; affordability is an economic decision context. The decision context should be aligned with national policies and programmes.

Step 2: Identify options

There are many technology options to meet the objectives determined in the decision context. A menu of options helps the stakeholders to review the potential of each technology in meeting the objectives of the decision context. Examples of technologies that address water challenges are presented for each response theme in Tables 4.1-4.6.

Step 3: Evaluate options

This step entails identifying the criteria (see section 4.4.2) for assessment and then assessing the performance of each technology option against the criteria. One way to identify criteria for evaluation is in a stakeholder setting where important criteria and their weights can be determined. For example, capital cost, technology lifespan, annual water savings are a few criteria against which a micro-irrigation technology can be assessed. Multi-criteria decision analysis (or similar tools) can subsequently be used to assess the overall performance of technologies. The outcome of this step will be ranked technologies based on priorities or a set of priority technologies, depending upon the assessment tool.

Step 4: Sensitivity check

One final check before shortlisting a prioritized pool of technologies for adaptation that will be implemented, is to check for their sensitivity to changes in key assumptions. For example, in a multi-criteria assessment, it is important to check the robustness of the prioritized technologies to criteria or their weights. Sometimes, when divergent views in a stakeholder setting are incorporated, the prioritized pool of technologies may not change significantly, even if the ranks of technologies change. This step can therefore also support building a consensus among stakeholders.

- **Cost-Benefit Analysis (CBA)**

Fundamentally, CBA looks into the enumeration and assessment of relevant costs and benefits for a project over a period of time to assess investment decisions (Drèze & Stern, 1987; Prest & Turvey, 1965; Sassone & Schaffer, 1978). If the benefits are more than the costs, the projects are deemed economically acceptable.

In the context of prioritization of technologies, this tool can be used to assess a bigger set of technologies, narrowing it down to those with the highest net benefits.

There are many direct and indirect costs and benefits of technologies for adaptation. The direct and tangible ones can be measured, or some assumptions can be made for estimating them. The indirect and intangible ones are difficult to value. For example, a large dam may help farmers with irrigation and reduce the impact of drought, which can be measured by a number of indicators such as production levels, increase in farm area under irrigation, etc. However, the increased benefits, say, of more energy and food security or increased political influence of the people benefiting from the dam, are extended benefits that cannot be measured directly.

Table 4.7: Criteria list and some indicators

Criteria	Sub-criteria	Indicators
Costs		Capital costs Operating costs Maintenance costs Institutional costs
Benefits	Institutional	Ease of implementation Alignment with national priorities
	Environmental	Ecosystem protection Quality and supply of water Support to ecosystem services Reduction in pollution Reduction in GHG emissions
	Social	Improved health Reduced poverty Preservation of natural heritage
	Economic	Economic performance Increase in income Reduced unemployment Increase in production

Often, by measuring only the tangible costs and benefits of technologies for adaptation in the water sector, the costs turn out to be much higher than the benefits. It is important for stakeholders to assess the intangible benefits and non-monetized gains such as improvement in overall welfare.

The CBA tool is still evolving and in the context of technologies for adaptation, with better estimation methods available in future, CBA-based decisions will be more evidence-based.

- **Multi-Criteria Decision Analysis (MCDA)**

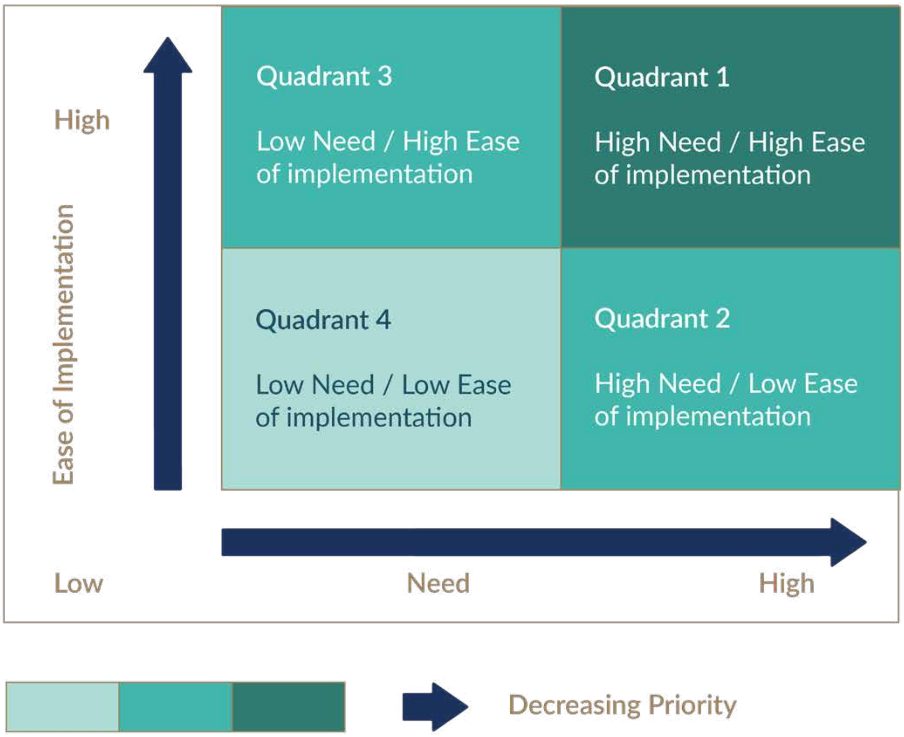
In prioritization of water technologies for adaptation, MCDA combines the use of both quantitative and qualitative criteria such as social, environmental, technical, economic and financial criteria. The central idea is that while prioritizing technologies for adaptation from a larger pool of technologies, only those which excel in several criteria should be implemented. For example, a small dam and rainwater harvesting are two technologies dealing with the same water challenge. Using MCDA, the decision makers can check for their performance on different criteria such as financial, environmental, etc.

The steps involved in MCDA include: establishing a decision context; identifying the performance criteria; rating the option's performance for each criterion; assigning weights; combining scores and weights; examining the results; and conducting a sensitivity check. The process seeks participation and subsequent agreement from stakeholders, which can make the process time/resource-consuming.

A key limitation of MCDA is in assigning weights, which can potentially be ambiguous or the stakeholders may not reach a consensus on their value.

Both CBA and MCDA tools can be used to prioritize technologies as they are based on designing a common metric for comparing and ranking options. They are both sensitive to assumptions. The key difference is that CBA emphasizes monetizing all the future benefits

Figure 4.4: Example of quadrant assessment
The tool uses a simple approach, and the analysis is not as robust as that of CBA or MCDA; however, in a small-scale implementation with a small pool of comparable technologies, this tool can be efficient for determining priority technologies. This tool is high on qualitative assessment, and hence must rely on engagement with stakeholders for prioritization.



and costs, while MCDA relies on measuring performance against each criterion (which could be quantitative or qualitative).

- **Quadrant method**

The quadrant method supports the classification of technologies into groups of high or low priorities. The technologies are classified in a matrix where each of the axes represents a criterion. Generally, very broad criteria are selected for representing the axes. For example, one axis can represent 'ease of implementation' and the other can represent 'need for a technology' (Figure 4.4). The axes show a scale of high and low for each criterion. The top right matrix, which is 'high need/high ease of implementation', is the highest-priority quadrant, and technologies classified in this quadrant should be implemented first, whereas technologies that fall in the bottom left quadrant should not be prioritized. The technologies falling within the remaining two quadrants can be implemented after the high-priority technologies. Between these two, the balance resources can determine which quadrant should be prioritized first.

Suggestions for background reading:

Aerts, J. and Droogers, P., 2009. 'Adapting to climate change in the water sector', pp. 87–108. In: *Climate Change Adaptation in the Water Sector*. Ludwig, F., Kabat, P., van Schaik, H. and van der Valk, M. (Eds). Earthscan: London, UK.

Van Beek, E., 2009. 'Managing water under current climate variability', pp. 51–77. In: *Climate Change Adaptation in the Water Sector*. Ludwig, F., Kabat, P., van Schaik, H. and van der Valk, M. (Eds). Earthscan: London, UK.

UN Environment, 2009. *Climate Change Adaptation Technologies for Water*. http://www.unepdhi.org/-/media/microsite_unepdhi/publications/documents/unep_dhi/cc_adaptation_technologies_for_water_red.pdf?la=en

5 MODULE 5. IMPLEMENTATION – HOW TO GUIDE IWRM UNDER A CHANGING CLIMATE

Photo: Joe Desousa

Goal

The objective of this chapter is to provide an overview of the elements leading to an increased integration of climate change in water sectoral planning and financing within the framework of national priorities for climate-resilient development. The module will focus on the policy, legislative and financing frameworks which deal with water as a social and economic public good, ensuring an equilibrium between water security, development and climate-risk management.

5.1 Action on water and climate under the Paris Agreement

The international policy framework

In 2015, 196 Parties to UNFCCC endorsed the Paris Agreement (UN, 2015). The Paris Agreement is implemented through NDCs, submitted by 193 Parties to UNFCCC (165 NDCs as of 1 January 2018) (WRI, 2018), which describe the measures Parties will take to reduce national emissions and adapt to climate change.

Countries have identified water as a key to adaptation in 93 percent of their national climate action plans (Intended Nationally Determined Contributions, or INDCs). As water is fundamental for food security, human health, energy production, industrial productivity, biodiversity, in addition to basic human needs and its availability, ensuring water security means ensuring security in all these domains.

According to UN (Water Development Report, 2015), the planet is facing a 40 percent shortfall in water supply by 2030, unless the world dramatically improves the management of this precious resource. This challenge is broadened as climate change impacts shift well-known patterns of water supply in many countries towards new extremes of flood and drought. In addition, water is critical for successful climate change mitigation, as many efforts to reduce GHG emissions depend on reliable access to water resources. Systematically addressing these challenges is, therefore, key to adapting to climate change and reducing the negative impacts of water-related disasters.

Within that scope, the Paris Agreement calls for all countries to engage in the process of formulation and implementation of NAPs, which are key instruments for enhancing and scaling up climate action as they will harmonize national and sectoral (including water sector) adaptation priorities with key policy planning processes such as NDCs as well as regional and global development objectives and frameworks, as defined by the Agenda 2030.

The Paris Agreement is the base of three axes: *Mitigation* (Art. 4), *Adaptation* (Art. 7) and *Loss and Damage* (Art. 8). Adaptation, in the simplest terms, refers to the actions that countries will need to take to respond to the impacts of climate change that are already happening, while at the same time preparing for future impacts. It refers to changes in processes, practices and structures that can reduce our vulnerability to climate change impacts.[20] EU states that the adaptation strategies have to be mainstreamed into sustainable development planning, and in the development of sector policies. Adaptation can also involve setting up institutional or organizational structures, or designing and implementing projects so that adaptation has to be taken into account in any public policy.[21]

[20] Summary of the Paris Agreement, http://bigpicture.unfccc.int/content/adaptation.html#content-adaptation

[21] Mainstreaming Climate Change Adaptation in the EU, https://climatepolicyinfohub.eu/mainstreaming-climate-change-adaptation-eu

National Adaptation Plans

NAP is an iterative process that aims to integrate considerations of climate change adaptation into policy-making, budgeting, implementation and monitoring processes at national, sectoral and subnational levels. The objectives of NAP process (decision 5/CP.17 paragraph 1) are twofold:

- 1) To reduce vulnerability to the impacts of climate change by building adaptive capacity and resilience; and
- 2) To facilitate the integration of climate change adaptation into new and existing policies, programmes and activities within all relevant sectors and at different levels.

NAPs build on existing policy processes and coordination structures, and should be based on sound scientific evidence. Initial guidelines for the formulation of NAPs were released in 2013 by the Least Developed Countries Expert Group (LEG)[22] of UNFCCC. LEG NAP Technical Guidelines contain a list of indicative activities that can be undertaken in the development of NAPs, grouped under four headings.

- 1) Laying the groundwork and addressing gaps;
- 2) Preparatory elements;
- 3) Implementation strategies; and
- 4) Reporting, monitoring and review.

