# 7

# Implications for policy and sustainable development

Climate change poses a major conceptual challenge to water managers, water resource users (e.g., in agriculture) as well as to policymakers in general, as it is no longer appropriate to assume that past climatic and hydrological conditions will continue into the future. Water resources management clearly impacts on many other policy areas (e.g., energy, health, food security, nature conservation). Thus, the appraisal of adaptation and mitigation options needs to be conducted across multiple water-dependent sectors.

Substantial changes have been observed over recent decades in many water-related variables, but clear formal attribution of the observed changes to natural or anthropogenic causes is not generally possible at present. Projections of future precipitation, soil moisture and runoff at regional scales are subject to substantial uncertainty. In many regions, models do not agree on the sign of projected change. However, some robust patterns are found across climate model projections. Increases in precipitation (and river flow) are *very likely* at high latitudes and in some wet tropics (including populous areas in east and south-east Asia), and decreases are *very likely* over much of the mid-latitudes and dry tropics [WGII Figure 3.4]. Interpretation and quantification of uncertainties has recently improved, and new methods (e.g., ensemble-based approaches) are being developed for their characterisation [WGII 3.4, 3.5]. Nevertheless, quantitative projections of changes in precipitation, river flows and water levels at the river-basin scale remain uncertain, so that planning decisions involving climate change must be made in the context of this uncertainty. [WGII TS, 3.3.1, 3.4]

Effective adaptation to climate change occurs across temporal and spatial scales, including incorporation of lessons from responses to climate variability into longer-term vulnerability reduction efforts and within governance mechanisms from communities and watersheds to international agreements. Continued investment in adaptation in response to historical experience alone, rather than projected future conditions that will include both variability and change, is *likely* to increase the vulnerability of many sectors to climate change. [WGII TS, 14.5]

## 7.1 Implications for policy by sector

*Water resource management*

- Catchments that are dominated by seasonal snow cover already experience earlier peak flows in spring, and this shift is expected to continue under a warmer climate. At lower altitudes, winter precipitation will increasingly be in the form of rainfall instead of snowfall. In many mountain areas, e.g., in the tropical Andes and many Asian mountains, where glaciers provide the main runoff during pronounced dry seasons, water volumes stored in glaciers and snow cover are projected to decline. Runoff during warm and dry seasons is enhanced while glaciers are shrinking, but will dramatically drop after they have disappeared. [WGII 3.4.1]
- Drought-affected areas are *likely* to increase; and extreme precipitation events, which are *very likely* to increase in frequency and intensity, will augment flood risk. Up to 20% of the world's population live in river basins that are *likely* to be affected by increased flood hazard by the 2080s in the course of climate change. [WGII 3.4.3]
- Semi-arid and arid areas are particularly exposed to the impacts of climate change on freshwater. Many of these areas (e.g., the Mediterranean Basin, western USA, southern Africa, north-eastern Brazil, southern and eastern Australia) will suffer a decrease in water resources due to climate change. [WGII Box TS.5, 3.4, 3.7] Efforts to offset declining surface water availability due to increasing precipitation variability will be hampered by the fact that groundwater recharge is projected to decrease considerably in some water-stressed regions [WGII 3.4.2], exacerbated by the increased water demand. [WGII 3.5.1]
- Higher water temperatures, increased precipitation intensity and longer periods of low flows exacerbate many forms of water pollution, with impacts on ecosystems, human health, and water system reliability and operating costs. [WGII 3.2, 3.4.4, 3.4.5]
- Areas in which runoff is projected to decline will face a reduction in the value of services provided by water resources. The beneficial impacts of increased annual runoff in some other areas will be tempered by the negative effects of increased precipitation variability and seasonal runoff shifts on water supply, water quality and flood risks. [WGII 3.4, 3.5]
- At the global level, the negative impacts of climate change on freshwater systems outweigh the benefits. [WGII 3.4, 3.5]
- Adverse effects of climate on freshwater systems aggravate the impacts of other stresses, such as population growth, land-use change and urbanisation. [WGII 3.3.2, 3.5] Globally, water demand will grow in the coming decades, primarily due to population growth and increased affluence. [WGII 3.5.1]
- Climate change affects the function and operation of existing water infrastructure as well as water management practices. Current water management practices are *very likely* to be inadequate to reduce the negative impacts of climate change on water-supply reliability, flood risk, health, energy and aquatic ecosystems. [WGII TS, 3.4, 3.5, 3.6]
- Adaptation procedures and risk management practices for the water sector are being developed in some countries and regions (e.g., the Caribbean, Canada, Australia, the Netherlands, the UK, the USA and Germany) that recognise the uncertainty of projected hydrological changes, but evaluation criteria on effectiveness need to be developed. [WGII 3.6]

