Foreword

While the causes of climate change are primarily from our use of energy, the impacts will be felt mainly through water. Climate change is expected to impact on countries in different ways, bringing more intense storms, increases or decreases in the annual rainfall, and floods and droughts. Undoubtedly changes in one of our most important resources will affect people, economies and the environment, perhaps in a dramatic way.

As we look at our current knowledge of climate change it is clear that we are still in a state of uncertainty. For most countries there is still much debate as to how climate change will manifest itself and what the effects will be. Yet despite this uncertainty there is pressure to act now and to allocate resources for climate change adaptation.

These training materials are intended to increase our understanding about climate change and to explore what we can do now. There are actions that can be taken to prepare for a more variable climate and we can make a case to our policy makers to prepare for change. The most important immediate action concerns the way we manage our water resources. Improving our management of water today will prepare us to adapt tomorrow. Improved understanding of our water resources will allow more efficient and flexible allocation systems and better investment in infrastructure, both to improve access to water and reduce risks from climate change. We can act now – and these training materials can help us to identify those actions.

Other materials are available from Cap-Net that cover more specific issues of climate change, such as hydro-climatic disasters, urban flood management and community management of floods.

Our collaboration with the World Meteorological Organization and UNESCO-IHE provides the framework within which this programme takes place and we are grateful for their support.

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Director, Cap-Net

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Photos
The following persons and institutions have provided photos used in this publication:
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Table of Contents

Introduction

This training manual and facilitator's guide is intended to introduce general concepts and the practical application of integrated water resources management (IWRM) as an instrument for adaptation to climate change. The target audience for the manual is twofold: participants in courses on the subject will be provided with conceptual and practical knowledge, and capacity builders will find assistance to conduct short training courses on IWRM and adaptation to climate change. The manual is built in such a way that it will be instructive and at the same time informative for the target group of such courses – mainly water managers and climate change adaptation policy developers. The format and contents of the manual are flexible enough to be adapted to different purposes and as such they could also be used for educational programmes and awareness campaigns. Teachers and moderators/facilitators are encouraged to adapt the materials to their particular regional or local contexts, tailoring the adaptation strategies and actions to each set of unique conditions as needed.

The document is structured in two main sections: a training manual and a facilitator's guide. The first part, the training manual, provides concepts, strategies, developments and guidance on the use of IWRM principles and functions, particularly at the river basin level, for adaptation to climate change manifestations and impacts. It argues that IWRM principles and concepts are instrumental when climate change adaptation is being strategized. To address this, the manual is structured according to seven topics:

- Introduction to IWRM and climate change;
- Drivers and impacts of climate change;
- Strategy development and planning for adaptation;
- Impacts of climate change on water use sectors;
- Dealing with uncertainties;
- Instruments and measures for adaptation; and
- Adaptation to climate change in water management.

For each of the chapters presented, goals are provided and throughout the document the user is challenged with questions and statements that should trigger reflection on the applicability of the concepts and strategies to their own situations. Additional reading resources are recommended at the end of each chapter.

The second section of the document consists of a Facilitator's Guide. It aims to provide capacity builders with practical guidance for the organization and conduct of courses or educational programmes on the subject. A sample course outline is provided to help in structuring a course on IWRM and climate change adaptation, but it is to no extent a blueprint for the organization of such a course. The Facilitator's Guide furthermore presents session outlines for the proposed course schedule that contain learning objectives, brief summaries of each session, materials to be used and suggested timelines for interactive group work, exercises and discussions. The guide also includes references to useful websites and other resources. Practical guidance for the conduct of a course is provided, including tips for planning a workshop and the use of icebreakers. We also recommend that the course organizer refer to the Cap-Net planning of short training courses tool posted on the Cap-Net website.

The combined training manual and Facilitator's Guide is also available on CD-ROM, including supporting materials such as presentations for the sessions, resource materials that can be used as background reading, references and case studies.

The development of the training manual has largely benefited from the inputs received from participants in several courses in different regions. The exchange between participants and the course developers has been very enriching in that it clearly pointed out weaknesses and adaptability of materials. The present package is intended to stimulate interactions between participants to contribute to a better understanding of the use and effectiveness of application of IWRM concepts and principles when strategizing climate change adaptation.

Part 1

Training Manual

1. INTRODUCTION TO INTEGRATED WATER RESOURCES MANAGEMENT AND CLIMATE CHANGE

Goal

The goal of this chapter is to introduce the concept of integrated water resources management (IWRM) and its principles, and to provide a preliminary overview of the ways that implementing IWRM can address challenges due to *climate change.*

1.1 Introduction

Water sustains life. It is therefore a basic human need and right without which human beings cannot survive. Each person needs a minimum of 20 to 40 litres of water per day for drinking and basic hygiene. However, the world's freshwater resources face increasing demands from population growth, economic activity and, in some countries, improved standards of living. It is also becoming clear that sustainable development includes maintaining healthy *ecosystems* and biodiversity, which require sufficient water. Competing demands and conflicts over rights of access occur amidst the fact that many people still do not have equal access to water and this has been described as an impending water crisis. According to the United Nations, access to safe drinking water and basic sanitation is essential for the achievement of the Millennium Development Goals (MDGs) (UN, 2006). It is a fundamental requirement for effective primary health care and a precondition for success in fighting poverty, hunger, child mortality, gender inequality and environmental damage.

Many people argue that the world faces an impending water crisis. Box 1.1 summarizes a few supporting facts.

Box 1.1: Water crisis – Facts

- 1.1 billion people still do not have access to safe water.
- Today, more than two billion people are affected by water shortages in over 40 countries.
- Four out of 10 people around the world still use sanitation facilities that do not meet basic requirements for health.
- Two million tonnes per day of human waste are deposited in watercourses.
- Each year, unsafe water and a lack of basic sanitation kill at least 1.6 million children below the age of five years.
- Half the population of the developing world are exposed to polluted sources of water that increase the incidence of disease.
- 90 percent of natural disasters in the 1990s were water-related.
- The increase in global population from 6 billion to 9 billion will be the main driver of water resources management for the next 50 years.

Cap-Net's Tutorial on Basic Principles on IWRM (2005a) notes that:

- Water resources are increasingly under pressure from population growth, economic activities and intensifying competition among users.
- Water withdrawals have increased more than twice as fast as population growth, and currently one third of the world's population lives in countries that experience medium to high water stress.

- Pollution is further aggravating water scarcity by reducing water usability downstream.
- Shortcomings in the management of water, a focus on developing new sources rather than managing existing ones better, and top-down sector approaches to water management result in uncoordinated development and management of the resource.
- More and more development means greater impacts on the environment.
- Current concerns about *climate variability* and climate change demand improved management of water resources to cope with more intense floods and *droughts*, as well as changes in seasonality.

This impending water crisis presents challenges to the water sector, many of which are multifaceted in that they must address questions such as:

- How can people access water and sanitation?
- How can competition among various users be addressed without undermining economic growth objectives?
- How can the protection of vital ecosystems be ensured?

Failure to address these complex challenges pushes societies further away from meeting the goal of sustainable development in general, and sustainable management and development of water resources in particular. There is growing support for the ability of IWRM to meet these challenges.

Box 1.2: Challenges and solutions in water supply and sanitation

Improving access to water can be difficult because responsibility for water resources management is usually shared by many different government departments in developing countries. No single department can take the lead, and they often have conflicting views. For example, agricultural departments are usually more interested in promoting irrigation and food production, while other ministries are more concerned with improving drinking water supplies and sanitation.

Improving access to water and sanitation requires:

- Commitment from developing country governments to make it a priority;
- Appropriate long-term financing;
- Arrangements to resolve the competing demands for water and other related environmental challenges;
- Increased advocacy on behalf of poor people to ensure that their demands are heard;
- Improved capacity of governments to facilitate service delivery to all citizens; and
- Improved responsiveness and accountability of government to meet the needs of all users, especially those of people living in poverty.

Source: Adapted from Department for International Development (DFID), 2006

1.2 What is Integrated Water Resources Management (IWRM)?

IWRM is the sustainable development, allocation and monitoring of water resource use in the context of social, economic and environmental objectives (Cap-Net, 2005a). It is cross-sectoral and therefore in stark contrast to the traditional sectoral approach that has been adopted by many countries. It has been further broadened to incorporate participatory decision-making of all stakeholders.

IWRM is a paradigm shift. It departs from traditional approaches in three ways:

- The multiple goals and objectives are cross-cutting so that IWRM departs from the traditional sectoral approach.
- The spatial focus is on the river basin instead of on single water courses.
- It entails a departure from narrow professional and political boundaries and perspectives, broadening them to incorporate participatory decision-making among all stakeholders (i.e., inclusion versus exclusion)

The basis of IWRM is that there is a variety of uses of water resources that are interdependent. The failure to recognize interdependency, coupled with unregulated use, can lead to water wastage and the unsustainability of water resources in the long term.

Box 1.3: Interdependency and the need for IWRM

High irrigation demands and river pollution from agriculture reduce the amount of available freshwater for drinking or industrial use; contaminated municipal and industrial wastewater pollutes rivers and threatens ecosystems; and leaving river water untapped to protect fisheries and ecosystems means that less can be diverted to grow crops. IWRM recognizes this interdependency of water uses.

Source: Cap-Net 2006

Integrated management does not segregate water users or take a sectoral approach as is done in many countries. Rather, water allocation and management decisions consider the impact of each use on the others. In doing so, the cross-cutting goals of social, economic and environmental sustainability are considered collectively, and cross-sectoral policies are examined to shape more coherent, coordinated policies. In short, IWRM recognizes that water is a scarce natural resource, subject to many interdependencies in conveyance and use.

Could you give examples from your own country where this interdependency of water uses exists?

The basic IWRM concept has been extended to incorporate participatory decision-making and will be discussed in more detail in Section 1.4, which deals with water management principles.

Different user groups (farmers, communities, environmentalists and others) may influence strategies for water resource development and management. That brings additional benefits, as informed users apply local self-regulation in relation to issues such as water conservation and protection of catchments far more effectively than central regulation and surveillance can achieve.

The term ‘management’ is used in its broadest sense, in that it highlights the need to not only focus on the development of water resources, but also to consciously manage water development that ensures sustainable use for future generations (Cap-Net, 2005a).

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1.3 The water management framework

IWRM occurs in a holistic framework, dealing with:

- All water (spatial);
- All interests (social);
- All stakeholders (participatory);
- All levels (administrative);
- All relevant disciplines (organizational);
- Sustainability (in all senses: environmental, political, social, cultural, economic, financial and legal). (Jaspers, 2001)

The framework is so broad, that the aim of IWRM is to discard sector approaches and to create environmental, institutional, social, technical and financial sustainability through the creation of a platform for government and stakeholders for planning and implementation, and to deal with conflicts of interests.

At the core of the water management framework is the treatment of water as an economic good as well as a social good, combined with decentralized management and delivery structures, greater reliance on pricing and fuller participation by stakeholders (World Bank, 1993). All of these principles and issues will be discussed in more detail in the following section (1.4).

What will a water management framework do?

1) Provide a framework for analysing policies and options that will guide decisions about managing water resources in relation to:
    - Water scarcity;
    - Service efficiency;
    - Water allocation; and
    - Environmental protection.

2) Facilitate consideration of relationships between the ecosystem and socio-economic activities in river basins.

The analysis should take account of social, environmental and economic objectives; evaluate the status of water resources within each basin; and assess the level and composition of projected demand. Special attention should be given to the views of all stakeholders, which should take place through activities designed to facilitate participation. Section 1.4 provides details on Principle 2 of the Dublin Principles, which highlight the benefits and challenges in attaining participation. Box 1.4 also indicates how participation can be operationalized by using consultative mechanisms, awareness building and education.

Stakeholder participation essentially involves four steps:

1. Identifying the key stakeholders from the large array of groups and individuals that could potentially affect, or be affected by, changes in water management;
2. Assessing stakeholder interests and the potential impact of the IWRM planning on these interests;
3. Assessing the influence and importance of the identified stakeholders; and
4. Outlining a stakeholder participation strategy (a plan to involve the stakeholders in different stages of the plan preparation).

The results of the analyses at a river basin level would become part of the national strategy for water resources management. The analytical framework would provide the underpinnings for formulating public policies on regulations, incentives, public investment plans, environmental management, and the linkages among them. A supportive legal framework and adequate regulatory capacity are required, as well as a system of water charges to endow water entities with operational autonomy and some financial autonomy for efficient and sustainable service delivery.

1.4 Water management principles

A decade and a half ago (at the International Conference on Water and the Environment, convened in Dublin, Ireland, in 1992), four main principles of water emerged that have become the cornerstones of subsequent water sector reform.

Principle 1: Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.

This principle highlights that water is critical to sustaining life. However, freshwater is a finite resource because the hydrological cycle on average yields a fixed quantity of water per period, and the quantity of water resources cannot be adjusted significantly by human actions. Furthermore, as a resource, water is paradoxically both essential to development and vulnerable to its effects. Effective management of water resources – which seeks to ensure that the services that are in demand can be provided and sustained over time – requires a holistic approach that links social and economic development with the protection of natural ecosystems. Effective management does not dichotomize land and water uses but sees the integration of these uses across the whole of a catchment area or river basin.

The integrated approach to management of water resources demands a coordination of the range of human activities that create the demand for water, determine land uses, and generate waterborne waste products. Principle 1 also recognizes the catchment area or river basin as the logical unit for water resources management.

Principle 2: Water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels.

Where water is concerned, everyone is a stakeholder. Accordingly, water development and management should be based on a participatory approach that draws on the principle of democratizing decision-making and gives recognition to the input of multiple stakeholders, including users, planners and policy makers at all levels.

Real participation only takes place when stakeholders are part of the decision-making process. This can occur directly when local communities come together to make water supply, water management and water use choices. Participation also occurs if democratically elected or otherwise accountable agencies or spokespersons can represent stakeholder groups; but even in this situation, access to information, consultation processes and opportunities to participate should also exist.

Benefits of participation:

- Participation emphasizes involvement in decision-making at the most feasible level (subsidiarity), with full public consultation and input from users in the planning and implementation of water projects. This leads to more successful projects in terms of scale design, operation and maintenance.
- Participation also helps to ensure that environmental resources are protected and that cultural values and human rights are respected.
- Participation can help coordinate interests and increase transparency and accountability in decision-making.
- Greater participation can also improve cost recovery, which is key to generating revenue and financing IWRM.

Box 1.4: Participation is more than consultation

Participation requires that stakeholders at all levels of the social structure have an impact on decisions at different levels of water management. Consultative mechanisms, ranging from questionnaires to stakeholder meetings, will not allow real participation if they are merely employed to legitimize decisions already made, to defuse political opposition or to delay the implementation of measures that could adversely impinge upon a powerful interest group.

Participation will not always achieve consensus. Arbitration processes or other conflict resolution mechanisms will also need to be put in place.

Participatory capacity needs to be created, particularly amongst women and other marginalized social groups. This may not only involve awareness raising, confidence building and education, but also the provision of the economic resources needed to facilitate participation and the establishment of good and transparent sources of information. It has to be recognized that simply creating participatory opportunities will do nothing for currently disadvantaged groups, unless their capacity to participate is enhanced.

Source: Cap-Net, 2005b

Box 1.5: Determinants, conditions for effective participation, and challenges

As noted, real participation occurs only when stakeholders are actually part of the decision-making process. However, there are determinants, conditions and challenges related to participation in most countries.

Determinants of the types of participation and conditions for effective participation

- The *spatial scale* (river basin or village water system) relevant to the particular water management and investment decision; and
- The nature of the political environment in which decisions take place.

Challenges to the participatory approach

Participation does not always achieve consensus as the following challenges reveal:

- Arbitration processes and other conflict resolution mechanisms are sometimes needed.
- Government intervention is sometimes needed to create an enabling environment for marginalized social groups such as people living in poverty, indigenous people, the elderly and women.
- Merely the opportunity to participate is insufficient to provide the benefits of the participatory approach. Disadvantaged groups must also have the capacity to participate; thus, capacity building is essential.