As climate change is changing weather patterns around the world, leading to more frequent and intense droughts and floods, several elements in NAP process require effective and timely climate data and information to serve water services. These include assessment of climate vulnerabilities and identification of adaptation options, development of products that help improve the understanding of climate and its impacts, and enhancement of capacity for planning and implementation of adaptation in the water sector. Learning how to harvest rainwater - cutting the peaks of water to fill the troughs - will be a key skill requirement in most parts of the world. This creates demand for climate services which provide science-based and user-specific information relating to past, present and potential future climate, addressing all climate-affected sectors.

Adaptation of water resources to climate change will benefit from the key elements of IWRM systems. Issues related to the natural level of national or transboundary river basins and lakes, or upstream to downstream water flows, will need to be addressed in conjunction with longer-term adaptation needs. Integrating adaptation in the water sector within development planning is essential if countries are to achieve and sustain their national development targets, both in the medium and long term.

A continuous and iterative series of actions to explicitly account for climate change in decision-making is necessary, including regular revisiting as information, knowledge, capacities and institutions change over time. The mobilization of all actors in the field, including local authorities, economic sectors and civil society, is vital to achieve international and national policy commitments on adaptation and resilience through water management.

5.2 The IWRM enabling environment

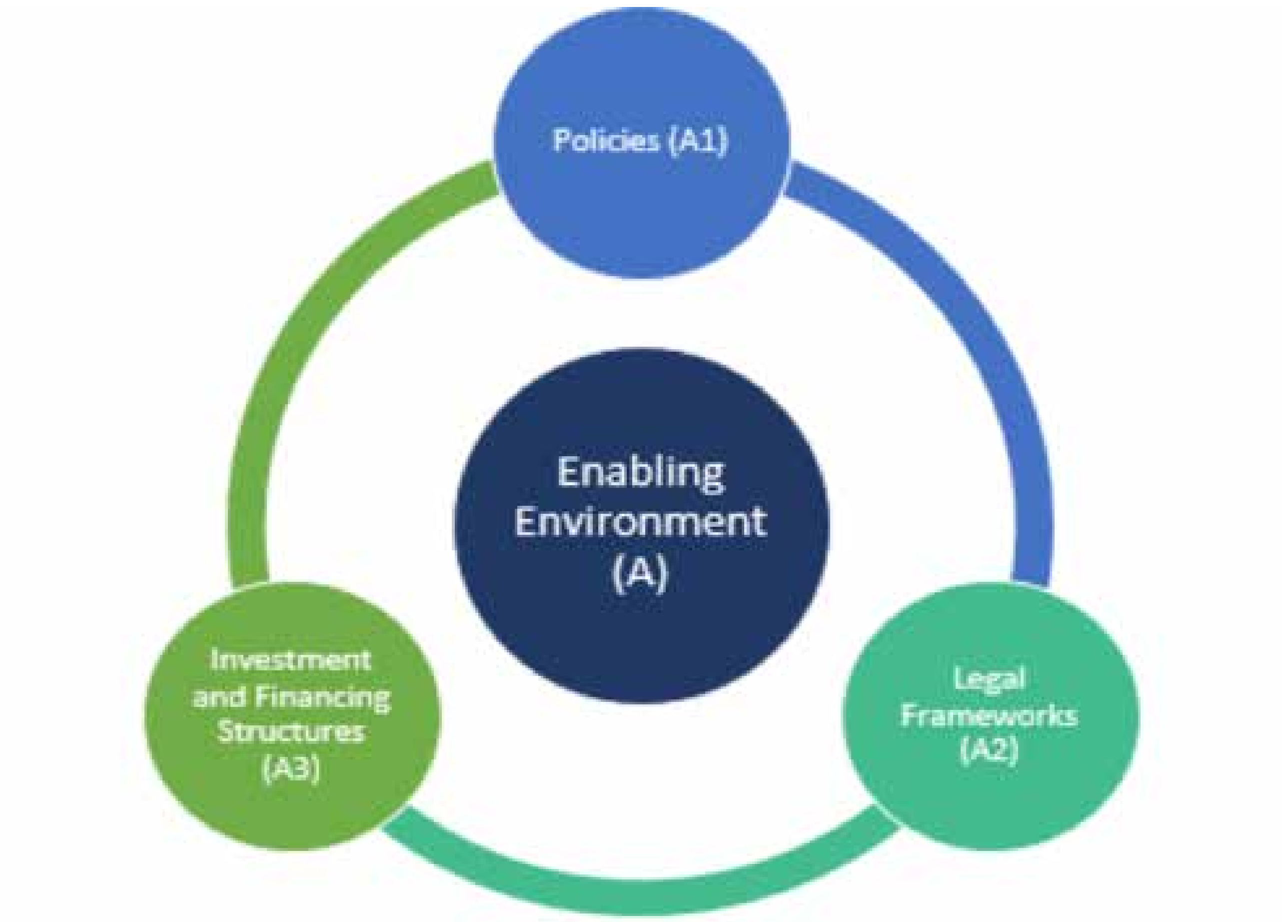
In order to achieve efficient, equitable and sustainable water management under a changing climate and within the IWRM approach, both top-down and bottom-up strategies for the participation of stakeholders need to be promoted – from the national level to the catchment or watershed level.

Integrating the rights and assets of all stakeholders (individuals as well as public- and private-sector organizations and companies, women as well as men, the poor as well as the better off), creates an enabling environment for environmental and climate-proofed equality. NAPs provide guidance to processes at the national level and beyond. These processes encompass not only government agencies and ministries, but also communities, the private sector, local municipalities, non-governmental organizations and other relevant stakeholders.

The enabling environment is also determined by national, provincial and local policies and

[22] LEG was established by COP in 2001 to provide technical guidance and advice to LDCs on NAPAs, the LDC work programme and NAP process.

Figure 5.1: IWRM enabling elements, GWP, 2017



legislation that constitute the 'rules of the game' and facilitate all stakeholders to play their respective roles in the sustainable development and management of water resources. The purpose of this enabling environment is to provide a set of solid foundations, establishing the priorities and best practices which can help water governance structure reach its goals, while balancing the social, economic and environmental demands for water resources.

These rules can be defined by the use of: policies, legislative frameworks, and financing and investment structures.

The three key elements of an IWRM enabling environment are interrelated and complementary. They are also relevant for NAP process as they are necessary for the formulation of comprehensive adaptation plans, programmes and policies, encouraging countries to consider institutional arrangements, the adequacy of scientific information and how climate change will impact specific development goals, sectors (including water) and activities. Sustainable, equitable and climate-resilient water management cannot be achieved without the policy, legislative and financing instruments and institutions to synergistically put it into practice.

5.2.1 Policies: setting goals for water use, protection and conservation (Balancing environmental sustainability, economic efficiency and social equity)

In the context of water governance, the first component for an enabling environment is represented by policy development. Policy formulation is at the core of governments' roles. Through its policies, the government can determine the direct and indirect activities of all stakeholder groups, including itself. This allows setting public goals for water use, protection and conservation. Policy development gives an opportunity for setting national objectives for the management of water resources and water service delivery with concerns for the overall development goals.

Due to climate change, the demand and pressure on water resources are increasing, both in terms of quantity and quality, and the multiple users of water are increasingly competing. The participation of as many different stakeholders and authorities as possible in the management of water resources is crucial. To be integrated, water resources policy must link with a nation's wider social and economic objectives that make up the development goals of the society and national sectoral policies. In the context of NAPs, it is essential to agree on a national mandate and strategy for NAP process and, notably, to identify aspects of current development efforts that are most at risk from climate change, assessing whether water-related development goals become unattainable owing to climate change. At this point a clear division of labour and responsibilities between different ministries and departments for addressing climate change risks should be established. Links with national and sectoral development goals should also be explicitly recognized.

As such, water policies are by nature tied to multisectoral approaches which ensure participatory, demand-driven and sustainable development. Therefore, water governance systems can come up with policies that are deemed both socially and economically sustainable and beneficial to reduce climate risks.

Equitable, sustainable and climate-proofed policies can deal with the many interrelated and complex issues, as shown in the case study on community-based approaches to flood management in Thailand and Lao People's Democratic Republic[23], including:

- Assessing the environmental, economic and social values of water;
- Assigning responsibilities to the various public and private actors including basin organizations;
- Recognizing the role of women as users and managers of water resources;
- Taking into account sustainability and environmental issues in the planning, design, construction, operation and management of major water projects;
- Assessment of the social impact of water resource developments;
- Introducing flexible drought and flood management strategies; and
- Linking water policies with other sectoral policies.

Climate change will significantly influence the water environment in the coming decades through changes in the spatial distribution and timing of rainfall, and water resource managers will have to increasingly adopt proactive and dynamic adaptation policies. An integrated approach between sustainable water resource management and adaptation to climate change (CCA) will have to consider the spatio-temporal dimensions of climate change as well as its multisectoral impacts so as to provide water security for the productive and non-productive sectors over time. A key focus of the integrated framework is to help decision makers to understand and incorporate climate change into policy and operational decisions at all scales and across all vulnerable sectors. This could be done, for example, through the generation of knowledge to understand and manage climate change risks to water resources, biodiversity, coasts, fisheries, human health, settlements or infrastructure. A growing number of countries and cities are incorporating water-related adaptation into their planning, policy and institutional response to predicted impacts such as rising sea levels, more frequent floods and increased precipitation.

IWRM policy, as shown by the Rhine Delta case[24], will seek adaptive and 'no-regret' interventions due to the uncertainties involved. The adaptive responses are interventions that can be changed/ adjusted marginally and in response to climate changes, and can closely follow and adjust to the ongoing development of the situation. 'No-regret' interventions are measures that prove to be beneficial, regardless of whether the predicted climate change impacts materialize. For example, increasing the irrigation capacity in rural areas may, on the one side, increase the ability to cope with extreme events such as floods and droughts but, on the other side, also brings great general benefits in terms of agricultural development.

[23] Further case studies developed under the Associated Programme on Flood Management can be found at http://www.floodmanagement.info

[24] Additional case studies of IWRM are available at: 'IFM as an Adaptation Tool For Climate Change: Case Studies' (WMO, 2011).

Case study 1

Community-based approaches to flood management in Thailand and Lao People's Democratic Republic, 2018

The project aimed to develop self-help capabilities in flood-prone communities in the two countries. The Associated Programme on Flood Management, a joint WMO/GWP initiative, worked alongside the Asian Disaster Preparedness Centre and a range of country partners for the three years of the project – from June 2013 to March 2016. With funding from USAID, the programme implemented flood risk assessments and preparedness measures using a participatory approach in four pilot communities prone to riverine and flash floods in Thailand and Lao People's Democratic Republic. Its community-centred approach aimed to reduce the negative impacts of floods while enhancing community preparedness and resilience to flood events. Flood risk has been a growing concern in the communities of Thailand and Lao People's Democratic Republic. With every flood situation, community capabilities have been reduced and investments in development – such as houses, hard assets, livestock, food or security – severely affected within a short period of time. However, until now, communities have not been actively engaged in flood risk management activities; they were simply seen as its beneficiaries. The first step in the pilot project was to familiarize them with flood/disaster management concepts. Communities were engaged in participatory risk assessments and preparedness measures for flooding to enable them to undertake such activities independently in the future and help neighbouring flood-prone communities to develop capacities in similar ways. The Associated Programme on Flood Management and the Asian Disaster Preparedness Centre recently conducted a post-project assessment in Thailand and Lao People's Democratic Republic. The objective was to determine the outcomes and long-term impacts of the project 15 months after its completion. During the assessment visit to the pilot communities, it was observed that they have improved awareness and capacities for better response in emergency situations, particularly in community-based flood preparedness and early warning infrastructures/services. Furthermore, several additional objectives were fulfilled, such as: the enhancement of participatory risk assessments and gender-inclusive participation; the establishment of a community-based flood management committee and a village disaster prevention and control committee; a shift from a reactive to a proactive approach with improved coordination and collaboration among hydro-meteorological departments and local communities.