*Ecosystems*

- The resilience of many ecosystems and their ability to adapt naturally is *likely* to be exceeded by 2100 by an unprecedented combination of change in climate, associated disturbances (e.g., flooding, drought, wildfire) and other global change drivers (e.g., land-use change,

pollution, over-exploitation of resources). [WGII TS]
- Greater rainfall variability is *likely* to compromise wetlands through shifts in the timing, duration and depth of water levels. [WGII 4.4.8]
- Of all ecosystems, freshwater ecosystems will have the highest proportion of species threatened with extinction due to climate change. [WGII 4.4.8]
- Current conservation practices are generally poorly prepared to adapt to the projected changes in water resources during the coming decades. [WGII 4.ES]
- Effective adaptation responses that will conserve biodiversity and other ecosystem services are *likely* to be costly to implement, but unless conservation water needs are factored into adaptation strategies, many natural ecosystems and the species they support will decline. [WGII 4.ES, 4.4.11, Table 4.1, 4.6.1, 4.6.2]

*Agriculture, forests*
- An increased frequency of droughts and floods negatively affects crop yields and livestock, with impacts that are both larger and earlier than predicted by using changes in mean variables alone. [WGII 5.4.1, 5.4.2] Increases in the frequency of droughts and floods will have a negative effect on local production, especially in subsistence sectors at low latitudes. [WGII SPM]
- Impacts of climate change on irrigation water requirements may be large. [WGII 5.4] New water storages, both surface and underground, can alleviate water shortages but are not always feasible. [WGII 5.5.2]
- Farmers may be able to partially adjust by changing cultivars and/or planting dates for annual crops and by adopting other strategies. The potential for higher water needs should be considered in the design of new irrigation supply systems and in the rehabilitation of old systems. [WGII 5.5.1]
- Measures to combat water scarcity, such as the reuse of wastewater for agriculture, need to be carefully managed to avoid negative impacts on occupational health and food safety. [WGII 8.6.4]
- Unilateral measures to address water shortages due to climate change can lead to competition for water resources. International and regional approaches are required in order to develop joint solutions. [WGII 5.7]

*Coastal systems and low-lying areas*
- Sea-level rise will extend areas of salinisation of groundwater and estuaries, resulting in a decrease in freshwater availability. [WGII 3.2, 3.4.2]
- Settlements in low-lying coastal areas that have low adaptive capacity and/or high exposure are at increased risk from floods and sea-level rise. Such areas include river deltas, especially Asian megadeltas (e.g., the Ganges-Brahmaputra in Bangladesh and west Bengal), and low-lying coastal urban areas, especially areas prone to natural or human-induced subsidence and tropical storm landfall (e.g., New Orleans, Shanghai). [WGII 6.3, 6.4]

*Industry, settlement and society*
- Infrastructure, such as urban water supply systems, are vulnerable, especially in coastal areas, to sea-level rise and reduced regional precipitation. [WGII 7.4.3, 7.5]
- Projected increases in extreme precipitation events have important implications for infrastructure: design of storm drainage, road culverts and bridges, levees and flood control works, including sizing of flood control detention reservoirs. [WGII 7.4.3.2]
- Planning regulations can be used to prevent development in high-flood-risk zones (e.g., on floodplains), including housing, industrial development and siting of landfill sites etc. [WGII 7.6]
- Infrastructure development, with its long lead times and large investments, would benefit from incorporating climate-change information. [WGII 14.5.3, Figure 14.3]

*Sanitation and human health*
- Climate-change-induced effects on water pose a threat to human health through changes in water quality and availability. Although access to water supplies and sanitation is determined primarily by non-climate factors, in some populations climate change is expected to exacerbate problems of access at the household level. [WGII 8.2.5]
- Appropriate disaster planning and preparedness need to be developed in order to address the increased risk of flooding due to climate change and to reduce impacts on health and health systems. [WGII 8.2.2]