Source: Cap-Net, 2006

In your country, are all stakeholders involved in decision-making on water supply, management and investment decisions?

Principle 3: Women play a central part in the provision, management and safeguarding of water.

It is widely acknowledged that women play a key role in the collection and safeguarding of water for domestic use and, in many countries, for agricultural use. However, women are less instrumental than men in key areas such as management, problem analysis and the decision-making processes related to water resources. Often the marginalized role of women in water resources management can be traced to social and cultural traditions, which also vary between societies.

There is strong evidence that water managers must consider that there is an urgent need to mainstream gender in IWRM to achieve the goal of sustainable water use. Cap-Net and the Gender and Water Alliance (GWA) developed a tutorial for water managers entitled ‘Why Gender Matters’. Some parts of the tutorial are covered in this section, but the manual users are advised to review the tutorial for a more complete understanding of the importance of having a gender-balanced approach in IWRM.

Basic linkages between gender and IWRM

There are three basic linkages between gender and IWRM issues:

1. Gender and environmental sustainability linkages

- Women and men affect environmental sustainability in different proportions and by different means, as they have different access, control and interests.
- Flood and drought events weigh heaviest on women because they lack the means to cope with disasters.

2. Gender and economic efficiency linkages

- In many societies, women pay for drinking water but have mobility restrictions and payment constraints. Allowing users to pay smaller amounts more frequently and nearer to home makes water more affordable for them. (Water supply)
- Technology choice affects affordability. Consulting female and male users may result in a more acceptable, user-friendly and sustainable service. (Water supply)
- Lack of access to finance for poor people and for women farmers prevents them from developing more prosperous and water-efficient agricultural enterprises and limits their participation in agriculture to that of a subsistence activity. (Agriculture)

3. Gender and social equity linkages

- Powerful groups of society, usually male-dominated, can exploit resources more systematically and on a large scale and can also drive industrial transformation of the environment; therefore, their potential to create damage is higher. (Environment)
- When water is not supplied by a piped system, the burden of water collection falls on women and children, who must expend considerable time and energy on this activity. (Water supply)
- Women rarely have equal access to water for productive use and are the first to be affected in times of water shortage. (Agriculture)

In your country, is a gender-sensitive approach being used in managing water resources? If not, why has this approach not been adopted?

- Women and children are the most susceptible to waterborne disease due to their roles in water collection, clothes washing and other domestic activities. (Sanitation)

Principle 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.

Many past failures in IWRM are attributable to ignoring the full value of water. The maximum benefits from water resources cannot be derived if misperceptions about the value of water persist.

Value versus charges

Value and charges are two distinct concepts. The value of water in alternative uses is important for the rational allocation of water as a scarce resource, whether by regulatory or economic means. Conversely, charging for water means applying an economic instrument to achieve multiple objectives, as follows:

- To support disadvantaged groups;
- To influence behaviour towards conservation and efficient water usage;
- To provide incentives for demand management;
- To ensure cost recovery; and
- To signal consumer willingness to pay for additional investments in water services.

When is water appropriate as an economic good?

Treating water as an economic good is imperative for logical decision-making on water allocation between competing water sectors, especially in an environment of water resource scarcity. It becomes necessary when extending the supply is no longer a feasible option. In IWRM, the economic value of alternative water uses helps guide decision makers in prioritizing investments. In countries where there is an abundance of water resources, it is less likely to be treated as an economic good since the need to ration water usage is not as urgent as in water-scarce countries.

Why is water a social good?

Although water is an economic good, it is also a social good. It is particularly important to view water allocation as a means of meeting the social goals of equity, poverty alleviation and safeguarding health. In countries where there is an abundance of water resources, there is more of a tendency to treat water as a social good to fulfil equity, poverty alleviation and health objectives over economic objectives. Environmental security and protection are also part of the consideration of water as a social good. Aesthetic and religious functions of water are often neglected or at least not sufficiently considered in water management.

Details on when it is appropriate to treat with water as an economic good and a social good will be dealt with in Chapter 2.

Applying the concepts

In the real world, in a situation of water scarcity, should water be provided to a steel-manufacturing plant because the manufacturer has the ability to pay more for water than thousands of poor people who have no access to safe water? Can you find any similar example

1.5 Importance of IWRM for adaptation to climate change

Water is the first sector to be affected by changes in climate. Climate change leads to intensification of the hydrological cycle and subsequently it has serious effects on the frequency and intensity of extreme events. Sea level rise, increased evaporation, unpredictable precipitation and prolonged droughts are just a few manifestations of climate variability directly impacting on availability and quality of water.

Through management of the resource at the most adequate level, the organization of participation in management practices and policy development, and assuring that the most vulnerable groups are considered, IWRM instruments directly assist communities to cope with climate variability. In 2001 the Intergovernmental Panel on Climate Change (IPCC) recognized the potential of IWRM to be used as a means of reconciling varied and changing water uses and demands, and it appears to offer greater flexibility and adaptive capacity than conventional water resources management approaches. It is critical that climate change in water governance be considered in the context of reducing *vulnerability* of poor people, in maintaining sustainable livelihoods and supporting sustainable development. The IPCC report makes recommendations on *adaptation*, vulnerability and capacity enhancement; the main recommendation asserts that reducing the vulnerability of nations or communities to climate change requires an increased ability to adapt to its effects. Working to improve the adaptive capacity at community level is likely to have a broader and more long-lasting effect on reducing vulnerability. Tailoring adaptation assistance to local needs requires the following actions:

- Addressing real local vulnerabilities;
- Involving real stakeholders early and substantively; and
- Connecting with local decision-making processes.

1.6 How can IWRM help address climate change?

As demonstrated earlier in this chapter, 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.

Key water resources management functions are:

- Water allocation;

- Pollution control;
- Monitoring;
- Financial management;
- Flood and drought management;
- Information management;
- Basin planning; and
- Stakeholder participation.

These functions are instrumental for integrated resources management and can be of help in coping with climate variability. For example:

- In monitoring water quantity and quality developments, management can proactively take action towards adaptation.
- Management of floods and droughts, as a key function of WRM, allows for direct intervention in cases of extreme events.
- In basin planning, risk assessment and adaptation measures can be incorporated.
- Water can be allocated to the most efficient and effective use to react to climate variability in a flexible manner.

In brief, IWRM makes it easier to respond to changes in water availability. 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 changing water conditions.

1.7 Implementing IWRM

While there has been progress in a general understanding the meaning of IWRM, its importance in the context of scarcity, an acknowledgement of the main (Dublin) principles and a growing recognition of the need to use the right mix of economic and financial instruments, the actual implementation of IWRM is a challenging process.
There are several roadblocks to implementing IWRM, starting with entrenched sectoral interests, professional insecurities and sociocultural myths. These challenges are nevertheless not insurmountable. Overcoming the barriers to the implementation of IWRM requires an incremental approach to negotiating differences, cross-sectoral integration and instituting reforms (including policy and legal reforms).

Conflicts among professionals working in the various sectors, combined with a sense of vulnerability in adopting alternative approaches to water development and management that permeates professional groupings, calls for skills in negotiating win-win solutions and providing platforms for very different stakeholders to develop collaboration in implementing IWRM. These processes take time and require patience.

IWRM can only be successfully implemented if, among other reforms, there is a concerted effort to integrate perspectives and divergent interests of various water users in the management framework. Formal mechanisms and means of cooperation and information exchange should be established at different levels to achieve cross-sectoral integration. Past informal attempts have not been successful, and a formalized set of mechanisms should have the effect of ensuring commitment at the various levels. Uncertainties are part of a shift in the management paradigm and the process of implementation considers dealing with them (see Chapter 5).

Existing institutional and legislative frameworks have not been entirely responsive to the demands and requirements for implementing IWRM. Implementing IWRM will therefore require reform at most stages in the water planning and management cycle.

Although there is an urgent need for reform, these changes can only take place incrementally – some occurring immediately and others taking several years of planning and capacity building. It will involve creating an enabling environment, and developing an institutional framework and management instruments for sustainable IWRM.

Box 1.6: Is there a water crisis, or are we on track to meet the target?

Water – Progress lagging: Target 10 of MDG7 is to halve the proportion of people without sustainable access to safe drinking water by 2015 (UN, 2006). The share of people throughout the world with access to safe drinking water has continued to rise, reaching 83 percent in 2004 (up from 78 percent in 1990). However, on current trends, Sub-Saharan Africa will not meet the target. This is due to factors such as high population growth rates, low government expenditure (particularly on operation and maintenance), conflict and political instability. Wide disparities between rural and urban areas persist in Sub-Saharan Africa, where city dwellers are twice as likely as their rural counterparts to have access to safe water.

Sanitation – Progress lagging: 1.2 billion people gained access to sanitation between 1990 and 2004. However, to meet the 2015 sanitation target, over 1.6 million people need to gain access to improved sanitation. The most serious problems are in Sub-Saharan Africa and South Asia.

Key messages

- Sub-Saharan Africa remains the area of greatest concern. Over the period 1990–2004, the number of people without access to safe drinking water increased by 23 percent and the number of people without sanitation increased by over 30 percent.
- There are huge disparities between regions: while the percentage of people who have access to drinking water through a household connection is as low as 16 percent in Sub-Saharan Africa, it is much higher in Eastern Asia (70 percent), North Africa (76 percent) and Western Asia (81 percent).

Source: DFID, 2006

Summary

Recently IWRM has come up as the internationally and locally accepted management system to ensure sufficient water resources of adequate quality, not only for today but also for generations to come. The four principles of IWRM are:

- Freshwater is a finite and vulnerable resource.
- Water development and management should be based on a participatory approach.
- Women play a central role.
- Water has an economic and a social value.

As water is the first sector to be affected by changes in climatic conditions, IWRM has an important role to play in addressing climate change issues. The key water resources management functions within an IWRM framework are instrumental for capacitating organizations and communities to cope with climate variability.

Think about it
Considering water management in your country.
How can it help address climate change?

Suggested reading

Cap-Net (2005) Tutorial on basic principles of integrated water resources management.
Global Water Partnership (2000) TAC Background Paper No. 4: Integrated Water Resources Management. GWP: Stockholm, Sweden.
WHO-UNICEF (2000) Global Water Supply and Sanitation Assessment 2000 Report. World Health Organization and United Nations Children's Fund. http://www.who.int/water_sanitation_health/monitoring/globalassess/en
WHO-UNICEF (2006) Meeting the MDG Drinking Water and Sanitation Target. The Urban and Rural Challenge of the decade.
United Nations (2009) Water in a Changing World. http://www.unesco.org/water/wwap/wwdr/wwdr3/pdf/WWDR3_Water_in_a_Changing_World.pdf

2. DRIVERS AND IMPACTS OF CLIMATE CHANGE

Goal

The aim of this module is to familiarize participants with the drivers and physical science basis of climate change, as well as to help them understand potential impacts on the water cycle and the consequences for water use and ecosystem functioning.

2.1 Understanding drivers and the physical science basis of climate change

Since the Fourth Assessment Report (AR4) of the IPCC became public in 2007, there has been no dearth of scientific evidence about global climate change. Atmospheric warming is unequivocally evident from observed increases in global average air temperatures, ocean temperatures, widespread melting of snow and ice and rising global average sea level. Concerning the attribution of the observed increase in global average temperatures since the mid-20th century, the AR4 states that this is "very likely due to observed increase in anthropogenic greenhouse gas concentrations" (IPCC, 2007a: 10).

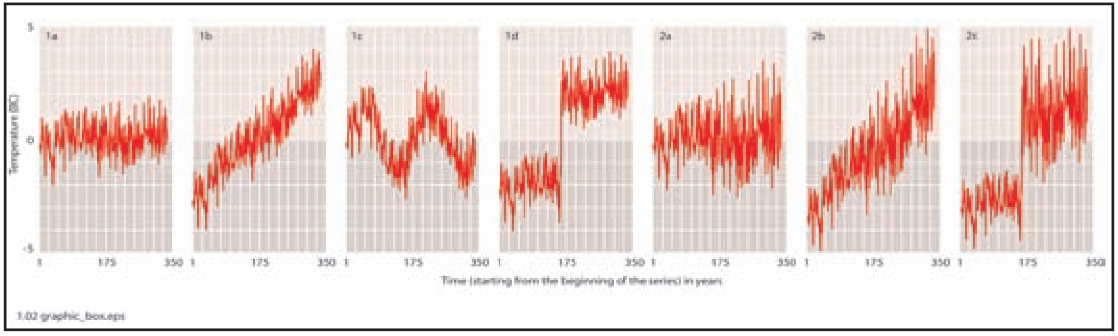
There is no doubt that this climate change is going to have impacts on water and many other sectors that are sensitive to climate variability and change. Therefore, it is imperative to develop a good understanding of some of the basic aspects of climate change and how it is detected before considering the impacts of such change.

2.1.1 Climate variability and climate change

The global climate system is composed of the *atmosphere*, the *hydrosphere* (liquid water), the *cryosphere* (ice and snow), the *lithosphere* (soil and rock) and the *biosphere* (plants and animals, including humans). The climate of a particular place is dependent on the complex nonlinear interactions between these components under the effects of solar radiation, the rotation of the earth and its orbital motion around the sun.

The climate is usually defined in terms of a statistical description (mean and variability) of variables such as temperature and precipitation over a period of time ranging from a few years to millions of years. The World Meteorological Organization (WMO) recommends 30 years as the minimum period for averaging these variables to ascertain variability (WMO, 2003).

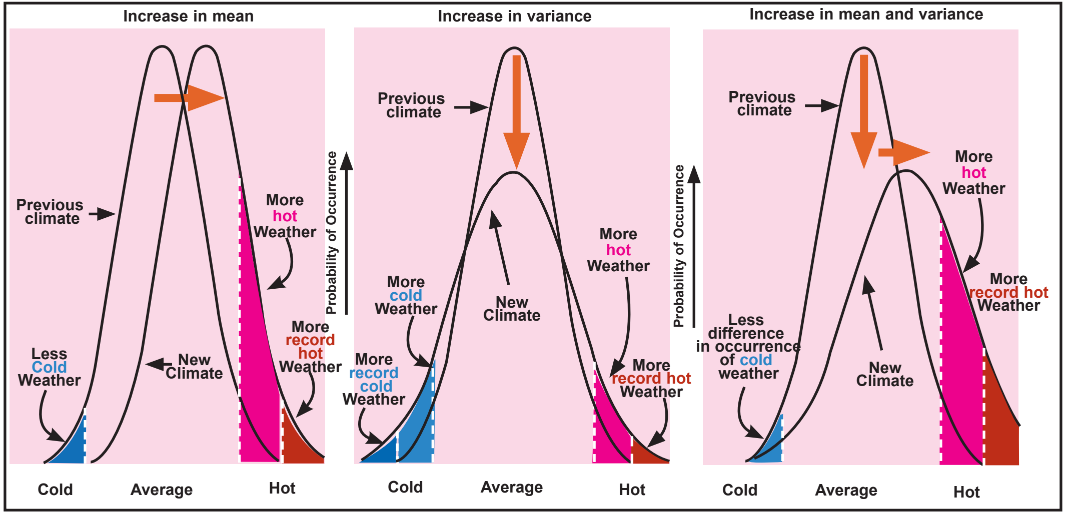
Figure 2.1: Climate variability and climate change



Source: Adapted from WMO, 2003

Figure 2.1 illustrates a number of (notional) temperature time series under climate variability and climate change. Figure 1a shows an example of climate variability: temperature fluctuates from observation to observation around a mean value. Examples 1b to 1d combine variability with climate change. Example 2a indicates an increase of variability with no change in the mean. Examples 2b and 2c combine increased variability with climate change.

Figure 2.2: Climate variability and climate change – illustrated in the form of probability distributions for temperatures



Source: Adapted from WMO, 2003

Can you define weather and climate?

It is important to stress that no individual weather event can be attributed to climate change and that instrumental records for such events are not long enough to characterize the severity of future events. Figure 2.2 indicates through simple statistical reasoning how increased variability and mean in different combinations will affect temperature extremes.

Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on *Climate Change* (UNFCCC), in its Article 1, 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'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and *climate variability* attributable to natural causes (IPCC, 2007b: 943)

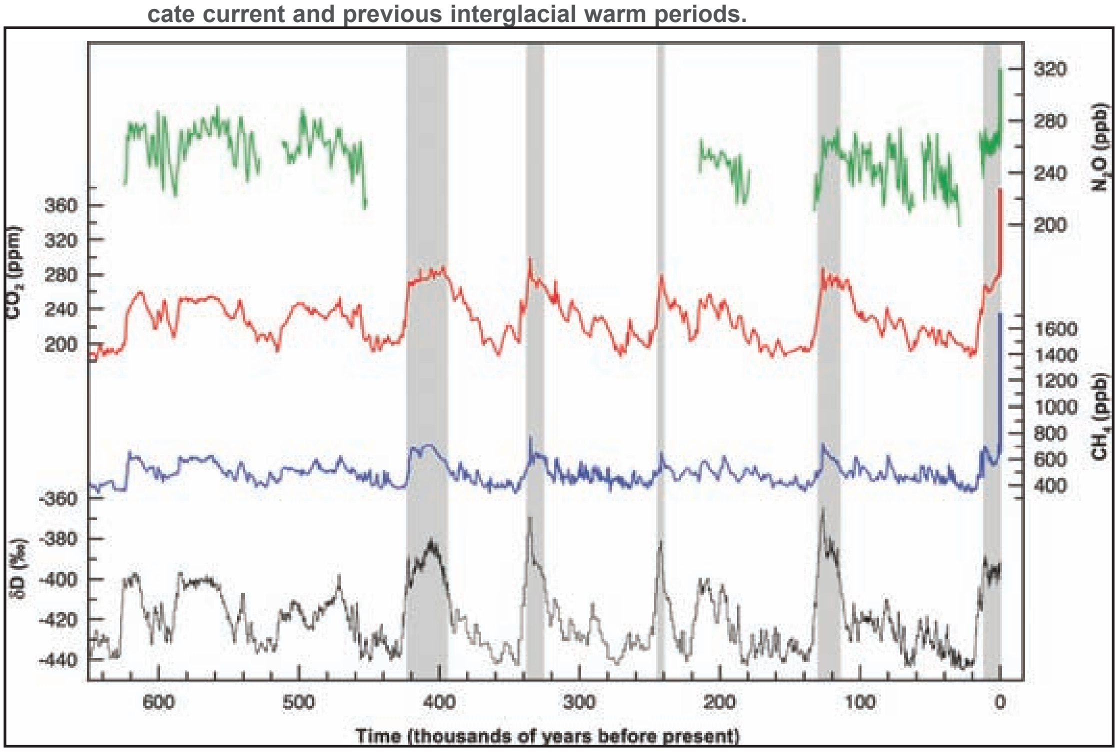
How do you differentiate between climate variability and climate change?

2.1.2 Greenhouse gas concentrations, radiative forcing and observed and projected temperature change

Water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs) are the major greenhouse gases available in the atmosphere; there are a few other gases, which appear in trace amounts only. The earth's surface emits radiation. This emitted radiation is absorbed by greenhouse gas molecules and re-emitted in all directions, causing a warming of the earth's surface. Any change in the greenhouse gas content of the atmosphere triggers change in the global climate by modifying climate variables such as temperature.

Figure 2.3 presents the variations of deuterium (δD) over 650,000 years in Antarctic ice, which is a proxy for local temperature, and the atmospheric concentrations of the greenhouse gases carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) in air trapped within the ice cores and from recent atmospheric measurements. Both natural and human-made factors can be responsible for the changes in the greenhouse gas content of the atmosphere. The natural greenhouse effect may be caused by changes in CO_2 and CH_4 concentration in the atmosphere that have been associated with transitions between glacial and interglacial episodes (shaded bands in Figure 2.3), vegetation, weathering of rocks etc.

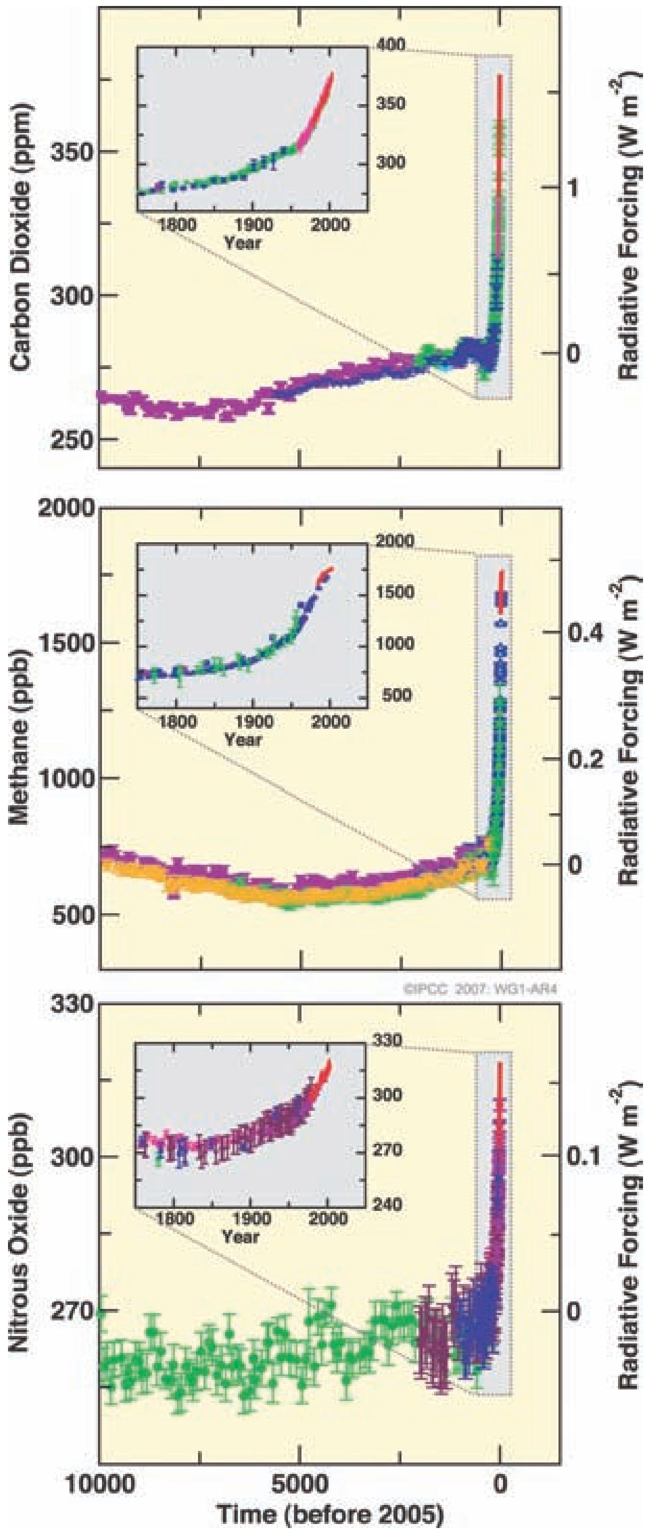
Figure 2.3: **Variations of deuterium (δD) in Antarctic ice, and of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) in air trapped within ice cores. Shaded bands indicate current and previous interglacial warm periods.**



Source: Solomon et al., 2007

The anthropogenic factors that have increased the amount of CO_2 and other greenhouse gases since the 18th century include burning of fossil fuels, forest clearing and industrial processes. The CO_2 concentration in the atmosphere has risen from 270 ppm to 370 ppm in the past two hundred and fifty years (Figure 2.3), mainly due to combustion of fossil fuels. This exceeds the natural variation (established through ice cores) over the past 650,000 years (180–300 ppm) (Jansen et al., 2007). The average annual growth rate in CO_2 concentration between 1995 and 2005 was 1.9 ppm y-1, which is significantly higher than the 40-year average since 1960 (1.4 ppm y-1), when the continuous record of atmospheric measurements began (Forster et al., 2007).

Figure 2.4: **Atmospheric concentrations of carbon dioxide, methane and nitrous oxide over the last 10,000 years (large panels) and since 1750 (inset panels)**



Source: IPCC, 2007a

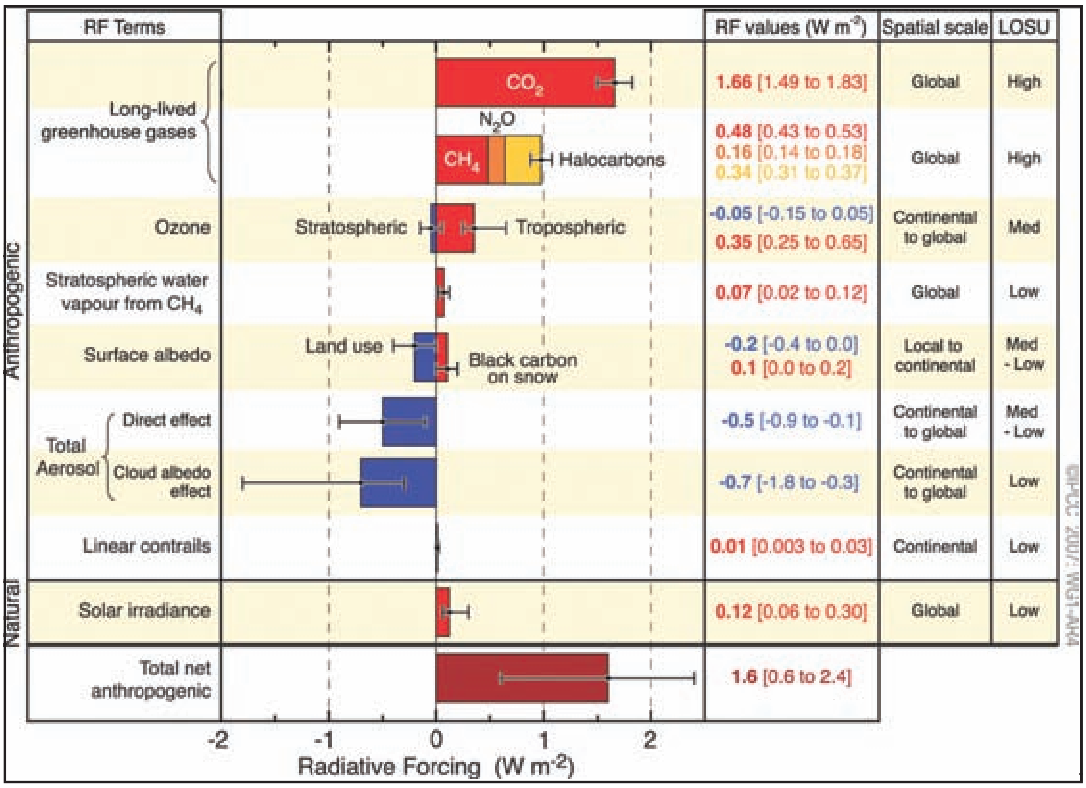
Radiative forcing

There is a balance between incoming solar radiation and outgoing terrestrial radiation. Any process that alters the energy balance of the earth-atmosphere system is known as radiative forcing (RF). Some of the major causes that may trigger radiative forcing include variation in the earth's orbit, solar radiation, volcanic activity and atmospheric composition (Forster et al., 2007). Figure 2.4 depicts the radiative forcing by the atmospheric concentrations of CO_2, CH_4 and N_2O over the last 10,000 years (large panels) and since 1750 (inset panels). Measurements are shown from ice cores (symbols with different colours for different studies) and atmospheric samples (red lines).

What is the IPCC definition of 'radiative forcing'?

In Figure 2.5, AR4 provides global average radiative forcing estimates and ranges in 2005 for anthropogenic agents and mechanisms, together with the typical geographical extent (spatial scale) of the forcing and the assessed *level of scientific understanding* (LOSU) in a comprehensive way (IPCC, 2007a). The net anthropogenic radiative forcing and its range are also shown. These require summing asymmetric uncertainty estimates from the component terms, and cannot be obtained by simple addition. Additional forcing factors not included here are considered to have a very low LOSU. Volcanic aerosols contribute an additional natural forcing but are not included in this figure due to their episodic nature.

Figure 2.5: Global average radiative forcing (RF) estimates and ranges in 2005 for anthropogenic carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and other important agents and mechanisms, together with the typical geographical extent (spatial scale) of the forcing and the assessed level of scientific understanding (LOSU)

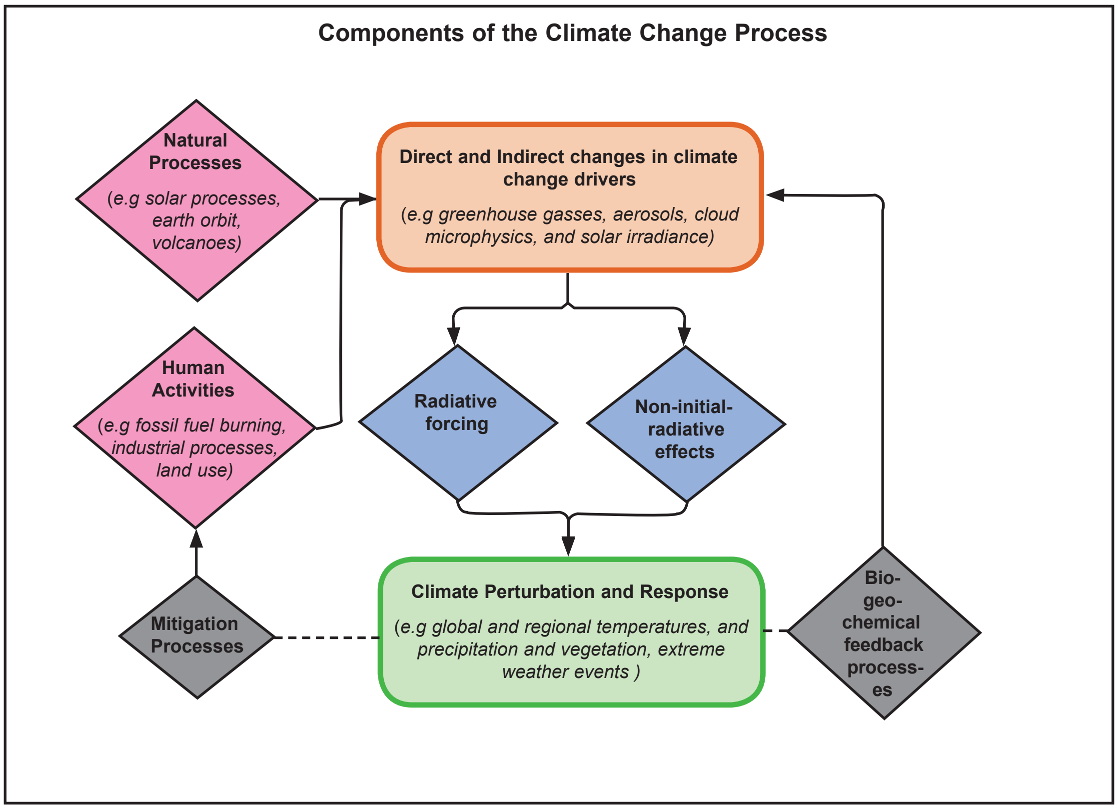


Source: IPCC, 2007a

Figure 2.6 presents the 'climate forcing' mechanisms that 'force' the climate to change by imposing a change in the planetary energy balance. The linkage of radiative forcing to other aspects of climate change is illustrated. Human activities and natural processes cause direct and indirect changes in climate change drivers. Radiative forcing and non-initial radiative effects lead to climate perturbations and responses. Climate change may also be attributed to natural and anthropogenic factors. The coupling among biogeochemical processes leads to feedbacks from climate change to its drivers. An example of this is the change in wetland emissions of CH_4 that may occur in a warmer climate (see also Box 5.1). The potential approaches to mitigating climate change by altering human activities (dashed line) are topics addressed by Working Group III of the IPCC.