Case study 2

Rhine Delta management planning, Netherlands

The River Rhine Delta constitutes one of the most densely populated areas in the Netherlands and is under considerable flood risk. The area of land available has decreased continually during the past centuries. The rivers have become confined by increasingly higher dikes (or flood embankments). At the same time, the land behind the dikes has sunk due to settlement and soil subsidence. It has been estimated that a breach in one of the dikes could place approximately 4 million Dutch citizens in danger from flooding. Starting in 2002, the Dutch government has worked with a total of 17 partners drawn from the provinces, municipalities and water boards to develop an integrated plan for the sustainable management of flood risk in the Rhine Delta. The programme, operating from 2007 until 2015, invested in reducing the risk of flooding as well as improving environmental quality by making the river regions more attractive and appealing to the public, and offering more room to nature conservation and recreation (Room for the River, 2007). Key measures implemented include: the relocation of dikes at a distance from riverbanks creating additional space within the floodplain for the river during annual flood events; the lowering and excavation of the floodplain in order to remove sediments which have been progressively deposited as a result of regular flooding; the removal of obstacles to flood flows; the strengthening of dikes making them more resistant to extreme weather events. The end result of the Room for the River programme is a more climate-resilient river system with areas of floodplain functioning in a more naturalistic manner and an enhanced environment which will provide several benefits to the large local population.


Photo: Kees Streefkerk

The 'no-regret' principle should also be applied during a post-disaster recovery and reconstruction phase. In particular, assets and infrastructures should be rebuilt according to the latest safety standards as advised by the 'Build Back Better' approach (UNISDR, 2017). In the case of an integrated flood management approach, post-flood recovery and reconstruction creates substantial opportunities (as well as challenges) to ensure that post-flood recovery and rebuilding do not contribute to future flood risks. It provides the opportunity to move vulnerable activities away from risk areas and introduce flood-proof infrastructures during rebuilding. For example, vital lifeline facilities, such as water and electricity supply, roads and telecommunications, hospitals and sewage systems, have to be repaired quickly, even if the repair is provisional, along with the restoration of education, health systems and contaminated water sources. The recovery period should be viewed as an opportunity to explore ways to improve the flood risk situation and incorporate enhanced resilience of rebuilt assets. Although authorities face great pressure for immediate and temporary solutions, they should grant building permits only after reassessment of the hazards. Furthermore, in applying future risk reduction from flooding, authorities need to learn from previous disasters.

Documenting the extent of the flooded area and the level of flooding by updating hazard maps is a key practice in preparing for future flood events and for determining evacuation routes, shelter locations and future land-use planning. IWRM policy also has to prioritize between structural and non-structural measures. The non-structural interventions are those that deal with the development of institutions and human resources aiming to build capacity to address the climate change impacts. Flood warning systems and emergency preparedness are among the non-structural interventions. The structural measures include infrastructural elements such as dams, flood walls and dikes. The financial situation of the nation will influence the choices and balances between structural and non-structural interventions. An integrated approach of water resource management and CCA could entail that NAPs will focus on issues of national strategic importance that contribute to broader national development as well as on sector-wide issues, such as those related to water security and infrastructure development.

To achieve the overall policy goals agreed by the government, policy makers need to design laws, rules and regulatory frameworks which represent the second element for an IWRM enabling environment.

Case study 3

German Act to improve preventive flood control

The Act came into force on 10 May 2005. The Act amends several Federal Acts (Water Act, Building Code, Regional Planning Act, Waterway Act, Act on the German Meteorological Service) to regulate stricter, more precise and identical provisions for flood prevention throughout Germany. Among others, the following provisions are worth mentioning:

- It is the duty of all to prevent flood damage as far as possible;
- The 16 German federal states (Länder) have to determine waters or water segments where flood damage has occurred or is expected to occur. For those waters, floodplains must be legally designated within five (high potential of damage) to seven years. The basis for the designation is a flood event that is expected to occur once every 100 years;
- Within the designated floodplains, the law of the federal states shall stipulate, for example, how to deal with hazardous substances, especially oil heating systems, and how to prevent or alleviate possible soil erosion and inputs of pollutants. The Act regulates and forbids new development sites through land-use plans. An exemption is only possible if nine strict conditions are met, including no alternatives for human settlement, no risk to life, significant health damage and material loss. If the Building Code allows buildings, for example, because there is already a land-use plan, an additional licence is necessary to prevent negative impacts on flood protection;
- The public and municipalities shall be warned through the designation of flood-prone zones, especially areas behind dikes or other flood protection devices;
- Flood control plans should be established within four years, if no such plans exist. These plans shall cover aspects such as control of water run-off, technical flood control, measures to preserve or restore retention areas and relocation of dikes;
- The Act regulates cooperation in river basin districts with regard to coherent flood prevention; and
- Designated floodplains and flood-prone zones have to be incorporated in land-use plans and spatial planning.

5.2.2 Legal and institutional frameworks: The water governance systems

Legal frameworks are defined as the rules to comply with in order to achieve policies and goals. Legal frameworks play an important role in the management of water resources at a range of scales – from local and national legislation covering domestic use, to international treaties that govern waters shared by sovereign nations.

The required water laws cover ownership of water, permits to use (or pollute) it, the transferability of those permits, and customary entitlements. They underpin regulatory norms for, e.g. conservation, protection, priorities and conflict management, as shown by the case study on the German Act to Improve Preventive Flood Control.[25]

Given the broad range of sectors that deal with water resource management, it is important to have a cross-sectoral overview of all laws that apply in order to avoid conflicting rules. This is sometimes a difficult exercise. A sound knowledge of different legal frameworks (e.g. regulations and procedures for strategic environmental assessments and environmental impact assessments) in different sectors provides a strong basis for adaptation planning and integration of climate change concerns into the planning process. Integrating climate change into the national development planning process will interface with overall political responsibilities including legislation and regulation. It will be essential to incorporate adaptation into policy frameworks that guide policies at lower levels (sectoral and local government) or within international relations as these govern shared resources (e.g. shared river basins), cross-border pollution and successful implementation of multilateral environmental agreements.

Appropriate legal frameworks, paired with institutional and coordination mechanisms, facilitate the formation of a governance system. Legal frameworks are a key component of governance systems, namely the range of political,

[25] Further information can be accessed at: 'The Legal and Institutional Aspects of Integrated Flood Management' (WMO, 2006).

social, economic and administrative institutions that are in place (or need to be in place) to develop and manage water resources sustainably. Under an effective governance system, all institutional actors involved in managing water resources, including citizens, organizations and private entities, work in cooperation towards a common direction. Effective water governance requires clear legal frameworks, comprehensive water policies, enforceable regulations, institutions that work, smooth execution and citizen-based mechanisms of accountability, as well as strong interconnections between these entities. Poor governance leads to increased political and social risks, institutional failure and insufficient capacities to deliver.

While operating and performing their respective functions, institutions must be accountable, responsive and efficient. Accountability means that in the process of policy development and implementation, each institution must be able to explain and take responsibility for actions taken. Clear obligations for each institution should be defined by the appropriate legislative and executive powers. In institutional arrangements guided by the IWRM paradigm, institutions do not see themselves as separate and/or dominant players but rather as components of a team. As part of this collective, institutions work together towards the mutual strategic goal of providing an environment promoting water security for all. IWRM strategy hopes that this vision will translate into law. Similarly, NAP process can be seen as a way to help diverse stakeholders to achieve their collective development, adaptation and sectoral goals considering a changing climate.

Institutional arrangements ensure social equity, economic efficiency and ecological sustainability in water management. Economic efficiency calls for increased service delivery with equity and minimum waste. To ensure this, appropriate price regulations and standards for limiting the damage to the environment should be specified.

Case study 4

Morocco’s integrated drought management system

Drought is a recurrent natural phenomenon of Morocco’s climate. The history of drought over the last millennium (year 1000–1984) showed over 89 droughts of one to six years duration, with an average occurrence interval of about 11 years. Morocco’s experience over the years has allowed the country to gradually establish an integrated drought management system, structured around three essential elements. The first one is a monitoring and early warning system: Morocco has developed national institutional and technical capacities, particularly in the areas of climate modelling, remote sensing and crop forecasting. The second element is represented by the emergency operational plans to alleviate the impacts of drought, including programmes to secure safe drinking water for rural populations or preserve livestock through feed distribution, and the conservation of forests and natural resources. The third element is a long-term strategy to reduce vulnerability to drought. This strategy is based on a risk management approach that reduces the vulnerability to drought of the national economy as a whole and of agriculture and the rural economy in particular. It involves a diverse and multidimensional array of policies that take into account drought risk in its geographical diversity and economic and social implications, as well as in its long-term recurrence. The core component of the strategy is a long-term investment programme aimed at developing hydropower infrastructure to reduce energy imports. Through optimized financing strategies and increased budget support for public infrastructure, the investment plan aims at improving access to water supply and sanitation, and increasing wastewater treatment capacity (rural water supply, sanitation and pollution control, service extension to poor peri-urban areas). In this context, an integrated approach has been adopted, along with expansion investments, to drive improvements in three major interrelated areas: (i) improving the hydraulic efficiency of irrigation systems; (ii) strengthening the managerial capacities of irrigation agencies; and (iii) increasing productivity. The case of Morocco shows that conserving water and improving efficiency of water usage leads to improved asset management in public irrigation, productivity, cost-effectiveness and sustainability of irrigated agriculture, and drives Morocco’s economic growth and development.

5.2.3 Investment and financing structures: Financial resources for water needs

Creating the investment structures and securing the funding to meet water needs is a key enabling factor in achieving sustainable, climate-resilient and responsive water governance. Water projects tend to be capital-intensive, and many countries have major backlogs in developing water infrastructure. In relation to NAPs, financial and technical means are necessary for the formulation and implementation of adaptation measures, as well as identifying gaps in capacity for successful adaptation planning. Yet countries, especially LDCs, have limited financial resources, particularly to fully assess and address the adaptation needs of the water sector and other vulnerable sectors.

The term 'investment' refers to the creation of a productive asset which yields benefits over a future period. Investment is needed in the conservation, management and development of the natural resources which underpin water supply (watersheds, catchments, river courses, wetlands, aquifers). Likewise, it is also required in the creation of hard (pipelines, dams, treatment works, pumps, distribution systems, hydropower stations) and soft infrastructure (administrative overheads, research & monitoring, consumer services, IT systems). Morocco's integrated drought management system is a case in point.[26]

The cost of this investment needs to be financed in various ways – charging water users, investments from government budgets, external aid, commercial loans and equity. Most water infrastructure investment traditionally comes from the public domain and depends on public budgets for most or all of its funding. Some types of water public goods have major financial costs (strategic storage dams and reservoirs, flood-control structures, multipurpose storage schemes, wastewater treatment plants, bulk water conveyances).

Water is widely considered a problematic area for attracting funding. This is due to a number of factors: the poor credit worthiness of borrowing institutions, the low levels of tariffs and cost recovery, political interference in operations, lack of suitable collateral, and the capital-intensive, long-term nature of major infrastructures. Also, the water sector tends to be regulated in a way that might generate so-called regulatory risks for investors.

5.2.4 Removing barriers to sustainable water resource management

The water sector can learn from a new perspective emerging from the climate change adaptation and mitigation experience (UN Environment, 2016) which looks at how limited public financial resources can create the conditions to attract private investment through the removal of behavioural, institutional, technological, regulatory and financial barriers (Table 5.1).

There are basically five principal types of barriers to climate-resilient development:

- 1) Information/behavioural (awareness, habits)
- 2) Institutional (delays in administrative processing)
- 3) Technological (lack of skills, etc.)
- 4) Regulatory (discriminatory policies, etc.)
- 5) Financial (upfront costs, etc.)

The creation of an enabling environment (through strategic goal-setting, multilevel governance, stakeholder engagement, regulatory policies to incentivize IWRM investments, financial policies and instruments) will help decision makers to make climate sectors attractive for private investors, by either reducing risks (stable policy context, guarantee instruments, etc.) or increasing rewards (premium prices, tax credits, etc.).

In the water sector, in order to minimize misallocation and investment failures and harmonize investment and financing decisions, policy makers often use decision frameworks, such as Strategic Financial Planning. Adopting an IWRM strategy actually boosts investment efficiency in this sector. Within the general framework of Strategic Financial Planning, a consensus is forming around the '3Ts' approach. This trend recognizes that water is ultimately paid for from one of the following three sources: Tariffs, Taxes and Transfers (from external or

[26] Further details are available at: 'National Drought Management Policy Guidelines: a Template for Action' (WMO, 2014).