*Climate information needs*

Progress in understanding the climate impact on the water cycle depends on improved data availability. Relatively short hydrometric records can underestimate the full extent of natural variability. Comprehensive monitoring of water-related variables, in terms of both quantity and quality, supports decision making and is a prerequisite for the adaptive management required under conditions of climate change. [WGII 3.8]

## 7.2 The main water-related projected impacts by regions

*Africa*
- The impacts of climate change in Africa are *likely* to be greatest where they co-occur with a range of other stresses (population growth; unequal access to resources; inadequate access to water and sanitation [WGII 9.4.1]; food insecurity [WGII 9.6]; poor health systems [WGII 9.2.2, 9.4.3]). These stresses and climate change will increase the vulnerabilities of many people in Africa. [WGII 9.4]
- An increase of 5–8% (60–90 million ha) of arid and semi-arid land in Africa is projected by the 2080s under a range of climate change scenarios. [WGII 9.4.4]
- Declining agricultural yields are *likely* due to drought and land degradation, especially in marginal areas. Mixed rain-fed systems in the Sahel will be greatly affected by climate

change. Mixed rain-fed and highland perennial systems in the Great Lakes region and in other parts of East Africa will also be severely affected. [WGII 9.4.4, Box TS.6]
- Current water stress in Africa is *likely* to be increased by climate change, but water governance and water-basin management must also be considered in future assessments of water stress in Africa. Increases in runoff in East Africa (and increased risk of flood events) and decreases in runoff (and increased risk of drought) in other areas (e.g., southern Africa) are projected by the 2050s. [WGII 9.4.1, 9.4.2, 9.4.8]
- Any changes in the primary production of large lakes will have important impacts on local food supplies. Lake Tanganyika currently provides 25–40% of animal protein intake for the surrounding populations, and climate change is *likely* to reduce primary production and possible fish yields by roughly 30% [WGII 9.4.5, 3.4.7, 5.4.5]. The interaction of poor human management decisions, including over-fishing, is *likely* to further reduce fish yields from lakes. [WGII 9.2.2, Box TS.6]

*Asia*
- The per capita availability of freshwater in India is expected to drop from around 1,820 $m^3$ currently to below 1,000 $m^3$ by 2025 in response to the combined effects of population growth and climate change. [WGII 10.4.2.3]
- More intense rain and more frequent flash floods during the monsoon would result in a higher proportion of runoff and a reduction in the proportion reaching the groundwater. [WGII 10.4.2]
- Agricultural irrigation demand in arid and semi-arid regions of east Asia is expected to increase by 10% for an increase in temperature of 1°C. [WGII 10.4.1]
- Coastal areas, especially heavily populated Asian megadelta regions, will be at greatest risk due to increased flooding from the sea and, in some megadeltas, flooding from rivers. [WGII 6.4, 10.4.3]
- Changes in snow and glacier melt, as well as rising snowlines in the Himalayas, will affect seasonal variation in runoff, causing water shortages during dry summer months. One-quarter of China's population and hundreds of millions in India will be affected (Stern, 2007). [WGII 3.4.1, 10.4.2.1]

*Australia and New Zealand*
- Ongoing water security problems are *very likely* to increase in southern and eastern Australia (e.g., a 0–45% decline in runoff in Victoria by 2030 and a 10–25% reduction in river flow in Australia's Murray-Darling Basin by 2050) and, in New Zealand, in Northland and some eastern regions. [WGII 11.4.1]
- Risks to major infrastructure are *likely* to increase due to climate change. Design criteria for extreme events are *very likely* to be exceeded more frequently by 2030. Risks include failure of floodplain levees and urban drainage systems, and flooding of coastal towns near rivers. [WGII 11.ES, 11.4.5, 11.4.7]
- Production from agriculture and forestry by 2030 is projected to decline over much of southern and eastern Australia, and over parts of eastern New Zealand, due to, among other things, increased drought. However, in New Zealand, initial benefits are projected in western and southern areas and close to major rivers, with increased rainfall. [WGII 11.4]