What are the causes for radiative forcing? Which gas mainly accounts for radiative forcing per year?

Figure 2.6: Diagram illustrating how RF is linked to other aspects of climate change assessed by the IPCC



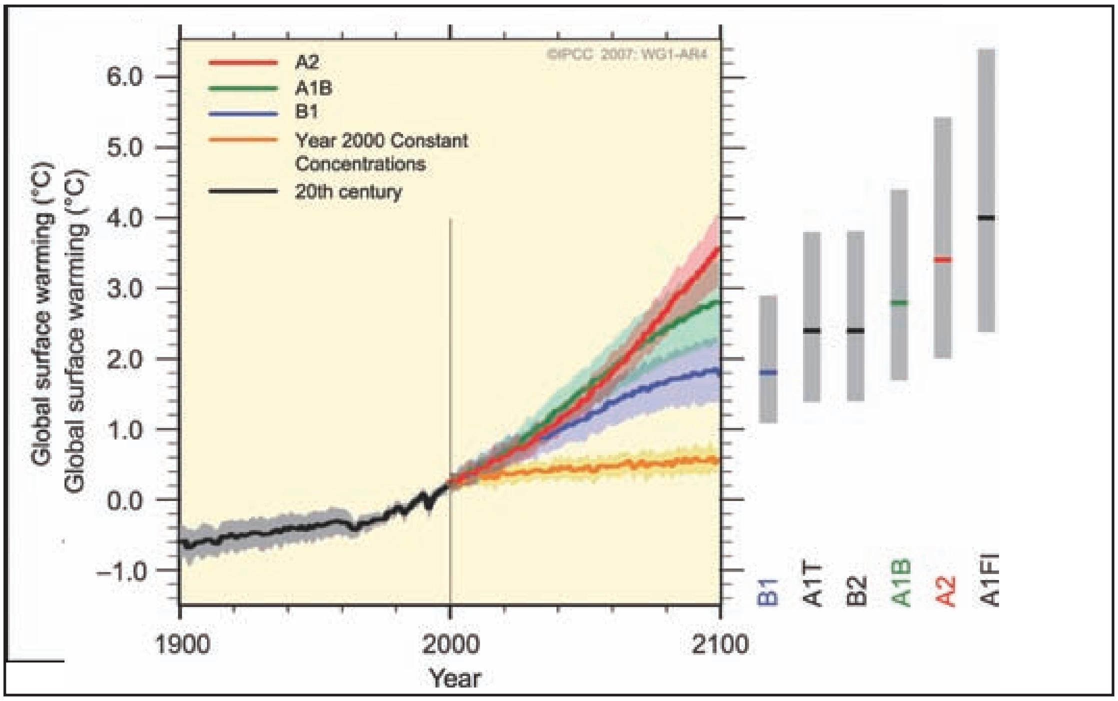
Source: Forster, 2007

Observed and projected temperature change

Anthropogenic climate change is manifested in the increase of the earth's averaged surface temperature as a result of increases in the concentrations of greenhouse gases in the atmosphere, which absorb, reflect and partially re-radiate terrestrial long wave radiation, preventing it from leaving the earth's atmosphere.

From examining long-term global mean temperature records, it has become clear to – and accepted by – the scientific community that the global mean temperature has increased by 0.6˚C over the 20th century, as shown in Figure 2.7. It is important to note that this change is not homogenous across the globe and is not linear. The records also show that the warmest year on record (until 2006) since scientific temperature observations began some 140 years ago was 1998, with surface temperatures averaging 0.55˚C above the 1961–1990 annual average. The second, third, fourth and fifth warmest years on record are 2002, 2001, 2004 and 1995, respectively. Eleven of the last 12 years (1995–2006) rank among the 12 warmest years in the instrumental record of global surface temperature (since 1850).

Figure 2.7: Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations



Source: IPCC, 2007a

The projected temperature change with respect to emissions scenarios (see Figure 2.8) is depicted in Figure 2.7. Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 *standard deviation* range of individual model annual averages. The orange line denotes the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the likely range assessed for the six Special Report on Emission Scenarios (SRES; see section 2.1.4).

2.1.3 Calibrating confidence and uncertainty

The IPCC has devised approaches to develop expert judgments, evaluating uncertainties and communicating confidence and uncertainty in findings that arise in the context of the assessment process (Manning et al., 2004). It is proposed to use language that minimizes possible misinterpretation and ambiguity to avoid uncertainty. However, terms such as ‘virtually certain’ or ‘likely’ can engage the reader effectively, but may be interpreted very differently by different people unless some calibration scale is provided. Therefore, three forms of language were used to describe different aspects of confidence and uncertainty and to provide consistency across the AR4 (see Box 2.1).

Box 2.1: Communicating confidence and uncertainty

Qualitatively defined levels of understanding

Level of agreement or consensus	**High agreement limited evidence**		**High agreement much evidence**
	Low agreement limited evidence		**Low agreement much evidence**
	Amount of evidence (theory, observations, models)		

Quantitatively calibrated levels of confidence

Terminology	**Degree of confidence in being correct**
Very high confidence	At least 9 out of 10 chance
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

Likelihood scale

Terminology	**Likelihood of the occurrence/ outcome**
Virtually certain	> 99% probability of occurrence
Very likely	> 90% probability
Likely	> 66% probability
About as likely as not	33 to 66% probability
Unlikely	< 33% probability
Very unlikely	< 10% probability
Exceptionally unlikely	< 1% probability

Source: Manning et al., 2004

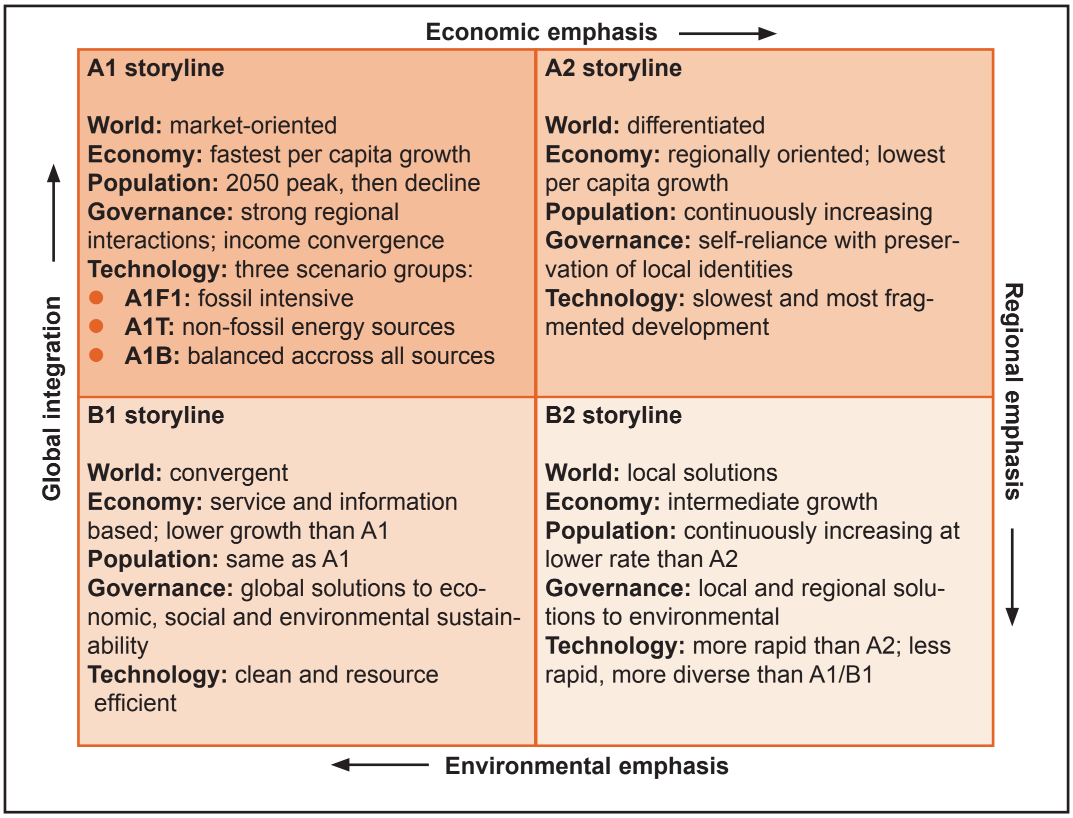
Are you aware of any signs of climate change? How certain are you that this is caused by climate change?

2.1.4 Emission scenarios

In 1992 IPCC released a set of six global emission scenarios (IS92a to f) known as IS92 scenarios. These are based on possible emissions of greenhouse gases under a wide range of assumptions of future population and economic growth. The IS92a scenarios (also known as the 'business as usual' scenarios) were the most widely used by scientists until they were updated in 2000 by IPCC and published through the SRES (IPCC, 2000).

The SRES scenarios are formulated in a fundamentally different way from previous scenarios, with a different range for each projection, called a 'storyline'. Four storylines have been defined, namely A1, A2, B1 and B2. These describe the possible ways the world population, land use changes, new technologies, energy resources and economic and political structure may evolve over the next few decades (Anandhi, 2007). These world future influences are represented in two dimensions: one represents economic or environmental concerns and the other represents the global or regional development patterns (Figure 2.8). For the A1 storyline, several emission scenarios were formulated but overall 'scenario families' were confined to four. The A1 storyline has three marker scenarios, namely A1B, A1F1 and A1T, whereas the others have only one each.

Figure 2.8: Scenarios considered by the IPCC in their Third Assessment Report of 2001



A1 storyline

World: market-oriented
Economy: fastest per capita growth
Population: 2050 peak, then decline
Governance: strong regional interactions; income convergence
Technology: three scenario groups:

- **A1F1:** fossil intensive
- **A1T:** non-fossil energy sources
- **A1B:** balanced accross all sources

A2 storyline

World: differentiated
Economy: regionally oriented; lowest per capita growth
Population: continuously increasing
Governance: self-reliance with preservation of local identities
Technology: slowest and most fragmented development

B1 storyline

World: convergent
Economy: service and information based; lower growth than A1
Population: same as A1
Governance: global solutions to economic, social and environmental sustainability
Technology: clean and resource efficient

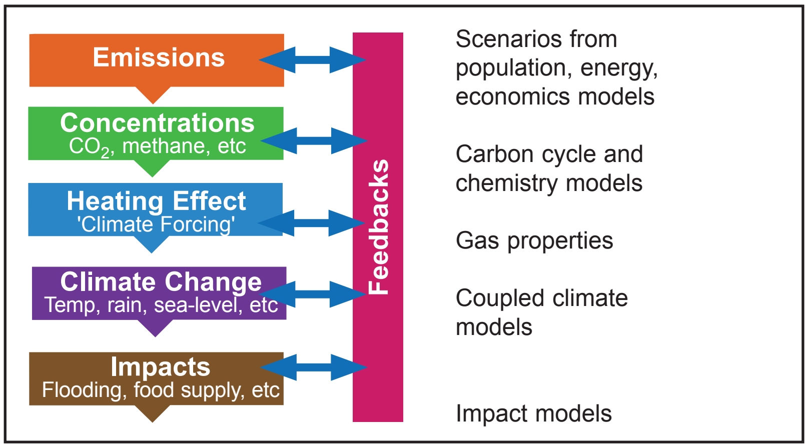
B2 storyline

World: local solutions
Economy: intermediate growth
Population: continuously increasing at lower rate than A2
Governance: local and regional solutions to environmental
Technology: more rapid than A2; less rapid, more diverse than A1/B1

Source: IPCC, 2001

A1 storyline: *This storyline designates very rapid growth with increasing globalization, an increase in global wealth, with convergence between regions and reduced differences in regional per capita incomes. It also assumes materialist consumerism, with rapid technological change and low population growth. There are three variants within this family for sources of energy: a balance across all sources (A1B), fossil intensive (A1F1) and non-fossil fuel (A1T).*
A2 Storyline: *In this storyline a heterogeneous market-led world with rapid population growth but less rapid economic growth than A1 has been considered. The underlying theme is self-reliance and preservation of local identities.*
B1 Storyline: *This storyline assumes a world of dematerialization and the introduction of clean technologies. The emphasis is on global solutions to achieve economic, social and environmental sustainability.*
B2 Storyline: *In this storyline population increases at a lower rate than in A2 but at a higher rate than in A1 with development following environmentally, economically and socially sustainable locally oriented pathways.*

Figure 2.9: From greenhouse gas emissions to climate change impact



Source: Saunby, 2007

It is essential to remember that these emission scenarios are based on assumptions of future driving forces such as demographic, socio-economic and technological development that may or may not be realized. As depicted in Figure 2.9, these emission scenarios are transformed into concentration scenarios, which are finally used for climate models to compute climate projections. There are uncertainties involved at every step, starting from emissions down through to the adaptation level, and at every successive stage the extent of uncertainties increases. It will be difficult for any government to invest in adaptation measures with such levels of uncertainties (see Chapter 5).

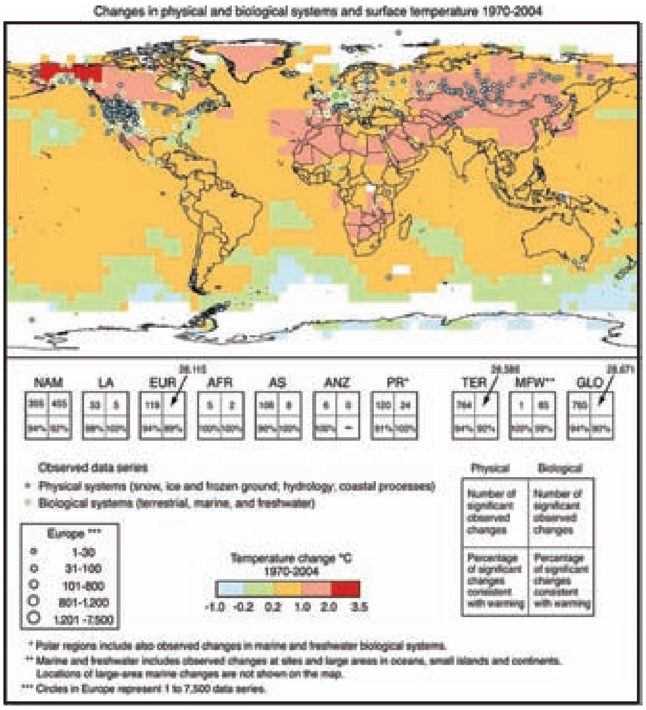
Which SRES scenario do you think is most relevant in your region and why?

2.2 Understanding observed and projected impacts on the water cycle

2.2.1 Observed changes and trends in the water cycle

The Fourth Assessment Report of IPCC (Rosenzweig et al., 2007) has produced a comprehensive composite picture (Figure 2.10) presenting locations of significant changes in data series of physical systems (snow, ice and frozen ground; hydrology; and coastal processes) and biological systems (terrestrial, marine and freshwater biological systems). These are shown together with surface air temperature changes over the period 1970–2004.

Figure 2.10: Locations of significant changes in data series of physical systems and biological systems together with surface air temperature changes over the period 1970–2004



Source: Rosenzweig et al., 2007

A subset of almost 29,000 data series was selected from about 80,000 data series from 577 studies. These met the following criteria: (1) ending in 1990 or later; (2)

spanning a period of at least 20 years; and (3) showing a significant change in either direction, as assessed in individual studies. These data series are from about 75 studies (of which about 70 are new since the Third Assessment). However, it should be noted that out of the 29,000 data series about 28,000 are from European studies. White areas do not contain sufficient observational climate data to estimate a temperature trend.

The 2x2 boxes show the total number of physical (left) and biological (right) data series with significant changes (top row) and the percentage of those consistent with warming (bottom row) for (i) continental regions: North America (NAM), Latin America (LA), Europe (EUR), Africa (AFR), Asia (AS), Australia and New Zealand (ANZ) and Polar Regions (PR) and (ii) global-scale: Terrestrial (TER), Marine and Freshwater (MFW) and Global (GLO). The numbers of studies from the seven regional boxes (NAM … PR) do not add up to the global (GLO) totals because numbers from regions except Polar do not include the numbers related to Marine and Freshwater (MFW) systems. Locations of large-area marine changes are not shown on the map.