Table 5.1: Barriers to sustainable water resource management

Barrier	Description
1. Information barriers	
Knowledge gaps	Consumers, lenders, developers, utility companies and planners, both in developed and developing countries, often lack adequate information about IWRM technologies and practices, how to assess them and how to implement them.
Reliability concern	IWRM might still suffer from bad press due to performance concerns associated with earlier technology generations or inexperienced service providers.
Higher cost perception	Consumers often give greater weight to upfront costs compared to recurring costs. Even if an investment is cost-effective over a few years, the necessity to pay the initial investment costs may deter consumers.
2. Institutional barriers	
Limited capacity to formulate IWRM policies and strategies	There may be limited capacity in assessing risks and opportunities, engaging stakeholders in defining a vision, and articulating it into concrete policies and strategies.
Weak policy implementation and enforcement	Government may not be in a position to implement IWRM policies and enforce existing standards.
3. Technical barriers	
Lack of technical skills	There may be a lack of technical skills to operate and maintain IWRM practices and technologies.
Lack of certification facilities	There may be a lack of national standards and certified operators to guarantee the quality and safety of clean and sustainable facilities and/or facilitate licensing processes.

4. Regulatory barriers	
Legacy policies/ regulations	Historically regulatory structures and policies in both developed and developing countries often favoured inefficient and unsustainable water management practices.
Administrative barriers	Multiple restrictions on location and construction for IWRM technologies due to concerns relating to safety and wildlife.
5. Financial barriers	
Higher risk management costs	Because of perceived higher technology risks and return uncertainty, risk management is more expensive for new clean water technologies.
Higher upfront costs	IWRM technologies can be more expensive than conventional technologies and subject to longer payback periods. Available loan terms may be too short relative to the equipment or investment lifetime.
Transaction costs	Transaction costs for IWRM initiatives are often higher because of the relatively smaller size of the projects. Bank regulations and investment policies, often designed for larger conventional water projects, can be inadequate or unsuitable for smaller, more numerous, distributed sustainable water management projects.

other philanthropic sources). The 3Ts create a stream of revenues that can be used to leverage commercial sources of funding – loans and equity – which eventually have to be serviced and repaid from these revenues.

There are several additional options for mobilizing financial, technical and capacity-building support under the multilateral processes, including at the local, national and regional levels. The adaptation activities prioritized through NAP process could be implemented in accordance with the modalities established under UNFCCC, as well as through other channels such as private finance.

5.3 Financing adaptation

Adaptation planning, and NAP process specifically, is crucial for scaling up adaptation interventions. Climate change finance has emerged in response to continuous calls for additional, predictable and sustainable support to help vulnerable countries to address impacts and risk. More specifically, climate finance refers to flows of funds towards activities that reduce GHG emissions or help societies adapt to the impacts of climate change.

Developing countries are in particular need of financial support, because they are the most vulnerable to the effects of climate change and they have more limited access to resources in the first place. This is why climate finance is one of the key areas for negotiation under UNFCCC.

Figure 5.2: Main streams of climate finance (UNITAR, 2014)

Climate finance can be classified into four basic types, ranging from national and international private-sector sources, to national and international public-sector sources. Flows of international public finance to developing countries for adaptation have been growing steadily in recent years. The financial instruments to support NAPs are manifold, reflecting the complexity and flexibility of adaptation planning.

UNFCCC has established various ways to transfer funds to developing countries, especially through international public sources, with the creation of the Global Environment Facility (GEF), the Kyoto Protocol's Adaptation Fund (AF), and most recently the Green Climate Fund (GCF) to finance implementation of the Convention and the Paris Agreement.

GEF, which has been operating for more than 20 years, is the most well established of these mechanisms. GEF is responsible for administering three important adaptation-related trust funds: the Special Climate Change Fund (SCCF), the Least Developed Countries Fund (LDCF) and AF.

GCF was created in 2010 as part of UNFCCC's financial mechanism to facilitate the development of climate change strategies and plans, including NAPs. By following a country-driven and country-owned approach – in terms of funding and integrating the funding into national planning – GCF will align climate finance with national priorities and planning processes. GCF project portfolio is implemented by partner organizations, known as Accredited Entities, in liaison with National Designated Authorities (NDAs).

Although the Paris Agreement has raised the political profile of climate resilience, financing adaptation still represents a challenge for international and national public funding. The 2016 Adaptation Finance Gap Report (UN Environment, 2016) presents the latest figures on the financial gap for adaptation – an amount that could range from US$140 billion to US$300 billion by 2030, and between US$280 billion and US$500 billion by 2050. This gap needs to be filled to meet the ambitions of the Paris Agreement.

Case study 5

The Sahel proposal to GCF

Following high-level policy endorsement of their NAPs, seven countries in the Sahel (Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Mali, Niger and Senegal) pooled together to develop a regional programme proposal to GCF. The proposal aimed to secure adequate resources for the implementation of the National Frameworks for Climate Services (NFCS) recently validated in each country, and implement priority activities identified in their national action plans to step up the delivery and use of climate services at the national scale. NFCS are an institutional mechanism to coordinate, facilitate and strengthen collaboration among national institutions to improve the co-production, tailoring, delivery and use of science-based climate information and services. In the absence of adequate national resources, this proposal to GCF was essential to ensure the operationalization of NFCS in each country. Each country striving to secure resources for implementation of its NFCS should explore developing proposals, targeting similar global climate finance funds. In these countries, partner forums or donor round-table discussions were organized in order to introduce the national strategic and action plans to development partners operating there. This helped to explain the funding gap, enlist support to secure funding for implementing identified priority activities, and agree on steps for implementation. Securing funds is a process that is resource intensive and it may require the development of different types of proposals, depending on the funding source.

To address the adaptation finance gap effectively, great emphasis should be put on scaling up the level of finance flowing towards adaptation. Increasing public policy effectiveness and efficiency is a key issue for this kind of action. The trend in international public finance for adaptation over recent years reflects increasing attention to mainstreaming adaptation into development cooperation practices (UN Environment, 2014) and a growing focus on climate-resilient development. Effectiveness and efficiency imply that available funds are targeted where they are most needed and used optimally to ensure they have the greatest possible impact, such as through partnership and collaboration across national borders or capitalization of regional synergies, as highlighted by the Sahel proposal to GCF.[27]

To this end, maximization of the number of beneficiaries, including the most vulnerable, and delivery of the highest value for money will be of the utmost importance to facilitate adaptation financing. Adaptation has the potential to be extremely beneficial and cost-effective when planned with uncertainty and implementation in mind. The IWRM approach integrated with NAPs and climate adaptation planning can ensure the identification of 'low-regret' options and actions that combine early planning for major future risks with flexibility and robustness for long-term decisions.

[27] Further information can be accessed at: 'Step-by-step Guidelines for Establishing a National Framework for Climate Services' (WMO, 2018).

Summary

Water is a key driver of economic and social development while it also has a basic function in maintaining the integrity of the natural environment. As the global population grows alongside the demand for water and the exposure of communities to extreme hydrological events, it is imperative that water issues are not considered in isolation. More systematic and integrated approaches are required to effectively and sustainably manage water resources under a changing climate. The establishment of enabling policy and legislation frameworks ensures the efficient, equitable and sustainable management of the world's limited water resources, creating the incentives for greater public and private engagement in climate change adaptation.

Suggested reading

WMO, 2006. *The Legal and Institutional Aspects of Integrated Flood Management*.

WMO, 2011. *IFM as an Adaptation Tool for Climate Change: Case Studies*.

UNFCCC, 2012. *National Adaptation Plans: Technical Guidelines for the National Adaptation Plan Process.*

GFCS-WMO, 2014. *Water Exemplar to the User Interface Platform of the Global Framework for Climate Services.*

WMO, 2014. *National Drought Management Policy Guidelines: A Template for Action.*

Global Water Partnership, 2015. *National Adaptation Plan Process: Water Supplement to the Technical Guidelines – Final Draft.*

UN Environment, 2016. *The Adaptation Gap Report.*

WMO, 2016. *Climate Services for Supporting Climate Change Adaptation: Supplement to the Technical Guidelines for the National Adaptation Plan Process.*

GFCS-WMO, 2017. White Paper on the Contribution of the Global Framework for Climate Services to Transforming Our World: the 2030 Agenda for Sustainable Development (Agenda 2030).

WMO, 2018. *Step-by-step Guidelines for Establishing a National Framework for Climate Services.*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Facilitators' Guide

Sample course programme

Day 1

Time	Topic	Content
09:00 – 10:30	Introduction	Introduction of programme and participants.
11:00 – 12:30	Introduction to Integrated Water Resources Management (IWRM) and climate change and its impacts on the major water sectors	Introduction to the training manual and its relevance in terms of addressing CCA. Presentation is followed by group discussion.
13:30 – 14:30	Outlining climate challenges, demand growth challenges and hotspots	Introduction and discussion: Discuss climate change impacts; climate change mitigation and adaptation; water and climate change adaptation challenges. Outline climate challenges, demand growth challenges and hotspots, resulting water resource challenges and water resource management challenges including vulnerable sectors and users.
14:30 – 15:30	Group discussion	Groups – report back
16:00 – 17:30	Cross-sectoral integrated water management	International frameworks; SDG 6; IWRM as a Tool for Justice and Human Rights. Presentation is followed by group discussion and wrap-up.

Day 2

Time	Topic	Content
08:30 – 09:00	Recap of previous day	Relevant topics are revisited and clarified. Participants are asked to volunteer to summarize the presentations and discussions in no more than three challenging statements that aim to trigger discussion.

09:00 – 10:30	Understanding drivers and impacts of climate change – Impacts	Introduction and discussion: An understanding of how climate change will impact water resources and ecosystems, and how this may affect water use is discussed. Exercise: Potential impacts of climate change on major water sectors focusing on water scarcity, flooding and consequences of sea-level rise.
11:00 – 12:30	Exercise	Groups formed according to 4 cases – define Terms of Reference of different teams in a climate change adaptation project in the water sector.
13:30 – 15:00	Impacts of climate change on water-use sectors	Introduction and discussion: What are the climate change impacts on water resources at global and regional levels? The expected impacts for various water-use sectors are highlighted: Observed and forecast impacts of climate variability and change in the hydrological cycle, water resource management and human societies.
15:30 – 17:30	Exercise	Same groups as previous session discuss impacts on: Case 1 – agriculture and rural floods Case 2 – reduced water quality Case 3 – ecosystem services and livelihoods Case 4 – human societies and human rights

Day 3

Time	Topic	Content
08:30 – 09:00	Recap of previous day	
09:00 – 10:30	Strategy development and planning for adaptation	Introduction and discussion: Building on the previous session, discuss new techniques for planning for adaptation. These range from National Adaptation Programmes of Action (NAPAs) to climate-risk screening. Presentation is followed by group discussion.

11:00 – 12:30	Climate change adaptation: Institutional frameworks and the transnational road to adaptation to climate change	Introduction and discussion: Introduction to dealing with climate change and how this can be included in environmental management approaches. Includes a presentation on prediction and resilience-oriented approaches as two different approaches to climate change adaptation.
13:30 – 18:00	Field visit	

Day 4

Time	Topic	Content
08:30 – 09:00	Recap of previous day	
09:00 – 10:30	Exercise	Some of the climate-risk screening and assessment tools can be used at national or local level, in programmes, policy or plans. Give examples from different countries/ regions in the plenary.
11:00 – 12:30	Technologies for addressing adaptation challenges	Introduction and discussion: Overview of adaptation measures and their typology.
13:30 – 15:00	Vulnerability: Feasibility, sustainability, social and financial implications	Exercise to define exposure, sensitivity and adaptive capacity.
15:00 – 17:30	Role play	Same groups as before to choose 1 of the 6 themes for climate variability: 1) climate risks; 2) too little water; 3) too much water; 4) water pollution; 5) sea-level rise; and 6) disaster preparedness. Within each of these themes, a number of key adaptation response types for tackling risk and uncertainty in the water sector are available. Each group should present their scenario, by bringing in examples of challenges they face in their own country, discussing commonalities between countries and how these may be overcome.