*Europe*
- The probability of an extreme winter precipitation exceeding two standard deviations above normal is expected to increase by up to a factor of five in parts of the UK and northern Europe by the 2080s with a doubling of $CO_2$. [WGII 12.3.1]
- By the 2070s, annual runoff is projected to increase in northern Europe, and decrease by up to 36% in southern Europe, with summer low flows reduced by up to 80% under the IS92a scenario. [WGII 12.4.1, T12.2]
- The percentage of river-basin area in the severe water stress category (withdrawal:availability ratio greater than 0.4) is expected to increase from 19% today to 34–36% by the 2070s. [WGII 12.4.1]
- The number of additional people living in water-stressed watersheds in 17 countries in western Europe is *likely* to increase by 16–44 million (HadCM3 climate model results) by the 2080s. [WGII 12.4.1]
- By the 2070s, hydropower potential for the whole of Europe is expected to decline by 6%, with strong regional variations from a 20–50% decrease in the Mediterranean region to a 15–30% increase in northern and eastern Europe. [WGII 12.4.8]
- Small mountain glaciers in different regions will disappear, while larger glaciers will suffer a volume reduction between 30% and 70% by 2050 under a range of emissions scenarios, with concomitant reductions in discharge in spring and summer. [WGII 12.4.3]

*Latin America*
- Any future reductions in rainfall in arid and semi-arid regions of Argentina, Chile and Brazil are *likely* to lead to severe water shortages. [WGII 13.4.3]
- Due to climate change and population growth, the number of people living in water-stressed watersheds is projected to reach 37–66 million by the 2020s (compared to an estimate of 56 million without climate change) for the SRES A2 scenario. [WGII 13.4.3]
- Areas in Latin America with severe water stress include eastern Central America, the plains, Motagua Valley and Pacific slopes of Guatemala, eastern and western regions of El Salvador, the central valley and Pacific region of Costa Rica, the northern, central and western intermontane regions of Honduras, and the peninsula of Azuero in Panama). In these areas, water supply and hydro-electricity generation could be seriously affected by climate change. [WGII 13.4.3]
- Glacier shrinkage is expected to increase dry-season water shortages under a warming climate, with adverse

consequences for water availability and hydropower generation in Bolivia, Peru, Colombia and Ecuador. Flood risk is expected to grow during the wet season. [WGII 13.2.4, 13.4.3]

*North America*

- Projected warming in the western mountains by the mid-21st century is *very likely* to cause large decreases in snowpack, earlier snowmelt, more winter rain events, increased peak winter flows and flooding, and reduced summer flows. [WGII 14.4.1]
- Reduced water supplies coupled with increases in demand are *likely* to exacerbate competition for over-allocated water resources. [WGII 14.2.1, Box 14.2]
- Moderate climate change in the early decades of the century is projected to increase aggregate yields of rain-fed agriculture by 5–20%, but with important variability among regions. Major challenges are projected for crops that are near the warm end of their suitable range or which depend on highly utilised water resources. [WGII 14.4.4]
- Vulnerability to climate change is *likely* to be concentrated in specific groups and regions, including indigenous peoples and others dependent on narrow resource bases, and the poor and elderly in cities. [WGII 14.2.6, 14.4.6]

*Polar regions*

- Northern Hemisphere permafrost extent is *likely* to decrease by 20–35% by 2050. The depth of seasonal thawing is projected to increase by 15–25% in most areas by 2050, and by 50% or more in northernmost locations under the full range of SRES scenarios. [WGII 15.3.4] In the Arctic, disruption of ecosystems is projected as a result. [WGII 15.4.1]
- Further reductions in lake and river ice cover are expected, affecting thermal structures, the quality/quantity of under-ice habitats and, in the Arctic, the timing and severity of ice jamming and related flooding. Freshwater warming is expected to influence the productivity and distribution of aquatic species, especially fish, leading to changes in fish stock, and reductions in those species that prefer colder waters. [WGII 15.4.1]
- Increases in the frequency and severity of flooding, erosion and destruction of permafrost threaten Arctic communities, industrial infrastructure and water supply. [WGII 15.4.6]