Many studies have reported evidences of observed changes and trends in precipitation and other associated hydrological variables. These trends have been evaluated during AR4 of the IPCC and are summarized below.

Cryosphere

Changes in systems and sectors related to accelerated melting in the cryosphere have been documented in glacial floods, ice and rock avalanches in mountain regions, run-off in snow and glacial basins, Arctic mammals, Antarctic Peninsula fauna, permafrost-based infrastructure in the Arctic, relocation of ski centres to higher elevation areas and impacts in indigenous livelihoods in the Arctic (high confidence). The changes in systems and sectors parallel abundant evidence leading to the assessment that the cryosphere is undergoing accelerated melting in response to global warming, including sea ice, freshwater ice, ice shelves, the Greenland ice sheet, glaciers, snow cover and permafrost (very high confidence).

Hydrology and water resources

Recent evidences show that areas most affected by increasing droughts are located in arid and semi-arid regions due to the already warm and dry climate (high confidence). In the last 20 years, there are documented increases in flash floods and landslides due to intensive and heavy rain in mountain areas during the warm season (high confidence).

Coastal processes and zones

Widespread coastal erosion and wetland losses are occurring under current rates of sea level rise, but at present, these are mostly the consequences of anthropogenic modification of the shoreline (medium confidence). In many low-lying coastal areas, development in conjunction with sea level rise over the last century has exacerbated the damage to fixed structures from modern storms, which would have been relatively minor a century ago.

Marine and freshwater biological systems

Many of the observed responses in marine and freshwater systems have been associated with rising water temperatures (high confidence). Climate change, in tandem with other human impacts, has already caused substantial damage to coral reefs (high confidence). The documented poleward movement of plankton by 10 degrees in the North Atlantic is larger than any documented terrestrial study. Observations indicate that lakes and rivers around the world are warming, with effects on thermal structure, lake chemistry, abundance and productivity, community composition, phenology, distribution and migration (high confidence).

Terrestrial biological systems

The overwhelming majority of studies examining global warming impacts on terrestrial species reveal a consistent pattern of change (high confidence). Responses of terrestrial ecosystems to warming across the northern hemisphere are well documented by phenological changes, especially the earlier onset of spring phases. Climate change over the past decades has resulted in population decrease and disappearance of certain species (medium confidence) and movement of wild plant and animals poleward and upward in elevation (medium confidence). Some evidence of adaptation is found in migratory species (medium confidence).

Agriculture and forestry

In North America and Europe, there is a lengthening of the frost-free growing season and an advance in spring-summer crop phenology, which may be attributed to recent warming (high confidence). Viniculture appears to be highly sensitive, with a documented improvement of quality related to warming. Reductions in precipitation, on decadal scales in the Sahel, are responsible for lower crop yields (high confidence).

Do you know of any examples of impacts of climate change on the water cycle? What do you expect for the future?

2.2.2 Projections of future climate change impacts on the water cycle

It is expected that climate change is likely to alter the hydrologic cycle in ways that will result in substantial impacts on water resource quantity as well as quality. Precipitation, which is the main component of hydrology, is expected to change in intensity and spatial distribution. A brief summary of potential impacts on the most important water resource elements as brought out by IPCC in AR4 is given below (Parry et al., 2007). In Chapter 4 more details will be presented on regional differentiation.

Precipitation changes

An increase in global average precipitation and evaporation as a direct consequence of warmer temperatures has been predicted (Figure 2.11). Evaporation will increase with warming because a warmer atmosphere can hold more moisture and higher temperatures increase the evaporation rate. An increase in global average precipitation does not mean that it will get wetter everywhere and in all seasons. In fact, all climate model simulations show complex patterns of precipitation change, with some regions receiving less and others receiving more precipitation than they do now. Changes in circulation patterns will be critically important in determining changes in local and regional precipitation patterns.

Figure 2.11 presents the range of winter and summer temperature and precipitation changes up to the end of the 21st century across recent models (15 – red bars) and pre-AR3 models (7 – blue bars). Coupled Atmosphere-Ocean General Circulation Model (AOGCM) projections under the SRES A2 emissions scenarios for 32 world regions is expressed as rate of change per century. Mauve and green bars show modelled 30-year natural variability. Numbers on precipitation plots show the number of recent A2 runs giving negative/positive precipitation change.

Changes in precipitation frequency and intensity

It is also expected that, in addition to changes in global average precipitation, there could be more pronounced changes in the characteristics of regional and local precipitation due to global warming. On an average, precipitation will tend to be less frequent but more intense, implying greater incidence of extreme floods and droughts.

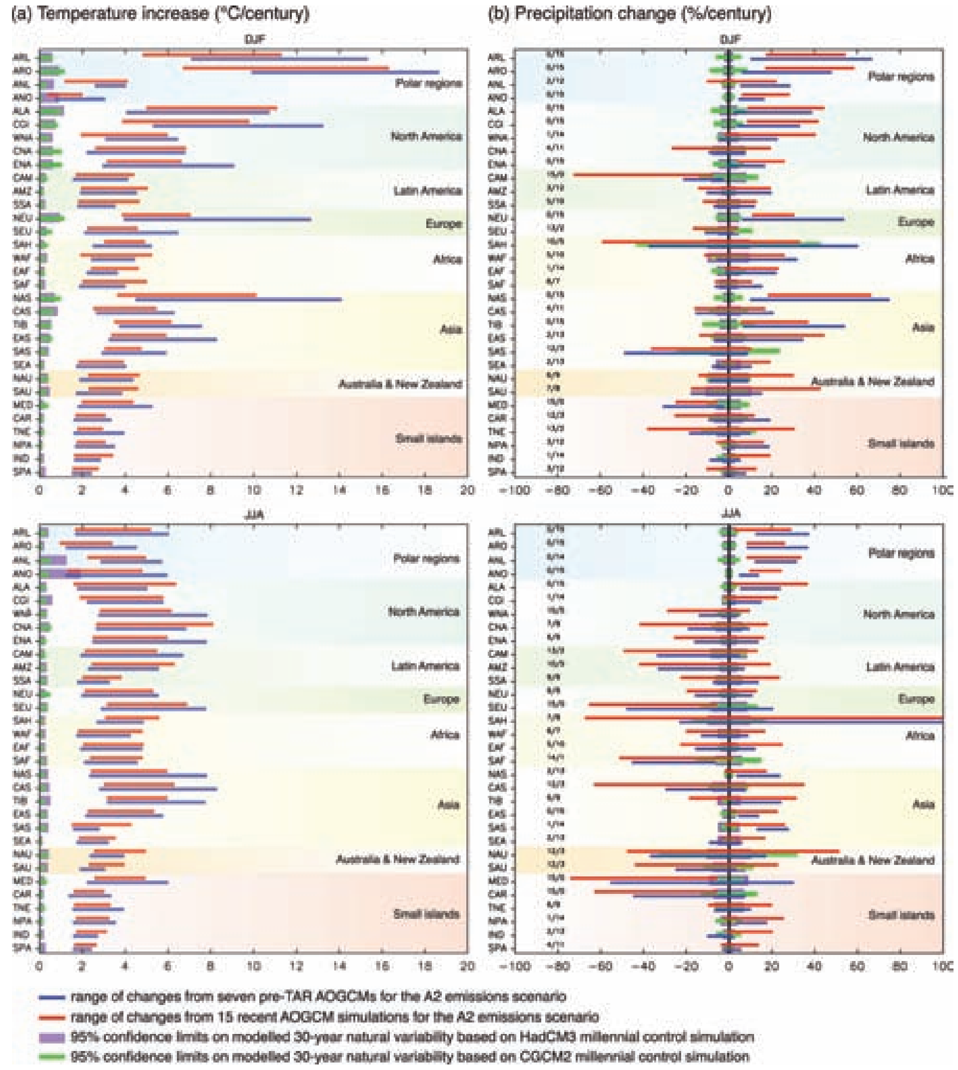
Changes in average annual run-off

Run-off changes will depend on changes in temperature and precipitation, among other variables. Most of the hydrological modelling studies have found that although there is global average increase in precipitation, there are substantial areas where there are large decreases in run-off due to higher temperatures, which lead to higher evapotranspiration losses. Thus, the global message of increased precipitation clearly does not readily translate into regional increases in surface and groundwater availability.

Impacts of sea level rise on coastal zones

Some of the key impacts of sea level rise in coastal areas, include (1) lowland inundation and wetland displacement, (2) altered tidal range in rivers and bays, (3) changes in sedimentation patterns, (4) more severe storm surge flooding, (5) increased saltwater intrusion into estuaries and freshwater aquifers and (6) increased wind and rainfall damage in regions prone to tropical cyclones.

Figure 2.11: Regional temperature and precipitation changes to the end of the 21st century (various models)



Source: Parry et al., 2007

Water quality changes

Although the IPCC did not find evidence for a climate-related trend in water quality (Kundzewicz et al., 2007), a number of impacts can be expected to occur. Thus, more intense rainfall generally results in increased run-off and subsequently in an increase in the concentration of suspended solids (and turbidity) in rivers and lakes. If this run-off is accompanied by the transport of pollutants (e.g. fertilizers, pesticides, stormwater overflows), water quality will deteriorate. On the other hand, high river discharges will reduce the concentrations of dissolved chemicals. Water quality will consequently improve, although the total pollutant load will not change. During drought periods, water quality can deteriorate, because of the opposite effect: less dilution of pollution. Changes in river flows will also affect the level of salt intrusion in estuaries: during low flows, salt concentrations in rivers will increase further inland, exacerbated by sea level rise. This will have repercussions for the production and supply of water for drinking, irrigation, industrial processes etc.

Higher water temperatures, up to 2°C since 1960, have been observed in lakes and rivers (see Rosenzweig et al., 2007 for an overview). This has resulted in earlier summer stratification and shallower thermoclines, depletion of nutrients in surface waters and increased nutrient concentrations in deeper water layers (cf. 4.2.2: Lake Tanganyika). In addition, harmful algal blooms seem to be linked to increasing water temperatures and increased respiration, and the resulting lowered oxygen concentrations in warmer waters will accelerate oxygen depletion, resulting in anaerobic conditions with their resulting impacts on aquatic production and fisheries.

There is no evidence yet of a climate change impact on water levels in shallow lakes (Rosenzweig et al., 2007). However, if lowering occurs during prolonged dry periods, re-suspension of bottom materials will be enhanced. This will decrease water transparency and could result in the release of nutrients (e.g. phosphate), enhancing eutrophication and/or the release of toxic compounds present in bottom sediments.

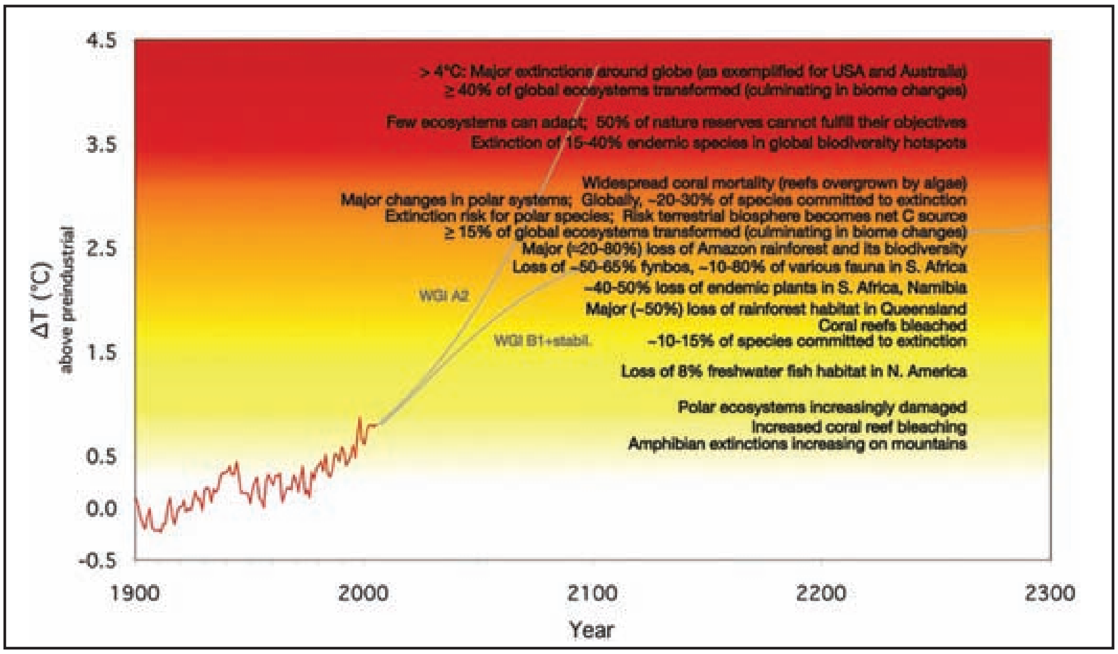
Groundwater changes

In many communities, groundwater is the main source of water for irrigation, domestic and industrial demands. Generally, there are two types of groundwater resources – renewable and non-renewable. Renewable groundwater is directly tied to near-surface hydrologic processes; it is thus intricately tied to the overall hydrologic cycle and could be directly affected by climatic change. In many places, because of increasing demands, the overdraft of renewable groundwater aquifers occurs because the rate of withdrawal exceeds the rate of recharge. Thus, climate changes could directly affect these recharge rates and the sustainability of renewable groundwater.

Climate change impacts on ecosystems

Projected risks due to critical climate change impacts on ecosystems for different levels of global mean annual temperature change (ΔT) are shown in Figure 2.12; these are relative to the pre-industrial climate and are used as a proxy for climate change. The red curve shows observed temperature anomalies for the period 1900–2005. The two grey curves provide examples of the possible future evolution of the global average temperature change, with time exemplified by Working Group I-simulated, multi-model mean responses to (i) the A2 radiative forcing scenario and (ii) an extended B1 scenario, where radiative forcing beyond 2100 was kept constant at the 2100 value. White shading indicates neutral, small negative or positive impacts or risks; yellow indicates negative impacts for some systems or low risks; and red indicates negative impacts or risks that are more widespread and/or greater in magnitude. Illustrated impacts take into account climate change impacts only and omit effects of land-use change or habitat fragmentation, over-harvesting or pollution (e.g. nitrogen deposition).

Figure 2.12 Projected risks due to critical climate change impacts on ecosystems

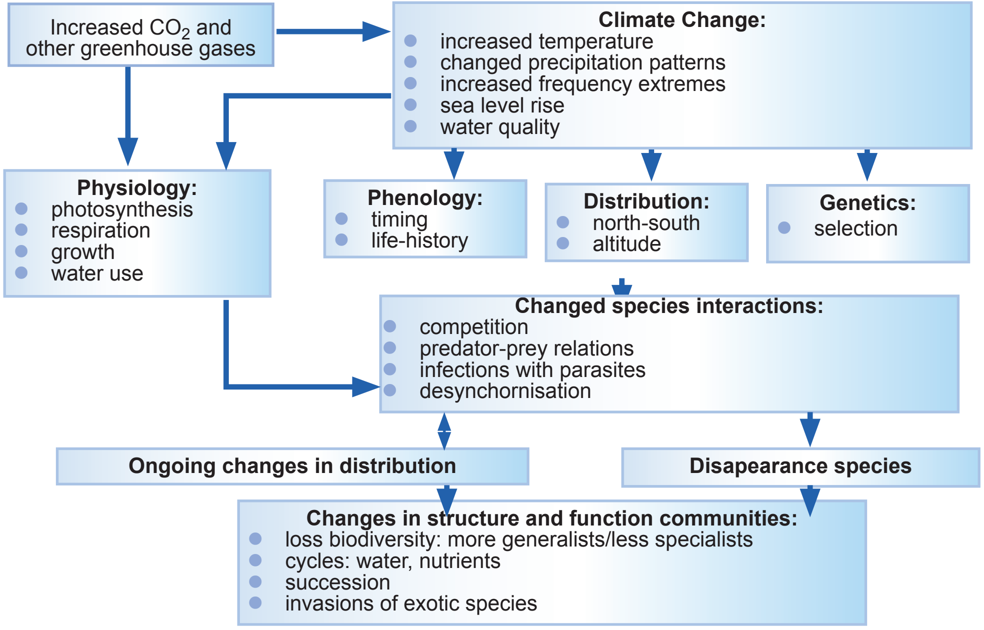


Source: Fischlin et al., 2007

2.2.3 Impacts on ecological processes

To understand the impacts of climate change on ecological processes, and therefore on ecosystems, biodiversity, food security, spread of diseases, etc., it must be realised that the increased concentrations of greenhouse gases in the atmosphere have both direct and indirect effects. Thus, increased atmospheric CO_2 levels will affect physiological processes like photosynthesis, respiration, growth and water use in plants. However, via increased temperatures, changed precipitation patterns, sea level rise, changes in water quality etc., various ecological relevant functions and processes are affected as well. Figure 2.13 summarizes some major climate change impacts on ecological processes and the consequences for the structure and functioning of ecosystems. Changes in phenology and distribution patterns are elaborated below.