Day 5

Time	Topic	Content
08:30 – 09:00	Recap of previous day	
09.00 – 10.30	Prioritization and prioritization tools	Discuss the prioritization process, and how it can be followed by stakeholders to determine a set of prioritized technologies for implementation.
11:00 – 12:30	Implementation: 'How to' Guide: IWRM under a changing climate	Introduction and discussion: The session provides an overview of the elements leading to an increased integration of climate change in water-sectoral planning and financing within the framework of national priorities for climate-resilient development.
13.30 – 15.30	Exercise	The 4 groups are challenged to strategize and incorporate adaptation in water resource management planning. See 4 case studies in manual.
15:30 – 16:00	- cont'd -	Reporting back and discussion.
16:00 – 16:30	General discussion	Lessons to be taken home.
17:00 – 17:30	Course evaluation & closure	

Session 1

Title: Introduction to Integrated Water Resources Management and climate change

Learning objectives

At the end of this session, participants will be able to:

- Explain the meaning of IWRM and its main principles in relation to climate change;
- Identify the main reasons for taking an IWRM approach;
- Analyse some areas where IWRM can assist adaptation to climate change.

Needs/requirements for the session

Presentation equipment
Flip charts or other group exercise reporting tools
Breakout space

Short summary

The session introduces the main principles and concepts of IWRM and addresses how it can help adaptation to changing climatic conditions for improved water availability and quality.

Time allocation

Presentation and discussion: 45 minutes
Exercise: 45 minutes
Total: 90 minutes

Exercise

Group discussion. Depending on the size of the group, divide in 3 or 4 groups and discuss the following questions:

Give examples of potential impacts on major water sectors related to water scarcity, flooding and sea-level rise. One potential exercise is to have participants fill in a table from scratch and add more sectors as they come to mind. The example here only considers three impact themes, but additional themes could be added. Some of the questions you may want to answer are:

- What is the evidence of commitment to IWRM in your country?
- How are men and women affected differently by changes in water resource management in your country?
- How adaptable are management practices in your country?
- What are climate change manifestations in your country that IWRM could address?

Session 2

Title: Drivers and impacts of climate change

Learning objectives

At the end of this session, participants will be able to:

- Explain the basic concepts of climate variability and climate change;
- Incorporate the language used by IPCC to communicate confidence and uncertainty;
- Identify climate change impacts on the water cycle, ecosystems and water use.

Needs/requirements for the session

Computer and projector
Breakout space

Short summary

An update of the key assessment findings of the Fifth Assessment Report (AR5) of IPCC, as well as highlighting the observed and forecast impacts of climate variability and change on the hydrological cycle, water resource management and human societies.

Time allocation

Introduction and discussion on drivers: 60 minutes
Group discussion and report back: 60 minutes
Introduction and discussion on impacts: 90 minutes
Total: 3 hrs 30 minutes

Exercise

Group discussion. Depending on the size of the group, divide in 3 or 4 random groups and discuss the following questions:

- Have you already noticed any changes in the climate of your region? Are these changes in agreement with IPCC observations and projections?
- What were the impacts on water resources?
- Predict future changes and how they might affect water resources.

End the exercise with brief (5-minute) oral reports to the whole group.

Session 3

Title: Strategy development and planning for adaptation

Learning objectives

At the end of this session, participants will be able to:

- Identify the main principles and processes that have been proposed for the process of preparing adaptation strategies, NAPAs and climate-risk screening;
- Explore some major sources of substantive guidance for adaptation planning;
- Explore through a case example the possibilities of transposing adaptation principles into a project context;
- Identify the linkages between adaptation plans and mitigation plans, and possible conflicting measures between the two.

Needs/requirements for the session

Presentation equipment
Flip charts or other group exercise reporting tools
Breakout space

Short summary

A look at the different elements such as institutional frameworks, tools and resources to consider when planning for adaptation.

Time allocation

Introduction and discussion on main principles and processes for preparing adaptation strategies: 120 minutes
Group discussion and report back with examples: 120 minutes
Discussion on adaptation plans and mitigation plans, and possible conflicting measures between the two: 90 minutes
Total: 5 hrs 30 minutes

Exercise

Group exercise and presentation to the plenary.

→ See exercise description and sample solution.

Session 4

Title: Technologies for addressing adaptation challenges

Learning objectives

At the end of this session, participants will be able to:

- Discuss the implications of climate change for water resources;
- Explain the expected consequences of climate change for major water-use sectors;
- Analyse and use the various methods to generate climate scenarios.

Needs/requirements for the session

Computer and projector
Breakout space

Short summary

Even if the release of anthropogenic GHGs could be highly reduced, there is still the need to adapt to the impacts of climate change, and it will take considerable time before the results of mitigation interventions will be visible. Water managers have to deal with changes in the hydrological cycle and related uncertainties today and in the near future. It is generally accepted that improving water management today will help us to adapt tomorrow, and there are many actions that can be taken to prepare for a more variable climate.

Time allocation

Introduction and discussion of impacts on water-use sectors: 90 minutes
Exercise and plenary presentations: 120 minutes
Introduction and discussion on techniques for assessing impacts: 90 minutes
Total: 5 hrs
Note: The exercise on techniques for assessing impacts will be combined with the exercise for dealing with uncertainties.

Exercise

Make the same groups as before to choose 1 of the 6 themes for climate variability: 1) climate risks; 2) too little water; 3) too much water; 4) water pollution; 5) sea-level rise; and 6) disaster preparedness. Within each of these themes, a number of key adaptation response types for tackling risk and uncertainty in the water sector are available. Each group should present their scenario.

Session 5

Title: Adaptation to climate change in water management

Learning objectives

At the end of the session participants will be able to:

- Understand the water resource management instruments available to address climate change manifestations;
- Strategize the use of different policies and instruments;
- Promote adaptation at the appropriate level.

Needs/requirements for the session

Presentation equipment
Flip charts or other group exercise reporting tools
Breakout space

Short summary

Overview of the elements leading to increased integration of climate change in water-sectoral planning and financing within the framework of national priorities for climate-resilient development. There is a focus on the policy, legislative and financing frameworks which deal with water as a social and economic public good, ensuring an equilibrium between water security, development and climate-risk management.

Adaptation to climate variability has to be incorporated into water resource management planning.
Finally, the participants are challenged to strategize and incorporate adaptation into water resource management planning.

Time allocation

Presentation and discussion: 90 minutes
Exercise: 150 minutes
Reporting back and discussion: 60 minutes
Total: 5 hours

Exercise

Groups work to incorporate climate change adaptation strategies and measures into IWRM planning. Tasks are described in the Exercises section.

Case descriptions for subsequent exercises:

Case 1:

A river basin is situated in a developing country in Asia with a monsoonal climate.

Population density is already high as is the poverty rate, and the population is projected to further increase in the coming three to five decades. Even though there are urbanization trends, the majority of inhabitants live in rural areas where livelihoods are directly linked to (subsistence) agriculture. Riverine flooding has been an annual feature in the past. Smaller (e.g. annual) floods are essential for maintaining soil fertility, riverine ecosystem health, and for replenishing water supplies in surface-water reservoirs and in groundwater systems connected to the floodplain. Negative impacts of larger floods are high loss of life, destruction of crops and livelihoods, disruption of the transport infrastructure, and damage to houses and other infrastructure. The recurrent flooding also leads to development funds being diverted towards disaster relief.

Case 2:

A river catchment is situated in a developing country in sub-Saharan Africa. There is one rainy season (October to March), which generally has a dry period in January. Population density is relatively low. Most livelihoods are dependent on rainfed agriculture. Artificial fertilizers are used sparsely because of high costs. Soil moisture conservation has been part of traditional farming practices, but because of mechanization is now less common. The population is projected to further increase in the coming three to five decades. Even though there are urbanization trends, the majority of inhabitants live in rural areas where livelihoods are directly linked to (subsistence) agriculture.

Case 3:

A coastal megacity is situated in a developing country in Latin America at the mouth of a large river. In recent years storms and high river discharges have resulted in flooding in some lower parts of the city. This has resulted in overflow of sewer systems, causing pollution of drinking water sources and the outbreak of waterborne diseases. During long drought periods the availability of sufficient drinking water could not be guaranteed. Because of migration from rural areas to the city, population density is projected to further increase in the coming three to five decades, leading to more development in high-risk areas.

Case 4:

A river basin is situated in a tropical developing country in South-East Asia. Population density is high, and the population is projected to further increase in the coming three to five decades. Even though there are urbanization trends, the majority of inhabitants are living in rural areas where livelihoods are directly linked to (subsistence) agriculture and fisheries. Smaller (e.g. annual) floods are essential for maintaining soil fertility, riverine ecosystem health, and for replenishing water supplies in surface-water reservoirs and in groundwater systems connected to the floodplain. The river is an important habitat for the commercially significant fish *Carnitop*, which spends part of its life cycle in upstream tributaries and part of it in downstream mangrove forests. *Carnitop* needs clear water, and its food source is very sensitive to pesticides.

Exercises

Session 2: Impacts of climate change on water-use sectors

Exercise 1

Based on the four cases presented, the groups will discuss the expected impacts on the sectors identified in the respective cases:

- Case 1 – agriculture and rural floods
- Case 2 – navigation and agriculture
- Case 3 – infrastructure and urban floods
- Case 4 – ecosystems and fisheries

Session 3: Strategy development and planning for adaptation

Exercise 2

Example of providing structure to a climate change adaptation project for the water sector

Note: this example is based on the case of an arid developing country where substantive research needs have been identified as part of a preliminary assessment. Therefore, emphasis is placed on strengthening the understanding of specific impacts for the water sector in that area. This may be applied differently in places where substantive research projects have already been completed or in a different climatic and socio-economic context.

The project objectives for this example are to:

- Create a national environment to facilitate use of climate information in:
  - Water resource planning;
  - Operation of water infrastructures;
  - Disaster management.
- Carry out scientific assessments of climate change impacts on water resources and build awareness;
- Assess impacts of climate change on existing or proposed water system operation rules, system design and sizing, policies and water-use strategies;
- Develop knowledge through applied research in water management issues related to climate predictions, variability and change; and thereby
- Contribute towards sustainable development by evolving adaptation strategies for planning and operation of water resources infrastructure and disaster management.

The following working groups have been devised to support the project. Note that roles vary among substantive scientific research tasks, coordination and facilitation tasks, and strategic planning and policy-making tasks. Participants may select the appropriate number of groups (4 or 5) for the exercise.

Working Group 1: Climate Information Group

Terms of Reference: The group will work closely with the national and international climate data providers such as climate modelling institutions, regional model developers, etc. Apart from meeting the requirements of this project, this working group (WG), once established, has the potential to meet the requirements of other climate change studies carried out by different sectors. For this purpose, the group shall work closely with WG 10 (Interministerial Coordination Group) and develop mechanisms to obtain inputs from other sectors. This WG will be responsible for providing the following climate information for use by other groups:

- (i) GCM scenarios/database;
- (ii) Downscaling and regional climate models;
- (iii) Climate and ocean interaction modelling for sea roughness;
- (iv) Seasonal climate outlooks; and
- (v) Numerical weather products.

Working Group 2: Data and Information Group

Terms of Reference: Various groups will require different kinds of historical information and data. These data should be managed in such a way that they are easily available to all the groups and are appropriately archived for use in all future climate studies. The group will be working on:

- (i) Assessment and compilation of available data;
- (ii) Assessment of data needs;
- (iii) Building a platform for data sharing and management;
- (iv) Assessment of data gaps; and
- (v) Recommendations on strengthening monitoring network for future needs and impacts of adaptation strategies.

Working Group 3: Water Demand Group

Terms of Reference: Future demands for water from different sectors are likely to change with the warming climate. In order to develop adaptation strategies, it is essential to assess these demands in close collaboration with various users. The group will:

- (i) Assess current and future demands;
- (ii) Interact with other ministries;
- (iii) Interact with various users; and
- (iv) Explore possibilities of demand management.

Working Group 4: Groundwater Group

Terms of Reference: The group will work in collaboration with WG 5 (Water Resources Assessment) for overall assessment of water resources, and will implement the following actions to study impacts of climate change on groundwater:

- (i) Groundwater recharge and its quality;
- (ii) Groundwater/freshwater interface in coastal areas; and
- (iii) Lakes and lagoons in coastal areas.

Working Group 5: Water Resources Assessment Group

Terms of Reference: The group will focus on assessment of surface-water resources in quantitative and qualitative terms. It will have close interaction with WG 1 (Climate Information Group) and WG 4 (Groundwater Group). The group will work on:

- (i) Study of inflow and outflow of surface-water reservoirs;
- (ii) Study of reservoir evaporation and water quality;
- (iii) Drainage system studies; and
- (iv) Studies of river water quality.