*Small islands*

- There is strong evidence that, under most climate change scenarios, water resources in small islands are *likely* to be seriously compromised [WGII 16.ES]. Most small islands have a limited water supply, and water resources in these islands are especially vulnerable to future changes and distribution of rainfall. Many islands in the Caribbean are *likely* to experience increased water stress as a result of climate change. Under all SRES scenarios, reduced rainfall in summer is projected for this region, so that it is *unlikely* that demand would be met during low rainfall periods. Increased rainfall in winter is *unlikely* to compensate, due to the lack of storage and high runoff during storm events. [WGII 16.4.1]
- A reduction in average rainfall would lead to a reduction in the size of the freshwater lens. In the Pacific, a 10% reduction in average rainfall (by 2050) would lead to a 20% reduction in the size of the freshwater lens on Tarawa Atoll, Kiribati. Reduced rainfall, coupled with increased withdrawals, sea-level rise and attendant salt-water intrusion, would compound this threat. [WGII 16.4.1]
- Several small-island countries (e.g., Barbados, Maldives, Seychelles and Tuvalu) have begun to invest in the implementation of adaptation strategies, including desalination, to offset current and projected water shortages. [WGII 16.4.1]

## 7.3 Implications for climate mitigation policy

Implementing important mitigation options such as afforestation, hydropower and bio-fuels may have positive and negative impacts on freshwater resources, depending on site-specific situations. Therefore, site-specific joint evaluation and optimisation of (the effectiveness of) mitigation measures and water-related impacts are needed.

Expansion of irrigated areas and dam-based hydro-electric power generation can lead to reduced effectiveness of associated mitigation potential. In the case of irrigation, $CO_2$ emissions due to energy consumption for pumping water and to methane emissions in rice fields may partly offset any mitigation effects. Freshwater reservoirs for hydropower generation may produce some greenhouse gas emissions, so that an overall case-specific evaluation of the ultimate greenhouse gas budget is needed. [WGIII 4.3.3.1, 8.4.1.1]

## 7.4 Implications for sustainable development

Low-income countries and regions are expected to remain vulnerable over the medium term, with fewer options than high-income countries for adapting to climate change. Therefore, adaptation strategies should be designed in the context of development, environment and health policies. Many of the options that can be used to reduce future vulnerability are of value in adapting to current climate and can be used to achieve other environmental and social objectives.

In many regions of the globe, climate change impacts on freshwater resources may affect sustainable development and put at risk the reduction of poverty and child mortality (Table 7.1). It is *very likely* that negative impacts of increased frequency and severity of floods and droughts on sustainable development cannot be avoided [WGII 3.7]. However, aside from major extreme events, climate change is seldom the main factor exerting stress on sustainability. The significance of climate change lies in its interactions with other sources of change and stress, and its impacts should be considered in such a multi-cause context. [WGII 7.1.3, 7.2, 7.4]

***Table 7.1:*** *Potential contribution of the water sector to attain the Millennium Development Goals. [WGII Table 3.6]*

| Goals | Direct relation to water | Indirect relation to water |
|---|---|---|
| ***Goal 1:*** Eradicate extreme poverty and hunger | Water is a factor in many production activities (e.g., agriculture, animal husbandry, cottage industries)<br>Sustainable production of fish, tree crops and other food brought together in common property resources | Reduced ecosystem degradation improves local-level sustainable development<br>Reduced urban hunger by means of cheaper food from more reliable water supplies |
| ***Goal 2:*** Achieve universal education | | Improved school attendance through improved health and reduced water-carrying burdens, especially for girls |
| ***Goal 3:*** Promote gender equity and empower women | Development of gender-sensitive water management programmes | Reduce time wasted and health burdens through improved water service, leading to more time for income-earning and more balanced gender roles |
| ***Goal 4:*** Reduce child mortality | Improved access to drinking water of more adequate quantity and better quality, and improved sanitation, to reduce the main factors of morbidity and mortality in young children | |
| ***Goal 6:*** Combat HIV/AIDS, malaria and other diseases | Improved access to water and sanitation supports HIV/AIDS-affected households and may improve the impact of health care programmes<br>Better water management reduces mosquito habitats and the risk of malaria transmission | |
| ***Goal 7:*** Ensure environmental sustainability | Improved water management reduces water consumption and recycles nutrients and organics<br>Actions to ensure access to improved and, possibly, productive eco-sanitation for poor households<br>Actions to improve water supply and sanitation services for poor communities<br>Actions to reduce wastewater discharge and improve environmental health in slum areas | Develop operation, maintenance, and cost recovery system to ensure sustainability of service delivery |