Figure 2.13: Impacts of greenhouse gases and climate change on ecological processes



Source: Adapted from Hughes, 2000

Phenology

Phenology is concerned with the dates of first occurrence of natural events in their annual cycle (e.g. the date of emergence of leaves and flowers, the first flight of butterflies and the first appearance of migratory birds). Such events are often triggered by climatic events (e.g. temperature) and therefore can be used as proxies for climate change. However, many species depend on each other (e.g. in complex food webs, for pollination, in mutualistic relationships, etc.), and therefore life cycles of many species are synchronized. Thus, if climate change will affect life cycles of different species differently, and if dependent species will not be able to adapt to the new situation, functional relations within ecosystems might be seriously hampered. For example, in temperate aquatic ecosystems (freshwater, marine) the spring bloom of phytoplankton is followed somewhat later by the development of zooplankton that feed on the algae. Various authors (in Rosenzweig et al., 2007) have observed an advancement of the spring algal bloom (up to four weeks). Moreover, although zooplankton phenology is also affected, in many cases, the zooplankton has not responded in the same way as the phytoplankton. In the North Sea, indeed, shifts of over six weeks in seasonal cycles of plankton communities, including fish larvae, have been observed. Responses, however, varied between different functional groups (Edwards and Richardson, 2004). Thus, populations of predators are at risk when their appearance does not correspond with availability of their main food. This is not only true for food web relations, but also for flowers that depend on insects for pollination, for example.

Distribution patterns

Different species are adapted to specific environmental conditions. If the environmental conditions change, species can react in different ways: they can adapt to the new environment, they can migrate to a more suitable environment (and become locally extinct) or they become completely extinct. When dealing with climate change, temperature and atmospheric CO_2 concentrations are the major direct factors that will change. These changes might be accompanied by changes in precipitation, storm frequencies, sea level rise, water quality etc., including their variability on time and spatial scales. An additional problem is that there are so many non-climate drivers that result from human activities. Thus, human population growth resulting in land use changes, land degradation, deforestation, urbanization, pollution etc. will affect survival of species in a complex way, with many interactions and feedback mechanisms.

How important is the impact of climate change on ecosystems compared to other stressors (e.g population growth, pollution or fragmentation)?

Box 2.2: Examples of range shifts (polewards and to higher elevations) and changes in population densities in relation to changes in climatic conditions

- Extension of southern species to the north;
- Changes in intertidal communities in the Pacific and around the British Isles;
- Kelp fish communities and offshore zooplankton communities off the southern California coast;
- Decline in krill in the Southern Ocean;
- Occurrence of subtropical plankton species in temperate waters;
- Changes in geographical distributions of fish species;
- Northward shifts in the distribution of aquatic insects and fish in the UK;
- Replacement of cold-water invertebrate and fish species in the Rhône River by thermophilic species;
- Bird species that no longer migrate out of Europe during the winter;
- Poleward expansion of distribution ranges (Table 1.9 in Rosenzweig et al., 2007);
- Extension of alpine plants to higher altitudes; and
- Spread of disease vectors (e.g. malaria, Lyme disease, bluetongue) and damaging insects.

Source: Rosenzweig et al., 2007

The global distribution of biomes (e.g. tropical rain forest, temperate forest, savanna, tundra, desert) mainly depends on a combination of water availability (or annual precipitation) and average temperature. Therefore, major shifts in the present distribution of global vegetation components are expected to occur under a changing climate. Of course, such shifts have occurred in the past on geological time scales. It is predicted that a rise in mean annual temperature of 3°C corresponds to a shift in isotherms of 300–400 km in latitude (in the temperate zone) or 500 m in elevation (Hughes, 2000), the effect of which could result in the disappearance of unique vegetation types.

What consequences will changes in ecological processes have for food production or health?

Summary

It is crucial to understand the physical science basis of the climate change and the associated drivers before looking into their possible consequences. Water, as a life-giving resource and also as the one that will be impacted the most by climate change, needs special attention. Water managers need to understand how climate change is going to impact water resources and ecosystems and how this may affect water use. However, they should also be aware of the uncertainties before they can make justified decisions.

Suggested reading

CPWC (2009) Business. Perspective Paper on Water and Climate Change Adaptation. The Co-operative Programme on Water and Climate (CPWC): Den

Haag, The Netherlands. http://www.waterandclimate.org/index.php?id=5thWorldWaterForumpublications810
CPWC (2009) The Changing Himalayas. Perspective Paper on Water and Climate Change Adaptation.
IPCC (2008) Technical Paper VI: Climate Change and Water. Intergovernmental Panel on Climate Change (IPCC).

3. STRATEGY DEVELOPMENT AND PLANNING FOR ADAPTATION

Goal

The aim of this module is to familiarize participants with the basic principles and steps of adaptation planning, as well as to provide a basic introduction to adaptation economics and the challenges and opportunities of adapting to climate change in the water sector.

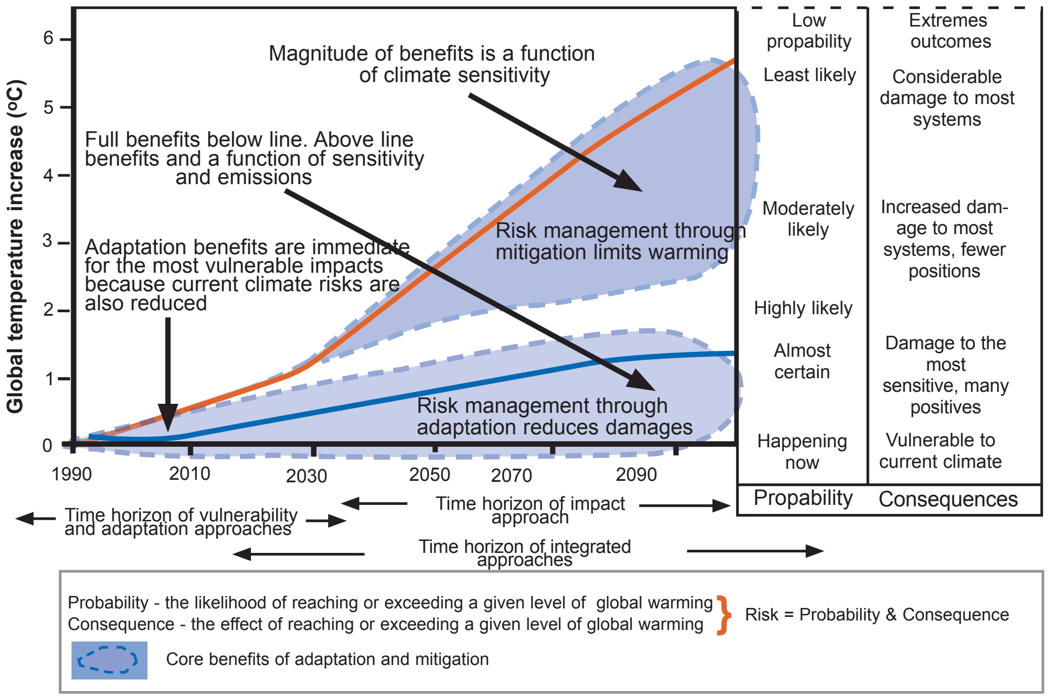
3.1 Introduction

IWRM is the key process that should be used in the water sector for water-related developments and measures, and hence for achieving the water-related MDGs. However, the potential impacts of climate change and associated increasing climate variability need to be sufficiently incorporated into IWRM plans. 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.

Adaptation is a process by which individuals, communities and countries seek to cope with the consequences of climate change, including climate variability. It should lead to harmonization with countries' more pressing development priorities such as poverty alleviation, food security and disaster management. 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 subchapters outline the elements of guidance available from a range of key international institutions engaged in the adaptation debate. The need to address climate change and increasing climate variability is a comparably new issue in the global water debate. Although the increase in extreme events was identified as a new challenge for water managers in Agenda 21 of the 1992 UN Conference on Environment and Development (the Earth Summit) in Rio de Janeiro (UN, 1992), this was not explicitly linked to climate change or increasing climate variability; it recommended a comprehensive set of measures for the water sector. The Implementation Plan of the 2002 World Summit on Sustainable Development (WSSD, 2002) reiterates that these recommendations are still valid today.

Figure 3.1: Risk management through 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 greenhouse gas emissions, the climate is still expected to warm for several decades, with all the projected implications for the water cycle. So, 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 3.1 illustrates this complementary approach for various degrees of warming and the net benefits expected from it.



Adapted from Source: IPCC 2007a: Figure 2.1

3.2 Guidance available under United Nations Framework Convention on Climate Change (UNFCCC)

The UNFCCC addresses adaptation through Article 4 by calling on Parties to "formulate, implement, publish and regularly update national and, where appropriate, regional programmes containing 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 the UNFCCC with inputs from various UN organizations and other international mechanisms. The ones highlighted here are the National Adaptation Programmes of Action and the Nairobi Work Programme. These processes play an essential role in promoting the climate change adaptation agenda and therefore should play a role in inspiring adaptation actions in the water sector. These processes should also be considered when setting up national IWRM plans.

National Adaptation Programmes of Action (NAPAs) provide a process for Least Developed Countries (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 itself would help address the adverse effects of climate change. The NAPA takes into account existing coping strategies at the grassroots level, and builds upon that 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 the NAPAs include:

- Synthesis of available information;
- Participatory assessment of vulnerability to current climate variability and extreme events and of areas where risks would increase due to climate change;
- Identification of key adaptation measures as well as criteria for prioritizing activities; and
- Selection of a prioritized shortlist of activities (see Chapter 5 for uncertainties and vulnerability indices).

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.

The **Nairobi Work Programme** is a 5-year programme (2005–2010) implemented by Parties to the UNFCCC, intergovernmental and non-governmental organizations (NGOs), the private sector and communities. Its objective is to assist all Parties to the UNFCCC, in particular developing countries, to:

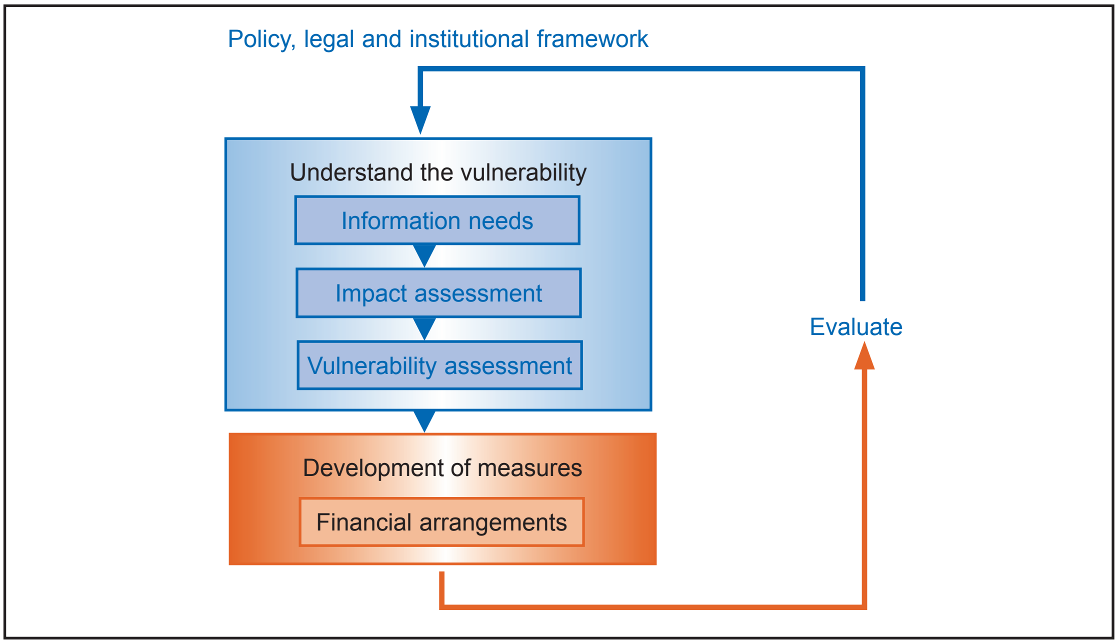
- Improve their understanding and assessment of impacts, vulnerability and adaptation to climate change; and
- Make informed decisions on practical adaptation actions and measures to respond to climate change on a sound scientific, technical and socio-economic basis, taking into account current and future climate change and variability.

The Programme is structured around nine areas of work, each vital to increasing the ability of countries to adapt. A recent UNFCCC workshop report on adaptation planning and practices (UNFCCC, 2007b) provides specific adaptation planning guidance for the water resources sector.

3.3 Main elements based on guidance available under UNECE

The United Nations Economic Commission for Europe (UNECE), under its Convention on the Protection and Use of Transboundary Watercourses and International Lakes, has embarked on a process to develop a guidance document on Water and Climate Adaptation (UNECE, 2009). Although it is presently available only in draft form, it provides a good synthesis of the current policy debate on the issue and the requirements and broad steps involved in adaptation planning for the water sector. The steps involved in developing an adaptation strategy are outlined in Figure 3.2.

Figure 3.2: Development of an adaptation strategy



Source: UNECE, 2009

The guidance document (UNECE, 2009) proceeds to outline some major principles for adaptation planning, namely:

1. Climate change is a process characterized by a number of **uncertainties and risks** relative in particular to the magnitude, timing and nature of the changes. However, decision makers are not used to such uncertainty when dealing with other problems. To take into account this situation, various methods should be used. These include sensitivity analysis, risk analysis, simulation and scenario development.

2. As climate change raises threats of harm to human health and the environment, the **precautionary principle** should be applied and preventive actions should be taken even if some cause-and-effect relationships are not yet fully scientifically proven. According to the precautionary principle, uncertainty about the damage to be incurred should not serve as an argument to delay action. In the face of great uncertainty, a precautionary approach might even result in a more stringent emission-reductions target and/or adaptation response.

3. The following **overarching principles** should apply to any adaptation policy framework:
    - Adaptation to short-term climate variability and extreme events is a basis for reducing vulnerability to longer-term climate change;
    - Adaptation policy and measures are assessed in a socio-economic development context;
    - Following the principles of sustainable development adaptation policy and measures take social, economic and environmental concerns into consideration and ensure that the needs of the present generation are met without compromising the needs of future generations; and
    - Adaptation policies/strategies are elaborated at different levels in society, including the local level.

4. Strong **interdepartmental (interministerial)** and **intersectoral cooperation** with the involvement of all relevant stakeholders should be a precondition for decision-making, planning and implementation.

5. IWRM should be applied to ensure the multi-layered integration of management in which existing approaches are distinct from one another and take into account the environmental, economic, political and sociocultural conditions of the respective region.