Working Group 6: Planning, Adaptation and Management Group

Terms of Reference: The group will synthesize inputs from different groups. It will use the information produced by WGs 3, 4 and 5, and will develop mechanisms and inputs for mainstreaming the climate-risk information generated in:

- (i) National water resource planning;
- (ii) Assessment of current and future development projects;
- (iii) Adaptation of policies and plans; and
- (iv) Environmental management of various waterbodies.

Working Group 7: Coastal Zone Management Group

Terms of Reference: The group will be responsible for assessing impacts of climate change on the following coastal elements and their impacts on various natural elements and human-made coastal structures or infrastructure in coastal areas:

- (i) Waves and currents patterns;
- (ii) Monitoring sea levels and land topography;
- (iii) Dynamics and ecosystems of lakes;
- (iv) Outlets of rivers and lagoons;
- (v) Coastal erosion;
- (vi) Impacts on coastal protection works; and
- (vii) Infrastructure in coastal areas.

Working Group 8: System Operation and Maintenance Group

Terms of Reference: The group will be responsible for assessing the sensitivity of the following water infrastructure structures to impacts of climate change on water availability:

- (i) Dams;
- (ii) Infrastructure (barrages, bridges, pump houses, etc.);
- (iii) Canals; and
- (iv) Drainage systems.

Working Group 9: Information and Awareness Group

Terms of Reference: WGs 9 and 10 are outreach groups and will be responsible for communicating the results of the project to the outside world. The group will develop communication strategies with the public and professionals, and will be responsible for improving:

- (i) Awareness among water professionals;
- (ii) Awareness among other sectors;
- (iii) Public awareness;
- (iv) Awareness through education; and
- (v) Interaction with NGOs, farmers' cooperatives and water-user associations to achieve the above.

Working Group 10: Interministerial Coordination Group

Terms of Reference: The group will be responsible for interacting with the following to assess their information needs and communicate results of the assessments periodically:

- (i) Different ministries and users;
- (ii) Other basin states;
- (iii) Local communities/government;
- (iv) Private sector; and
- (v) NGOs.

Table 1: Sample table format that can be used by the groups to propose possible measures

Type of measures	Flood-prone situation	Drought-prone situation	Impaired water quality	Health effects
PREVENTION/ IMPROVING RESILIENCE measures				
PREPARATION measures				
REACTIVE measures				
RECOVERY measures				

Session 4: Technologies for addressing adaptation challenges

Exercise 3: Dealing with uncertainties

For the four cases the same groups will carry out a risk assessment, using the Climate Vulnerability Index (CVI) to identify major uncertainties.

The Climate Vulnerability Index

CVI is based on a framework that incorporates a wide range of issues. It is a holistic methodology for water resources evaluation, in keeping with the sustainable livelihoods approach used by many donor organizations to evaluate development progress. The scores of the index range on a scale of 0 to 100, with the total being generated as a weighted average of six major components. Each of the components is also scored from 0 to 100.

The six major categories or components are shown in Table 2.

Exercise 4: Instruments and measures for adaptation

Each group is assigned to one of the case studies given, for which they have to work out and present the following issues:

1. Identify a set of likely impacts on the state of water resources in terms of spatial and temporal distribution (including extreme events) and quality. Your assumption is that those impacts have been assessed at least as 'likely' by a scientific impact assessment.

2. Rank these impacts to define a set of measures that need to be considered in adapting to the projected impacts and explain the intended effect for each measure. Preferably, this set of measures should include a combination of policy measures, technological measures, and measures aiming at risk-sharing.

Table 2: CVI components

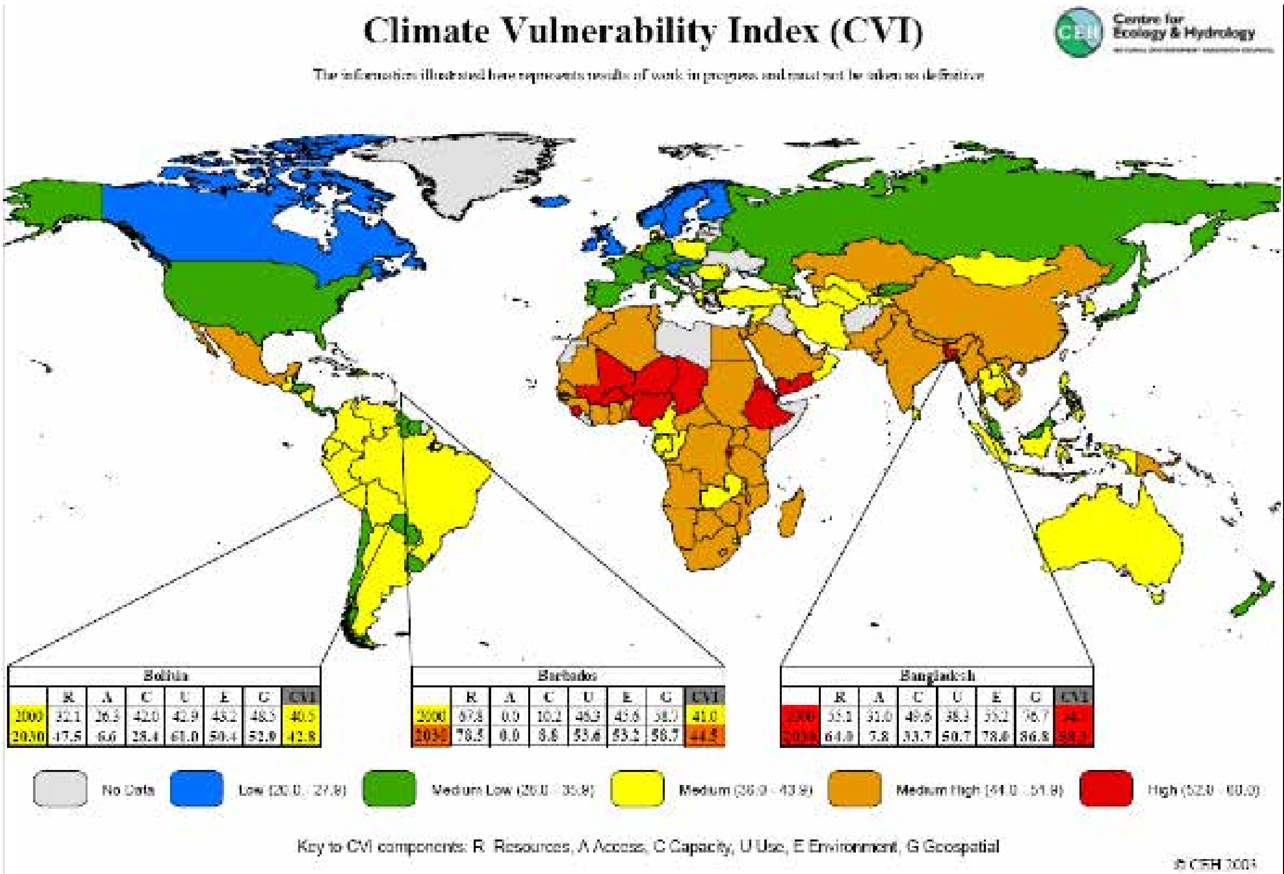
CVI component	Subcomponents/variables
Resource (R)	• assessment of surface-water and groundwater availability • evaluation of water storage capacity, and reliability of resources • assessment of water quality, and dependence on imported/desalinated water
Access (A°	• access to clean water and sanitation • access to irrigation coverage adjusted by climate characteristics
Capacity (C)	• expenditure on consumer durables, or income • GDP as a proportion of GNP, and water investment as a % of total fixed capital investment • education level of the population, and the under-five mortality rate • existence of disaster warning systems, and strength of municipal institutions • percentage of people living in informal housing • access to a place of safety in the event of flooding or other disasters
Use (U)	• domestic water consumption rate related to national or other standards • agricultural and industrial water use related to their respective contributions to GDP
Environment (E)	• livestock and human population density • loss of habitats • flood frequency
Geospatial (G)	• extent of land at risk from sea-level rise, tidal waves or landslides • degree of isolation from other water resources and/or food sources • deforestation, desertification and/or soil erosion rates • degree of land conversion from natural vegetation • deglaciation and risk of glacial lake burst

3. Classify these measures: Are they anticipatory or reactive, and do they apply to the natural system or to the human system?

4. For each measure you select, provide indications on the following criteria:

- Are the measures economically justifiable even if the projected impacts turn out to be smaller? (i.e. can they be labelled 'no-regret' or 'low-regret' measures?)
- Are there major known constraints to their application, e.g. financial/political constraints, acceptability by stakeholders?
- Do the measures compromise climate change mitigation targets in the sense of significantly increasing GHG emissions?
- Try to identify possible externalities of applying such measures, e.g. in the areas of livelihood security, food security, ecosystem health and poverty reduction.

Figure 1: *Source: Sullivan and Meigh, 2005*



Session 5: Implementation – How to guide IWRM under a changing climate

Exercise 5

Description:

The WGs of the previous exercises are expected to further elaborate their respective cases.

Assignment to the groups:

Develop a strategy for adaptation to climate change using the concepts, principles, tools and techniques presented during the week.

In developing the strategy, consider the following elements:

- Problem analysis;
- Scenarios and models;
- Principles and concepts of IWRM;
- Health impacts;
- Legal options;
- Financial and economic impacts;
- Possible adaptation measures;
- Strategy development for different sectors and dealing with uncertainties;
- Planning process and stakeholder participation;
- Capacity-building;
- Community and basin-level activities; and
- The roles of river basin organizations and local authorities.

Use the IWRM planning cycle and identify the actors at each stage of the cycle, actions to be taken, expected outputs and indicators for success.

Tip: useful material: Cap-Net Training Manual and Operational Guide, IWRM Plans (2005)

Role Play: Lake Naivasha

Please read the following description of Lake Naivasha, Kenya (http://en.wikipedia.org/wiki/Lake_Naivasha). In this description, it becomes clear that water levels are dropping in the lake, which affects many stakeholders. This process is steered by a complex set of natural and anthropogenic drivers, and climate change is likely to be one of them. Climate-change scenarios predict a decrease in annual rainfall in the Naivasha area.

Description of Lake Naivasha

Surface area 139 km^2; average depth 6 m; max. depth 30 m; surface elevation 1,884 m.

Lake Naivasha is a freshwater lake in Kenya, lying north-west of Nairobi, outside the town of Naivasha. It is part of the Great Rift Valley. The name derives from the local Maasai name *Nai'posha*, meaning 'rough water' because of the sudden storms which can arise. The lake has a surface area of 139 km^2, and is surrounded by a swamp, which covers an area of 64 km^2, but this can vary largely depending on rainfall. It is situated at an altitude of 1,884 m. The lake has an average depth of 6 m, with the deepest area being at Crescent Island, with a depth of 30 m. Njorowa Gorge used to form the lake's outlet, but it is now high above the lake and forms the entrance to Hell's Gate National Park.

The lake is home to a variety of wildlife; over 400 different species of bird have been reported. There is a sizeable population of hippos in the lake. There are two smaller lakes in the vicinity of Lake Naivasha: Lake Oloiden and Lake Sonachi (a green crater lake). The Crater Lake Game Sanctuary lies nearby, while the lakeshore is known for its population of European immigrants and settlers. Between 1937 and 1950, the lake was used as a landing place for flying boats on the Imperial Airways passenger and mail route from Southampton in Britain to South Africa. It linked Kisumu and Nairobi.

Floriculture forms the main industry around the lake. However, the largely unregulated use of lake water for irrigation is reducing the level of the lake and is the subject of concern in Kenya. Fishing in the lake is also another source of employment and income for the local population. The lake varies in level greatly and almost dried up entirely in the 1890s. Having refilled, water levels are now dropping again. The town of Naivasha (formerly East Nakuru) lies on the north-east edge of the lake.

The water level of Lake Naivasha is dropping, and therefore the Lake Naivasha Riparian Authority (LNRA) proposes to restrict the use of water. LNRA believes that this is the only way its members can benefit from the lake in the long term. Especially with expected effects of climate change, immediate action is needed.