6. **No-regret** and **low-regret** options should be considered as a priority. No-regret options are measures or activities that will prove worthwhile even if no (further) climate change occurs. For example, monitoring and early-warning systems for floods and other extreme weather events will be beneficial even if the frequency of the events does not increase as expected. Low-regret options are low-cost options that can potentially bring large benefits under climate change and will have only low costs if climate change does not happen. One example is accounting for climate change at the design stage for new drainage systems by making pipes wider.

7. The selection of scenarios and related methodologies and measures to deal with adaptation to climate change should take into consideration possible **side effects** of their implementation.

8. Measures to cope with the effects of climate change have to be taken into account at **different scales**, both in space and in time. Regarding the spatial component, measures should account for local issues as well as regional and basin-wide issues. Regarding the time component, distinctions should be made between the strategic, tactical and operational levels.

9. **Estimating costs** of a measure is a prerequisite for ranking a measure and including it in the budget or in a wider adaptation programme. The four major methods used for prioritizing and selecting adaptation options are cost-benefit analysis, multi criteria analysis, cost-effectiveness analysis and expert judgement. The costs of non-action that could lead to a number of environmental and socio-economic effects (e.g. lost jobs, population displacement and pollution) should also be considered.

While the above generic principles are necessary to guide adaptation policy, they do not say much about translating policy into action. As countries begin to report on their achievements in the UNFCCC context, they provide case scenarios on adaptation planning and practice, and it will be necessary to synthesize information gained from them. For the purpose of this manual, an example case is provided in the exercises for this chapter that shows one option how to move from **principles to practice** in form of an adaptation planning project in an arid developing country context.

- **What is the role and potential of sectoral adaptation planning?**
- **Do you know examples of cross sectoral adaptation planning?**
- **What do you think is the most adequate spatial level for adaptation planning?**

3.4 Main elements based on guidance available under UNDP

UNDP as a major international development partner has developed the Adaptation Policy Framework (APF). The steps of the APF are depicted in Figure 3.3, below. Each step has a separate technical paper that specifies the requirements in detail. The APF process can be used for formulating and designing adaptation-related projects or for exploring the potential to add adaptation considerations to other types of projects. Projects can focus on any population scale, from village to national level. The following steps are part of the APF:

Component 1: Scoping and designing an adaptation project involves ensuring that a project – whatever its scale or scope – is well integrated into the national policy planning and development process. This is the most vital stage of the APF process. The purpose is to put in place an effective project plan so that adaptation strategies, policies and measures can be implemented.

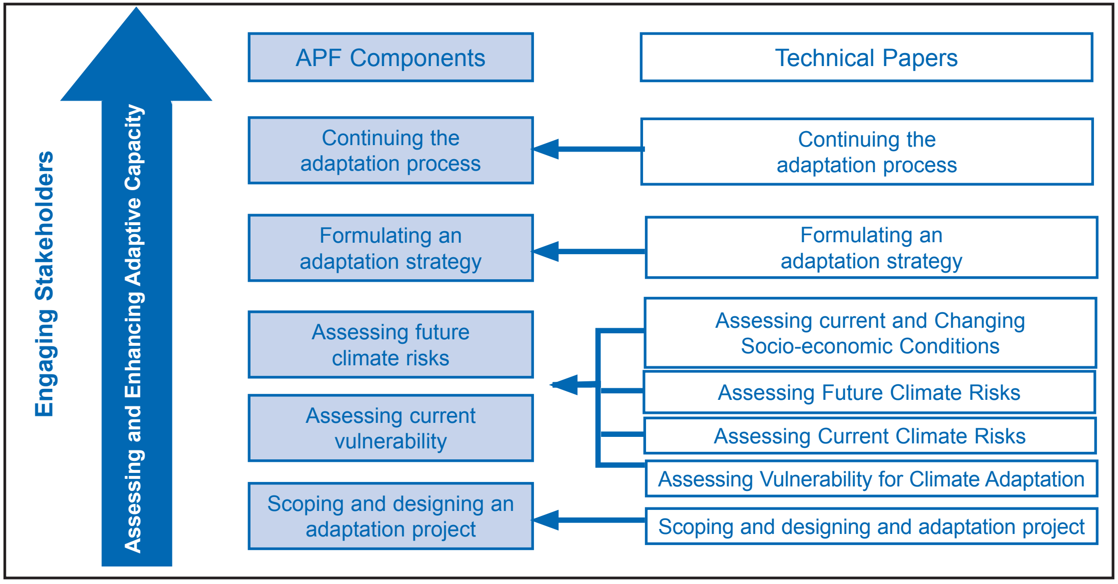
Component 2: Assessing current vulnerability involves responding to several questions, such as: Where does a society stand today with respect to vulnerability to climate risks? What factors determine a society's current vulnerability? How successful are the efforts to adapt to current climate risks?

Component 3: Assessing future climate risks focuses on the development of scenarios of future climate, vulnerability and socio-economic and environmental trends as a basis for considering future climate risks.

Component 4: Formulating an adaptation strategy in response to current vulnerability and future climate risks involves the identification and selection of a set of adaptation policy options and measures, and the formulation of these options into a cohesive, integrated strategy.

Component 5: Continuing the adaptation process involves implementing, monitoring, evaluating, improving and sustaining the initiatives launched by the adaptation project.

Figure 3.3: Components of the Adaptation Policy Framework (APF)



Source: UNDP, 2004

The APF distinguishes four basic ways of focusing an adaptation project, namely hazards-based, vulnerability-based, adaptive-capacity and policy-based approaches. Table 3.1 below provides definitions and examples of the four approaches for different institutional scales of application.

Table 3.1: Identifying adaptation project focus according to scale of implementation

	Hazards-based approach	**Vulnerability-based approach**	**Adaptive-capacity approach**	**Policy-based approach**
	Increasing resilience to severe flooding and future climate risks	**Improving access to new markets and supporting livelihood diversification under future climate**	**Improving awareness in and the resilience of the business community to climate change, including variability**	**Reducing vulnerability to storm surges and sea level rise induced by climate change**
National	How can national meteorological services be changed to better monitor the evolution of future hazards?	How will recent changes in world markets affect acquaculture in Bangladesh (already at risk of inundation from sea level rise) under future climate?	Which business sectors will be most affected by climate change and why? What awareness raising is needed, and for whom? What fora should be involved?	What incentives or disincentives should be used to discourage the development of coastal zones vulnerable to sea level rise and storm surges induced by climate change?
Regional	How can flood early warning systems be made more effective under future climate for hard-to-reach communities?	How can access to new markets required by livelihood diversification activities be facilitated to moderate future climate?	How can regional businesses most effectively support livelihoods identified as being vulnerable to climate change, including variability?	Realignment or retreat? How to decide which areas are protected and which will become submerged under future climate?
Local	What techniques are most appropriate for effective local-level disaster preparedness planning under future climate?	How can credit schemes best support livelihood diversification in rural areas to reduce climate risks?	Which participatory visioning processes are most appropriate to identify threats and potential opportunities resulting from scenarios of climate change for members of local trade associations and businesses?	What stakeholder-led projects are most appropriate for investigating ways to mitigate flood damages in an urban area under future climate?

Source: UNDP, 2004

3.5 Dialogue on climate change adaptation for land and water management

In April 2009, a set of key stakeholders who were engaged in the Dialogue on Adaptation for Land and Water Management agreed on five Guiding Principles for Adaptation to Climate Change after a regional consultation process. Those principles, reproduced subsequently, "promote sustainable development while responding to the impacts of climate change” (Dialogue on Adaptation for Land and Water Management, 2009). The principles include the following:

Guiding Principle No. 1 (Sustainable Development):
Adaptation must be addressed in a broader development context, recognizing climate change as an added challenge to reducing poverty, hunger, disease and environmental degradation.

Guiding Principle No. 2 (Resilience):
Building resilience to ongoing and future climate change calls for adaptation to ‘start now’ by addressing existing problems in land and water management.

Guiding Principle No. 3 (Governance):
Strengthening institutions for land and water management is crucial for effective adaptation and should build on the principles of participation of civil society, gender equality, subsidiarity and decentralization.

Guiding Principle No. 4 (Information):
Information and knowledge for local adaptation must be improved and must be considered a public good to be shared at all levels.

Guiding Principle No. 5 (Economics and Financing):
The cost of inaction, and the economic and social benefits of adaptation actions, call for increased and innovative investment and financing.

For more detailed information please consult the full statement (Dialogue on Adaptation for Land and Water Management, 2009).

3.6 Economics of adaptation

A lot of debate has circled around the economic aspects of addressing the climate change issue, both on the cost and benefits of mitigating climate change and adapting to it. The most widely cited report is the Stern Review, published in 2006 by the British Government (Stern, 2006). It implies the need to incorporate adaptive actions and appropriate policies in countries’ development strategies, integrated into development plans and the adaptation funding and spending at regional, national and local level, and not by setting up parallel processes, as stated in the Review:

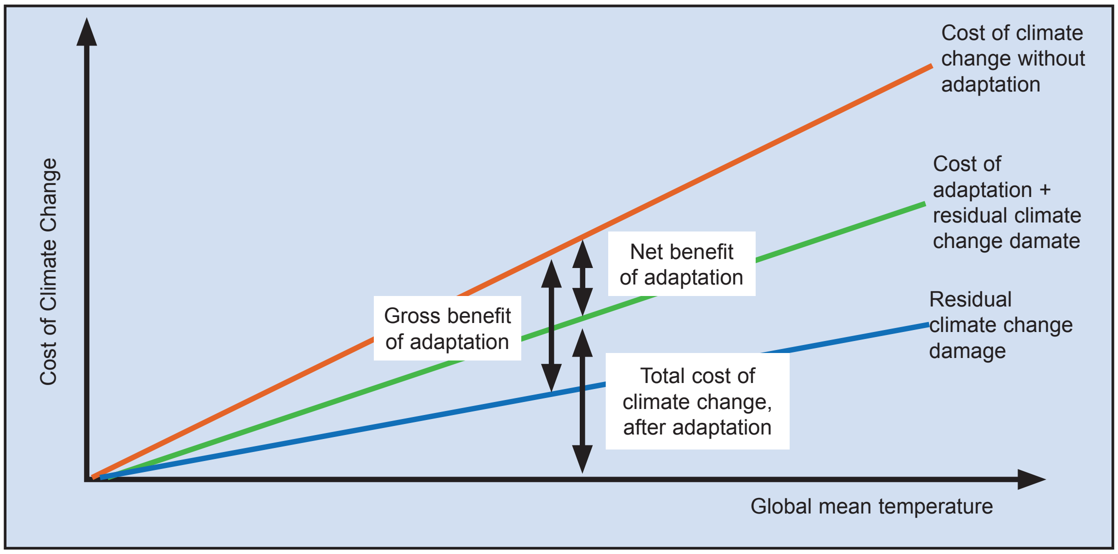
> “Taken together, all this implies that rather than treating adaptation as separate from development, it should be seen as an additional cost and complexity to delivering standard development goals. Specifically, adaptation has the same target outcomes as development, including sustaining or improving social protection, health, security, economic sufficiency – and so spending (whether labelled adaptation or development) ought to be prioritized according to the expected impacts on these outcomes. The most effective way of achieving this is to integrate climate risk, and the additional resources required to tackle it, into

What would be implications of separating climate change adaptation from the general development programmes and targets? Would that be possible in your country?

planning and budgeting for and delivering these development goals." (Stern, 2006)

The Stern Review addresses the economic aspects of adaptation that are discussed in Chapter 5 of the report. While avoiding damage from climate change is considered a benefit of adaptation, the review is clear that there can often be a substantial residual damage (or risk). Figure 3.4 provides a substantially simplified model for the economics of adaptation. The relationship between cost of climate change and increases in global mean temperature are shown here as linear, while in reality trends in cost for increasing temperature may be exponential.

Figure 3.4: Cost and benefits of adaptation in relation to global mean temperature



Source: Stern, 2006

The concept of **'net benefits' of adaptation** is crucial to the model – i.e. the damage avoided minus the cost of adaptation. The concept of net benefits as an indicator in policy design is already common practice in a number of climate-related development policies, such as integrated flood management: the net benefits of a flood management strategy are the overall benefits incurred by using the floodplain minus the cost of flood protection and the residual flood damages (WMO, 2004). This implies that in planning decisions there is a need to combine risk management (as a construct of probability and associated consequence) with a perspective on acceptable risk in view of benefits incurred. This perspective helps to avoid maladaptation in the sense of unnecessarily limiting development opportunities crucial for poverty reduction/livelihood generation.

What would the diagram in Figure 3.4 look like for an example of a flood defence project?

3.7 Challenges and opportunities of adaptation

Challenges

- **Insufficient monitoring and observation systems and data sharing**
  Understanding the current status of water resources forms the baseline for

detecting and establishing the significance of trends, e.g. in rainfall and run-off patterns or in soil moisture distribution. Insufficient monitoring and observation systems for ground and surface water resources – i.e. quantity and quality, prevailing rainfall patterns and the status of the cryosphere – is an inhibiting factor for many countries in terms of water resources management and development, and consequently for adaptation planning. Insufficient data on changes in land use in river basins make assessing hydrological changes due to climate variation very difficult.

Even if these data are available, they may be treated as 'strategic resources' and may not be shared widely enough, or the institutional arrangements may not be robust enough to generate conclusive statements about the state of the resource. Therefore, water resources assessment – including the needs for operational monitoring programmes – should be seen as an indispensable (early) part of adaptation planning.

- **Lack of basic information**

  This represents perhaps the major current obstacle to adaptation planning as various countries can begin to afford investing in the collection of basic information. In the area of climate information, because of the aforementioned deficiency in monitoring capacity, historical in situ climatological records are sparse and remotely sensed information can complement – but not replace – such records. Regarding climate prediction on seasonal to inter-annual timescales, only a few highly specialized centres are currently in the positions to provide such products at the required quality but not yet at the spatial and temporal scales in which water managers operate.

- **Settlements in vulnerable areas**

  Even outside of a climate change scenario, the issues posed by population growth (especially in developing countries) and the resulting pressure on limited land and water resources are enormous. Climate change is expected to exacerbate these problems by affecting the frequency and/or intensity of water-related hazards, such as floods, flash floods, mudflows and landslides. Poverty and urbanization are the major factors that continue to drive people into previously unoccupied vulnerable zones, as the land there is cheaper or it is the only land left to settle. Adaptation planning, therefore, must incorporate a development perspective.

- **Appropriate political, technological and institutional framework**

  Adaptation must not be understood as a process independent of a country's development but as an integral part of it. While the weakness of institutional structures and institutional capacity remains a key challenge of the water sector in the developing world, there is an additional challenge posed by adaptation processes: the risk of sidelining established institutional structures. Consideration is needed in adaptation planning to strengthen and clearly define the role of competent authorities, NGOs and the private sector in their pursuit of adaptation objectives. There is renewed need for a multidisciplinary process that allows for a shift towards economically efficient, socially equitable and environmentally sustainable adaptation (and mitigation) options. The political discourse over recent years in devising climate change mitigation options has clearly demonstrated that need (e.g. use of biofuels).

- **Social equity in decision-making**

  The lack of stakeholder representation in decision-making is a major obstacle to more equitable solutions in water management in general, and the climate change nexus does not make issues less complex in that field. Vulnerabilities to the impacts of climate change have a vast potential for increasing inequities in societies, as the natural resource basis may be further depleted and livelihoods – particularly in agriculture – are threatened by lack of investment and capacity building in the sector. While climate change is considered to be only one factor in determining migration decisions, the implications on intergenerational and gender equity can be vast. This is especially valid if rural communities are disrupted (e.g. where the male workforce is leaving to find work, leaving behind communities of elderly, women and children). Therefore, developing a gender-sensitive perspective on the vulnerabilities of various groups and the different roles they can take in adaptation planning is required. An additional complicating element in equity in decision-making is that future generations are not represented in the process and that government has to take up that role.