LNRA calls for a meeting to discuss and present its plans to the following stakeholders[28]: the small-scale farmers; the floriculture sector; the tourism industry; Naivasha municipality; the Ministry for Water and Irrigation; fishermen's association and the Kenya Marine and Fisheries Research Institute (KMFRI).

How to play

Each stakeholder is represented by a participant, and another participant acts as a guardian angel of the stakeholder. In this case, there are eight stakeholders, meaning that 16 participants play and the rest of the participants observe. All participants are involved in the role play, as a stakeholder, guardian angel or observer. The responsibilities are presented in Table 3 below.

Based on the information in Table 4[29] and the description of the lake, the stakeholder and his or her guardian angel get some time (10–15 minutes) to prepare for the stakeholder meeting. During this time, they agree on goals they want to achieve as an outcome of this meeting and a strategy to achieve these goals. Goals can be, for example, an agreement on water restriction or to prevent an agreement on water restriction. LNRA prepares an agenda for the meeting and prepares itself for chairing the session as well as formulating goals and a strategy. During the play, the observers try to figure out the goals of the different stakeholders and assess if they have reached these goals. During the preparation time, the observers could agree to distribute tasks (focus on a specific stakeholder, for example).

During the play the stakeholders sit in a half-circle opposite the observers in such a way that the stakeholders can all see each other. The guardian angels sit behind the stakeholders, write their

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[28] The description and opinions of the stakeholders are loosely based on IUCN/LNRA (2005). *Lake Naivasha: Local Management of a Kenyan Ramsar Site.* IUCN Eastern Africa Regional Programme, Lake Naivasha Riparian Association, Nairobi, p. 78.

[29] The stakeholder characteristics should be handed out to the respective stakeholder and guardian angel, e.g. LNRA is not supposed to see the characteristics of the floriculturists.

Table 3: Roles and responsibilities of the participants

Role	Responsibility
Stakeholder	Prepares goals and a strategy for the meeting together with the guardian angel Participates actively in the play and places him or herself in the shoes of the stakeholder (only thinks about the greater picture if that is important for him or her as a stakeholder) Implements the suggestions of the guardian angel Carries out a self-evaluation during the feedback session reflecting on the goals and strategy
Guardian Angel	Prepares goals and a strategy for the meeting together with the stakeholder By giving messages on slips of paper, helps the stakeholder in following the agreed strategy
Observer	Gives feedback on the play (identifying the stakeholders' goals and strategies, negotiation skills, etc.) Makes links between the role play and how this is related to reality (what can you learn from this role play) Respects the players and realizes that they are acting

suggestions on slips of paper, and hand these to their respective stakeholders. LNRA opens the meeting and the play starts. During the play, the observers are ignored. The facilitator intervenes if the meeting is not progressing or if the discussion becomes 'too intense'. The play runs for about 15 minutes. After this, the observers give their feedback. Then the stakeholder and guardian angel change position and the play starts again, followed by a second round of feedback.

Facilitation

The course facilitator explains the process and keeps track of time. It is important to reserve enough time for the whole session, as sometimes the play itself or the feedback session evolve into very useful discussion and insights about stakeholder participation. The facilitator can also spice up the meeting (if needed) by slipping notes to the stakeholders, stimulating them to take more extreme positions in the debate. The facilitator stops the play when it is going in circles, entering a status quo or if time demands. The facilitator leads the feedback sessions and ends the whole role play with some concluding remarks and lessons learned.

[30] Are fictive and do not always reflect reality.

Table 4: The characteristics of the stakeholders

Stakeholder	Characteristics[30]
LNRA	Wants sustainable management of the lake Realizes the potential effects of climate change Does not trust the floriculturists Thinks the municipality only takes note of short-term issues Overconfident Wants to leave the meeting with an agreement
Small-scale farmers' association	Knows the area very well, lived there for generations Realizes the need for restrictions Feels restrictions should mainly (if not only) apply to the floriculturists Does not like the floriculturists and feels that these foreign-owned companies do not care about the lake at all Believes that the municipality is 'owned' by the floriculturists
United floriculturists	Feel they have every right to use as much water as they need as they provide employment and are the main contributors to economic growth of the area Arrogant; don't want to be at the meeting Try to 'play' the municipality and the ministry Do not want an agreement on water restrictions, unless it does not apply to them
Tourism industry	Depends on the ecosystem for its income Is supported by the Ministries of Tourism and Environment and Natural Resources and the Kenya Wildlife Services Likes to liaise with LNRA Thinks the large industries (floriculturists) should not abstract water from this vulnerable ecosystem Constructively looking for an agreement
Naivasha municipality	Tends to value employment over sustainability Doesn't believe climate change will influence the area much Is not so much 'in touch' with the small-scale farmers and fishermen Is very upset by rumours that it is 'owned' by the floriculturists
Ministry of Water and Irrigation	Is not aware of the local sensitivities Appreciates the invitation Believes an agreement on restricted use seems needed Tends to support the floriculturists, but may be responsive to solid arguments Has the potential to make or break the agreement (support LNRA or floriculturists) Feels important
Fishermen's union	Supports all initiatives that would help increase the water level in the lake Not well organized Feels overlooked
KMFRI	Gives feedback on the play (identifying the stakeholders' goals and strategies, negotiation skills, etc.) Makes links between the role play and how this is related to reality (what can you learn from this role play) Respects the players and realizes that they are acting

Planning a workshop and developing training skills

Content:

- What to consider when planning a workshop
- Dynamics and energizers
- Ice-breaking
- Planning workshops on climate change and water resources

This chapter has been designed to support those people who will develop training activities on adaptation to climate change impacts and how IWRM can help.

Introduction

Training activities with adult participants have specific needs that have to be considered when planning the event to ensure training objectives are met. Adult learners favour learning by doing, by sharing experiences and by the application of new knowledge in real work environments.

The planning process is a tool that you, as the facilitator, can use to enhance the learning process of the participants.

1. Target group

Considering that training has to be adapted for different audiences, you have to be sure that your training materials address different needs and that they meet the requirements of the trainees' profiles. It is also important to identify the material you will use and anticipate all your needs during the planned sessions.

2. External factors

A good preparatory exercise is to project possible training scenarios. In this way, you can try to control external factors that may influence the training event; for example, holidays, weather conditions and political events. This exercise also gives you the chance to identify particular opportunities that may come up.

3. Internal factors

It is important to be realistic and plan capacity-building according to your strengths and the extra support you are able to raise. Below are some practical tips for planning, conducting and evaluating the training course.

A. Before the training

- Set your training objectives.
- Identify and evaluate the training method, and choose the most suitable one for your goals.
- Identify your regional/local counterparts.
- Prepare a budget adjusted to your needs and costs, consider all expenditures and keep an amount for rainy days.
- Solicit financial support.
- Identify the material developed from expert sources, and plan review and integration.
- Address administrative and venue issues (restrooms, breakout rooms for WG sessions, layout of the meeting room, access to Internet, air conditioning, electrical connections, evacuation route, etc.).
- Decide how you will measure the objectives.
- Try to establish the situation or knowledge of the participants (e.g. use an application form, ask participants to write a motivation or an analysis of the situation in their region).
- Identify the improvements you are aiming for.
- Identify assignment responsibilities.
- Prepare energizers and dynamic sessions while planning the content.
- Make a list of materials and equipment you will need.

B. During the training

- Assign 'policing' or organizational roles to volunteer participants.
- Assess and address special needs of participants and trainers.
- Make sure material is circulated on time.
- Add interactive sessions to the technical sessions, as practical application of concepts and principles is part of the learning process.
- Plan daily recaps to evaluate the activities and participants' understanding, but be careful that recaps are not just summaries of presentations.

- Consider the breaks you need and the way to bring participants back to the session (play music, ring a bell, turn on/off lights).

C. After the training

- Measure the achievements of the objectives by the indicators identified.
- Review feedback from trainers and participants. Assess what improvements can be made to the programme, materials or facilitation.
- Review the effectiveness of the chosen training method and allocated time.
- Identify any remaining training gaps, and include them in future plans.
- Review your financial results.

If you plan to replicate your training activity, then you have to work on preparing follow-up activities:

1. Meet in groups by regions or countries (depending on the number of participants and the target group you identified for the follow-up).

2. Prepare a proposal to run an activity in your region/country or at the basin level, making use of the programme and materials of the training just conducted on IWRM and climate change.

3. You need to:

- Identify your target group;
- Decide on the duration of the activity;
- Establish the contents according to the length, and the needs and characteristics of the region or country;
- Identify regional or local speakers/ experts;
- Make a list of requirements to run your training activity;
- Identify responsible persons;
- Make a timetable;
- Identify funding; and
- Prepare a presentation to share in the plenary.

Facilitating group work

Sometimes it is acceptable for people to divide themselves as they please, for example, based on where they choose to sit when they first arrive in the workshop. However, sometimes you will want to create new groups. This is useful if you feel that certain groups do not have a good mix of age, gender, experience, etc., or if you think that it would be useful as a sort of mini-energizer to get people to move into different places. There are a number of ways of doing this. The easiest way to organize people is to decide on the number of groups you want and then to walk around the room giving each person a number in order, "1, 2, 3, 1, 2, 3, 1 ..." and so on until everyone has a number (for three groups). Then ask all the 'number 1s' to move around and sit together. (NAP ToT Participants Manual, UNITAR)

Some ice-breaking/energizing suggestions

Breaking the ice is very important when you are working with adult learners. You are not only responsible for the quality of the material and to guarantee delivery but also for group dynamics. Some icebreakers are presented to help trainers to organize the session, but you can be creative and use your own. Icebreakers are a way to encourage communication and for the group to begin to get to know each other.

Team-building icebreakers

Activity to meet each other (15 minutes)

Divide the meeting participants into groups of four or five people by giving them names according to the issues of the workshop, e.g. lake, river, rain, spring, etc. Alternatively, you can use colours or other references. You can also give the participants a chocolate or candy with a different label, so they meet with the people who share the same label of candy.

Tell the newly formed groups the rules and their assignment. Prepare a clear and simple guide to make it easy. The assignment can be something easy, such as to find five things they have in common, that have nothing to do with work (no body parts and no clothing). This helps the group explore shared interests more broadly.

One member (a volunteer) of the group must take notes and be ready to read their list to the whole group upon completion of the assignment. Then ask each group to share their list with the whole group.

How far have you travelled? (15 minutes)

How far have you come? This is a good icebreaker when people do not know each other, as they have to talk about where they have travelled from. Ask people to arrange themselves in a single line, in the order of how far they have travelled. (UNITAR)

Animal card (30 minutes)

You can distribute randomly, cards with images of animals in pairs, and ask the participants to meet the person with the matching card. Each one has to introduce the other participant to the plenary by saying something special about the other participant. You can prepare the main question that must be something personal, something that makes him/her special or different. Allow 10 minutes for the pairs to meet and the remaining 20 minutes for introductions to the rest of the group.

The treasure box (30 minutes)

Bring a dark bag or box and ask the participants to give you something that is important to them; avoid pencils or pens, and instead suggest eyeglasses (in their case), driver's licence, rings, watches, etc. When all the treasures are in the bag, draw one and ask the owner to say his or her name and say something personal that very few people know. The group will decide if the information is personal enough to recover the treasure, and if not, the participant has to try again. Don't be easy on the person, keep the item until the group is satisfied.

Roll the ball (20 minutes)

Another way to introduce the participants is to bring a small, colourful ball to toss around, and ask the participants to stand up and present themselves one by one as they catch the ball. Make sure that all the participants receive the ball. You can use the same exercise when participants are tired, and ask them to say the name of the person to whom they throw the ball. The one who fails will have a punishment: sing, dance, or something else that the group decides.

The name game (15 minutes)

Sit the participants in a circle. One of the persons (or a leader) starts the game by saying, "Hi! My name is ..." Then the next person in the circle continues by saying, "Hi! My name is ... and sitting next to me is ..." This continues around the circle, until the last person introduces him-/herself and also has to introduce the entire circle! This is a great way to learn names.

Other activities to develop during the workshop

The baby picture game

Each person is instructed before the course to bring a baby picture of him or herself. Collect all the pictures and carefully display them on a large sheet of paper on the wall, assigning a number to each picture. Place a big envelope on the side; keep it there until the last day. The participants must identify the other participants from their baby pictures, linking the number to the name, and put this in the envelope during the workshop. On the last day of the training, the person who guessed the most names and pictures right will win a prize.

Sharing chairs

Everyone gets a chair and sits in a circle. The leader reads out a list of items. If any of them apply to a participant, he or she must move the appropriate number of seats clockwise. For example: 1. "Anyone with one brother, move one seat clockwise. If you have two brothers, move two seats." 2. "Anyone with black hair, move one seat clockwise." 3. "Anyone over the age of 21, move three seats counterclockwise." 4. "Everyone wearing brown shoes move one seat." The fun happens when you move, but your neighbour doesn't, and you must sit on his/her lap! Sometimes, you can have three people occupying the same chair! Make sure you have lots of categories so that everyone gets several chances to move.

Dr. Mix-Up

All the participants stand in a circle, holding hands. Select one person to be 'Dr. Mix-Up'. That person leaves the room for a moment. While he/she is gone, everyone else does their best to get tangled up, by climbing over arms, under legs, etc., without letting go of their neighbours' hands. When the circle is suitably tangled, everyone yells, "Dr. Mix-Up! Come and fix us!" Dr. Mix-Up then comes in and tries to untangle the circle by directing individuals to go under arms, around bodies, etc.

Shoe factory

Have the group stand in a large circle shoulder to shoulder. Then ask everyone to remove their shoes and put them in the centre. After the group has formed a pile with their shoes, the leader directs everyone to choose two different shoes other than their own. They should put them on their feet (halfway if they are too small). The group then needs to successfully match the shoes and put them in proper pairs by standing next to the individual wearing the other shoe. This will probably result in a tangled mess and lots of giggles!

Suggested reading

1. **Delivering Training Effectively for NAPs** (UNITAR) https://globalsupportprogramme.org/sites/default/files/uploaded-images/final_participants_manual.pdf

UN Photo:Logan Abassi

Glossary

Adaptation

Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, thereby moderating harm or exploiting beneficial opportunities. Various types of adaptation can be distinguished including anticipatory, autonomous and planned adaptation.

Aquifer

A body of permeable rock able to hold or transmit water.

Atmosphere

The gaseous envelope surrounding the Earth. The dry atmosphere consists almost entirely of nitrogen and oxygen, together with trace gases including carbon dioxide (CO_2) and ozone (O_3) (IPCC, 2007c).

Autonomous adaptation

Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. Also referred to as spontaneous adaptation.

Biofuel

A fuel created from organic matter or combustible oils produced by plants. Examples of biofuel include alcohol, black liquor from the paper-manufacturing process, wood and soybean oil.

Biosphere

The part of the Earth system comprising all ecosystems and living organisms in the atmosphere, on land or in the oceans, including derived dead organic matter (IPCC, 2007c).

Carbon storage

An approach to mitigating the contribution of carbon emissions to global warming based on capturing CO_2 from large point sources such as fossil-fuel power plants. In this way, the CO_2 might then be permanently sequestered from the atmosphere.

Climate change

Any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in UNFCCC, which defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (IPCC, 2007c).

Climate variability

Variations in the mean state and other statistics (such as standard deviations, statistics of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

Cryosphere

The component of a climate system consisting of all snow and ice (including permafrost) on and beneath the surface of the Earth and its oceans.

Desalination

A process that removes any excess salt and other minerals from water or soil (soil desalination). http://en.wikipedia.org/wiki/Desalination-cite_note-1

Detention basins

A type of stormwater management facility installed on, or adjacent to, tributaries of rivers, streams or lakes that is designed to protect against flooding as well as downstream erosion by storing water for a limited period of time. They are also referred to as 'dry ponds', 'holding ponds' or 'dry detention basins'. There are some detention ponds called 'wet ponds', which are designed to permanently retain some volume of water at all times.

Drought

In general terms, drought is a "prolonged absence or marked deficiency of precipitation", a "deficiency that results in water shortage for some activity or for some group", or a "period of abnormally dry weather sufficiently prolonged for the lack of precipitation to cause a serious hydrological imbalance" (Heim, 2002). Drought has been defined in a number of ways: Agricultural drought relates to moisture deficits in the topmost 1 metre or so of soil (the root zone) that affects crops; meteorological drought is mainly a prolonged deficit of precipitation; and hydrological drought is related to below-normal streamflow, lake and groundwater levels. A megadrought is a long, drawn-out and pervasive drought, lasting much longer than normal, usually a decade or more.

Ecosystem

The interactive system formed from all living organisms and their abiotic (physical and chemical) environment within a given area. Ecosystems cover a hierarchy of spatial scales and can comprise the entire globe, continents (biomes) or small, well-circumscribed systems such as a small pond.

El Niño

A warm-water current that periodically flows along the coast of Ecuador and Peru, disrupting the local fisheries. The oceanic event is associated with a fluctuation of the inter-tropical surface pressure pattern and circulation in the Indian and Pacific Oceans, called the Southern Oscillation. This coupled atmosphere-ocean phenomenon is collectively known as *El Niño*-Southern Oscillation. During an *El Niño* event, the prevailing trade winds weaken and the equatorial countercurrent strengthens, causing warm surface waters in the Indonesian area to flow eastward and overlie the cold waters of the Peru Current. This event has a great impact on the wind, sea-surface temperature and precipitation patterns in the tropical Pacific. It has climatic effects throughout the Pacific region and in many parts of the world. The opposite of an *El Niño* event is called *La Niña* (see below).

Eutrophication

The process by which a body of water (often shallow) becomes (either naturally or by pollution) rich in dissolved nutrients, with a seasonal deficiency in dissolved oxygen.

Evapotranspiration

The combined process of water evaporation from the Earth's surface and transpiration from vegetation.

Feedback

An interaction mechanism between processes; it occurs when the result of an initial process triggers changes in a second process, and that in turn influences the initial one. A positive feedback intensifies the original process, and a negative feedback reduces it.

Flash flood

Flooding that occurs suddenly and rapidly in low-lying areas, differentiated from regular flooding in that it usually occurs within six hours of the flood-triggering event. It is usually caused by heavy rain followed by a thunderstorm, hurricane or tropical storm. Flash floods can also occur after the collapse of a dam.

Fossil fuels

Fuels that contain a high percentage of carbon and hydrocarbons. They are created through the anaerobic decomposition process of buried dead organisms that lived up to 300 million years ago. Fossil fuels range from those with low carbon and hydrogen ratios like methane, to liquid petroleum used in automobiles, to non-volatile materials composed of almost pure carbon, like anthracite coal.

Global warming

The increase in the average temperature of the Earth's surface air and oceans. IPCC concludes that anthropogenic GHGs are responsible for most of the observed temperature increase since the middle of the 20th century, while natural phenomena such as solar variation and volcanoes produced most of the warming from pre-industrial times to 1950 and resulted in a small cooling effect afterward.

Greenhouse effect

The process in which the absorption of infrared radiation by the atmosphere warms the Earth. In common parlance, the term 'greenhouse effect' may be used to refer either to the natural greenhouse effect, due to naturally occurring GHGs, or to the enhanced (anthropogenic) GHGs, which result from gases emitted due to human activities.

Greenhouse gases

Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, its atmosphere and clouds; this property causes the 'greenhouse effect'. Water vapour (H_2O), CO_2, nitrous oxide (N_2O), methane (CH_4) and (O_3) are the primary GHGs in the Earth's atmosphere. The Kyoto Protocol (see below) addresses CO_2, N_2O and CH_4, and also the GHGs sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) (see Chapter 3 for more details).

Hydrological cycle

Also referred to as the water cycle, it describes the continuous movement of water above and below the surface of the Earth. Water undergoes changes in its states (liquid, vapour and ice) at various points in the water cycle although the total balance of water on Earth remains constant over time.

Hydropower

Also known as water power, this is power or energy that is derived from the force of moving water; it may be harnessed for purposes such as commercial electric power.

Hydrosphere

As defined in physical geography, the zone containing the combined mass of water found on, under and over the surface of a planet, including seas, lakes, aquifers, etc.

Kyoto Protocol

The Kyoto Protocol was adopted at the Third Session of COP to UNFCCC in 1997 in Kyoto, Japan. It contains legally binding commitments, in addition to those included in UNFCCC. Countries included in Annex B of the Protocol (most member countries of OECD and those with economies in transition) agreed to reduce their anthropogenic GHG emissions (CO_2, CH_4, N_2O, HFCs, PFCs and SF_6) by at least 5 percent below 1990 levels in the commitment period 2008 to 2012. The Kyoto Protocol entered into force on 16 February 2005.

La Niña

The cold phase (or opposite effect) of *El Niño*, during which the cold pool in the eastern Pacific intensifies and the trade winds strengthen.

Level of Scientific Understanding (LOSU)

This is an index on a 4-step scale (High, Medium, Low and Very Low) designed to characterize the degree of scientific understanding of the radiative forcing agents that affect climate change. For each agent, the index represents a subjective judgement about the reliability of the estimate of its forcing, involving such factors as the assumptions necessary to evaluate the forcing, the degree of knowledge of the physical/chemical mechanisms determining the forcing, and the uncertainties surrounding the quantitative estimate.

Lithosphere

The hard and rigid outer layer of the planet which includes the crust and uppermost mantle and can run to 80 km deep.

Multicriteria analysis

An evaluation methodology developed for complex problems with many objectives within a decision-making process. It takes into consideration a full range of social, environmental, technical, economic and financial criteria.

Non-structural measures

According to UNISDR, non-structural measures are defined as any measure not involving physical construction, and that uses knowledge, practice or agreement to reduce risks and impacts, in particular through policies and laws, public awareness raising, training and education.

Permafrost

Perennially frozen ground that occurs where the temperature remains below 0 °C.

Phenology

The study of natural phenomena that recur periodically (e.g. development stages, migration) and their relation to climate and seasonal changes.

Photic zone

Surface layer of the ocean that receives sunlight. The uppermost 80 m or more of the ocean, which is sufficiently illuminated to permit photosynthesis by phytoplankton and plants, is called the euphotic zone. The thicknesses of the photic and euphotic zones vary with the intensity of sunlight as a function of season and latitude and with the degree of water turbidity.

The bottommost, or aphotic, zone is the region of perpetual darkness that lies beneath the photic zone and includes most of the ocean waters.

Radiation

Any process in which energy is emitted by one 'body' and travels through a medium or space, ultimately to be absorbed by another 'body'.

Radiative forcing

The change in the net vertical irradiance at the tropopause due to an internal and external change in the forcing of the climate system, such as change in concentration of CO_2 or the output of the sun (IPCC, 2007c).

Rainwater harvesting

The accumulation and storing of rainwater. It has been practised in areas where there is more than sufficient water for drinking and for domestic and agricultural usage.

Resilience

The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change.

Social equity

Equality, fairness and impartiality for all in terms of access to resources, the ability to participate in political and cultural life, and self-determination in meeting basic needs.

Spatio-temporal resolution

Precision of measurement with respect of space and time.

Standard deviation

In probability theory and statistics, standard deviation refers to the measure of the variability or dispersion of a population, a data set, or a probability distribution. A low standard deviation indicates that the data points tend to be very close to the mean value, while high standard deviation indicates that the data are 'spread out' over a large range of values.

Structural measures

According to UNISDR, structural measures are known as any physical construction to reduce or avoid possible impacts of hazards, or application of engineering techniques to achieve hazard-resistance and resilience in structures or systems (UNISDR, 2004).

Thermocline

The region in the world's ocean, typically at a depth of 1 kilometre, where the temperature decreases rapidly with depth and which marks the boundary between the surface and the ocean.

Thermohaline circulation

Large-scale, density-driven circulation in the ocean, caused by differences in temperature and salinity.

Thermophilic

A condition of relatively high temperatures, between 45 and 80 °C (113 and 176 °F).

Vulnerability

The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and the variations to which a system is exposed, its sensitivity and its adaptive capacity.

Waterborne diseases

Diseases caused by pathogenic microorganisms, which are directly transmitted when contaminated water is consumed.

Wetlands

Transitional, regularly waterlogged areas of poorly drained soils, often found between an aquatic and a terrestrial ecosystem, that are fed from rain, surface water or groundwater. Wetlands are characterized by a prevalence of vegetation adapted for life in saturated soil conditions.

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