Opportunities

- **Planning new investments for capacity expansion**

  Being able to predict impacts of climate change on water resources may help accelerate planning and investment decisions in new water resources development schemes. These schemes are urgently needed in areas that lack essential water infrastructure, as this lack has been an impediment to the development process in the past. In many areas, increasing storage and demand-side management options have been a challenging political and financial issue that should be revisited, especially in view of unfolding variability conditions in rainfall patterns. Such schemes may also be an element of economic stimulus packages that have large portfolios for infrastructure investment in support of the construction sector. Proposals that have completed the legally mandated planning cycle but that may have lacked funding or mainstream political support should now be the focus of attention to such investment to avoid misinvestment and maladaptation.

- **Maintenance and major rehabilitation of existing systems**

  Similarly, neglected aspects of water infrastructure maintenance (dam safety, drainage systems and channel maintenance, levee rehabilitation, etc.) should undergo revitalization through the reassessment of design procedures (such as the ‘probable maximum precipitation’ and ‘probable maximum flood’), safety levels and safety and monitoring programmes. This is an opportunity to strengthen infrastructure and public safety beyond the questions of climate change.

- **Operation and regulation of existing systems for optimal use and accommodating new purposes**

  The added complexity of climate variability and change offers a number of opportunities to reassess and optimize the operation and regulation of water infrastructure. This could include the requirements for minimum environmental flows and other ecological requirements related to water quality, seasonality of flow, vulnerability of upstream and downstream communities to rapidly changing flow rates, as well as the transboundary arrangements for water sharing, etc.

- **Modifications in processes and demands (water conservation, pricing, regulation)**

  Increasing climate variability may also be an opportunity to establish smarter and more robust regulations on water conservation and pricing (although not by increasing regulation, per se). This has been a difficult task, even under the assumption of a stationary climate.

- **Introduce new efficient technologies**

  Expected changes in water availability may boost the development and application of innovative and efficient technologies for water resources development (e.g. desalination and reuse) as well as water resources conservation (wastewater treatment systems, irrigation efficiency improvements ('more crop per drop'), etc. Such new schemes, however, require thorough testing to establish their respective merits and demerits to minimize the risk of conflicting objectives in the areas of climate change adaptation and mitigation.

- Which concrete challenges and opportunities do you find in your environment when it comes to climate change adaptation in the water sector?
- Do you feel it is justified to employ the climate change debate to facilitate improvements of current water resources management? What are the benefits and risks of taking such an approach? What role do principles of scientific integrity play under political pressure to deliver an adaptation strategy?

Summary

Adaptation to present climate variability and extreme events forms the basis for reducing vulnerability to future climate change. An adaptation strategy has to be developed within the development context of the country or region in which it is to be implemented to avoid maladaptation. Adaptation happens at various levels within the society: national, regional, local, community and individual. The adaptation process is as important as the adaptation strategy, especially in optimizing available resources across sectors and engaging the broadest possible group of stakeholders.

Suggested reading

Cap-Net (2005) Integrated Water Resources Management Plans: Training Manual and Operational Guide.

CPWC (2009) Arid and Semi-Arid Regions. Perspective Paper on Water and Climate Change Adaptation. The Co-operative Programme on Water and Climate (CPWC): Den Haag, The Netherlands. http://www.waterandclimate.org/index.php?id=5thWorldWaterForumpublications810

CPWC (2009) Deltas. Perspective Paper on Water and Climate Change Adaptation.

CPWC (2009) Energy. Perspective Paper on Water and Climate Change Adaptation.

CPWC (2009) Local Government. Perspective Paper on Water and Climate Change Adaptation.

CPWC (2009) Financial Issues. Perspective Paper on Water and Climate Change Adaptation.

Web link

UNFCCC Climate Change Adaptation home page:
http://unfccc.int/adaptation/items/4159.php

4. IMPACTS OF CLIMATE CHANGE ON WATER USE SECTORS

Goal

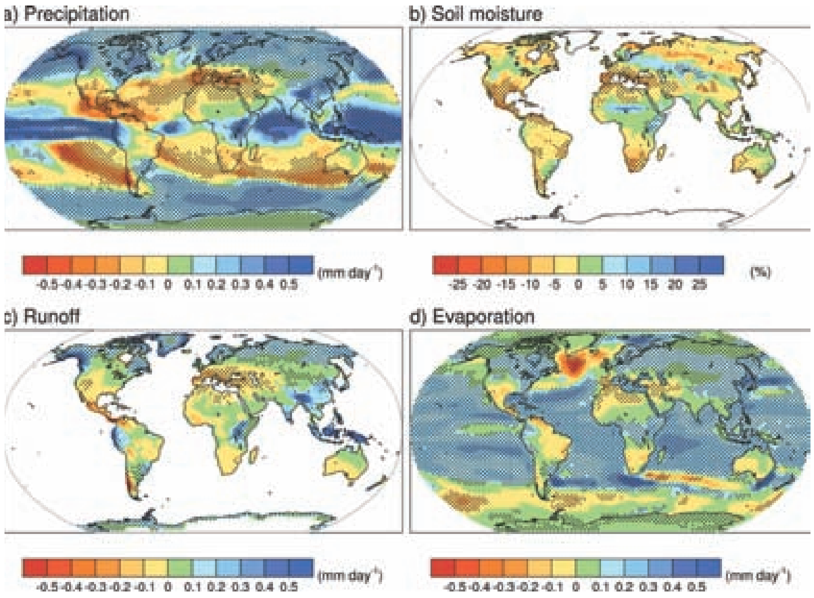
The aim of this chapter is to familiarize the participants with the expected impacts of climate change in different regions and on selected water use sectors, as well as with methods how to analyse and assess these impacts.

4.1 Projected climate changes by region

Although climate change is expected to increase global temperatures, its impact on water resources is more complex (see Chapter 2) and varies across the world. While some regions are expected to receive more precipitation, other regions will face increased water stress due to significant reduction in net precipitation. The recent IPCC report (Bates et al., 2008) provides an overview of projected impacts on the water resources of different regions of the globe.

Climate change projections are solely based on Global Circulation Models (GCMs). Figure 4.1 presents results from fifteen GCMs comparing changes of annual means of four hydro-meteorological variables (precipitation, soil moisture, run-off and evaporation) for the period 2080–2099, relative to 1980–1999 for the SRES A1B scenario (cf. Figure 2.8). Regions where the models agree on the sign of the mean change are stippled. The modelling results indicate projected increased water scarcities in several semi-arid and arid regions including the Mediterranean Basin, western USA, southern Africa and north-eastern Brazil. In contrast, precipitation is expected to increase in high latitudes (e.g. northern Europe) and some subtropical regions.

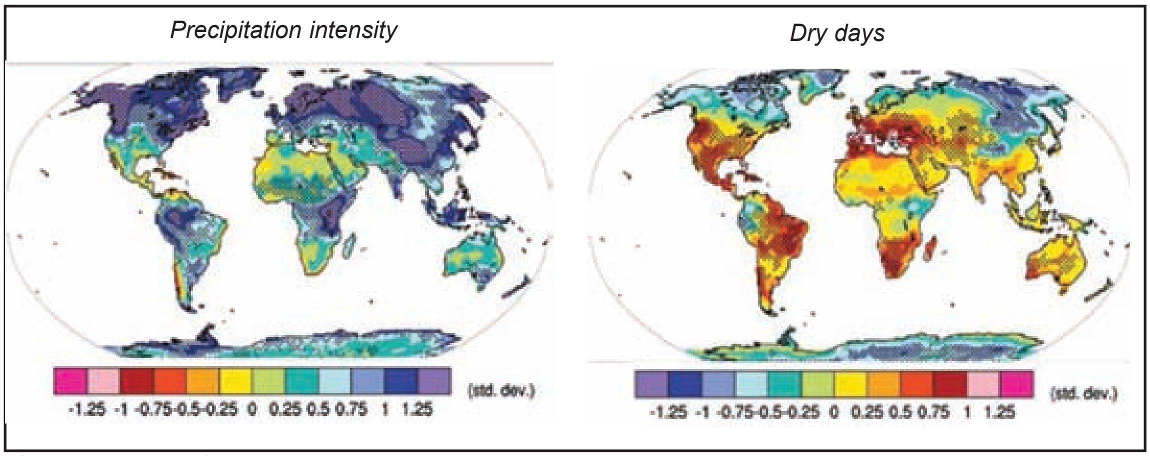
Figure 4.1: Fifteen model mean changes in (a) precipitation (%); (b) soil moisture (%); (c) run-off (%) and (d) evapotranspiration (%). Changes are annual means: scenario A1B, period 2080–2099 relative to 1980–1999



Source: Bates et al., 2008

Climate change is expected to increase the frequency and intensity of both floods and droughts in many parts of the world, as shown in modelling results of nine GCMs presented in Figure 4.2, with stippling indicating regions where at least five of the models agree that the changes are statistically significant. The results show that precipitation intensity will increase in high latitude and subtropical regions, while drought conditions will intensify in the Mediterranean basin, western USA, South Africa and north-eastern Brazil.

Figure 4.2: Global projections of precipitation intensity and dry days (annual maximum number of consecutive dry days)



Precipitation intensity

Dry days

Source: Adapted from Bates et al., 2008

The following is a brief summary of expected impacts of climate change in different regions (Bates et al., 2008):

Africa

Climate change is expected to exacerbate water scarcity conditions in northern and southern Africa. In contrast, eastern and western Africa are expected to receive more precipitation. Severe drought conditions in the Sahel have persisted for the past three decades. The Nile Delta is expected to be severely impacted by rising sea levels.

Asia

Climate change is expected to reduce precipitation in the headwaters of the Euphrates and Tigris. Winter precipitation is expected to decrease over the Indian subcontinent, leading to greater water stress, while monsoon rain events are expected to intensify. Maximum and minimum monthly flows of the Mekong River are expected to increase and decrease, respectively. The observed decline of glaciers is expected to continue reducing water supplies to large populations.

Australia and New Zealand

Run-off in the Darling Basin, which covers 70 percent agricultural water demand in Australia, is expected to decline significantly. Drought frequency is expected to increase in the eastern parts of Australia. River run-off in the South Island is expected to increase.

Europe

In general, mean annual precipitation is projected to increase in northern Europe and decrease further south. The Mediterranean and some parts of central and eastern Europe will be more prone to droughts. Flood risk is expected to increase in eastern and northern Europe and along the Atlantic coast.

Latin America

The number of wet days is expected to increase over parts of south-eastern South America and central Amazonia. In contrast, weaker daily precipitation extremes are expected to increase over the coast of northeast Brazil. Extreme dry seasons are projected to become more frequent in central America, for all seasons. Glaciers are expected to continue the observed declining trend.

North America

Climate change will constrain North America's already over-allocated water resources, especially in the semi-arid western USA. Water levels are projected to drop in the Great Lakes. Shrinkage of glaciers is expected to continue. Delay and shortening of snow cover will decrease snow pack strategic storage capacity.

What are the expected changes in climate for your region and how do you expect water resources will be affected?

4.2 Impacts on water use sectors

4.2.1 Agriculture

Positive impacts of climate change could increase growth rates because of increased CO_2 concentrations and length of growing season. However, as agriculture is the largest water consumer, it will strongly be affected by variability in rainfall, temperature and other weather conditions (Kabat and van Schaik, 2003) and consequently to climate change. As well, the impacts on rain-fed agriculture vis-à-vis irrigated systems are not well understood (FAO, 2007). More than 80 percent of global agricultural land is rain-fed and, when in arid and semi-arid conditions, production will be very vulnerable to climate change (Bates et al., 2008). In addition, although irrigated land represents only about 18 percent of global agricultural land, its yields are on average 2–3 times more than those in rain-fed areas. Thus, global food production depends both on precipitation and, increasingly, on the availability of water resources. Increased variability in the latter, in turn, will affect irrigated agriculture. At low latitudes, for example, early snowmelt can cause floods in spring leading to water shortages in summer (Bates et al., 2008). In addition, if reduced precipitation leads to an increase in the use of water for irrigation, the incidence of waterborne diseases might increase due to the use of insufficiently treated wastewater (Bates et al., 2008).

Obviously, too little water will directly and negatively affect agriculture production. On the other hand, extreme precipitation events could lead to excessive soil moisture, soil erosion, direct damage to plants and a delay in farm operations, all of which disrupt food production (Bates et al., 2008). FAO (2007) categorizes climate change impacts on food production into two groups: biophysical and socio-economic (Table

4.1). Altogether, overall food production might not be threatened, but regional and local differences will be considerable and those least able to cope (e.g. smallholder farmers in marginal areas) will be affected hardest.

How will agricultural production in your region be affected by the expected changes in climate? Is this positive or negative? Can you think of any adaptation measures in case of negative impacts?

Table 4.1: Biophysical and socio-economic impacts of climate change on food production

Biophysical	Socio-economic
● Physiological effects on crops, pasture, forests, livestock (quantity and quality) ● Changes in land, soil, water resources (quantity and quality) ● Increased weed and pest challenges ● Shifts in spatial and temporal distribution of impacts ● Sea level rise, changes to ocean salinity and acidity ● Sea temperature rise causing fish to inhabit different ranges	● Decline in yields and production ● Reduced marginal GDP from agriculture ● Fluctuations in world market prices ● Changes in geographical distribution of trade regimes ● Increased number of people at risk of hunger and food insecurity ● Migration and civil unrest

Source: Adapted from FAO, 2007

4.2.2 Fisheries

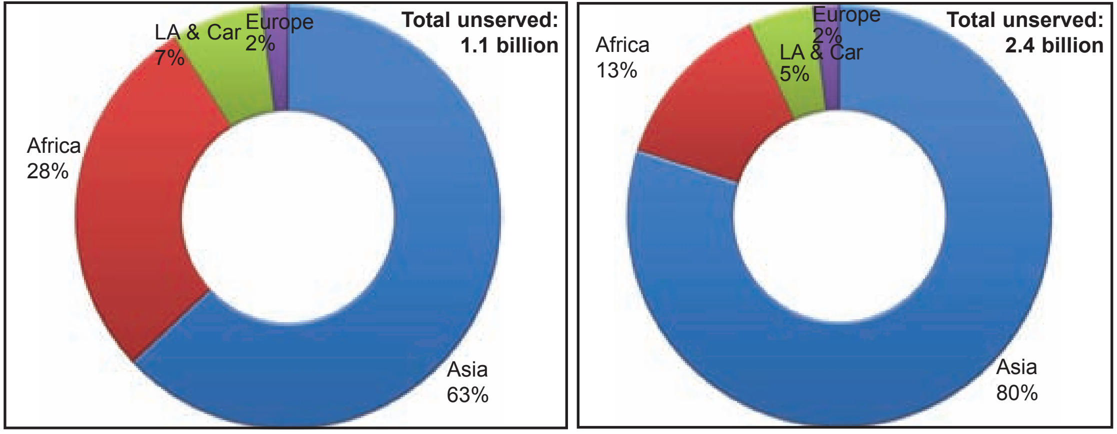
Some expected impacts of climate change on fisheries and aquaculture include stress due to increased temperature and oxygen demand, deteriorated water quality, reduced flows, etc. However, it is likely that human impacts (caused by population growth, flood mitigation, water abstractions, changes in land use, overfishing) will be greater than climate effects (see Bates et al., 2008). For example, O'Reilly et al. (2003) observed a decline in pelagic fisheries in Lake Tanganyika, which they attributed to a combination of the impacts of climate change and overfishing. Lake Tanganyika is a large (mean width, 50 km; mean length 650 km), deep (mean depth, 570 m; maximum depth, 1,470 m) north–south trending rift valley lake that is an important source of both nutrition and revenue to the bordering countries of Burundi, Tanzania, Zambia and the Democratic Republic of Congo. Deep-water temperatures increased between 1920 and 2000 and the depth of the thermocline has decreased since 1940. This has been attributed to the effects of climate change resulting in increased ambient temperatures and reduced wind velocity causing a reduction of the mixing depth. Consequently, primary productivity in the (narrower) photic zone has decreased, as has the input of deep-water nutrients into this productive zone.

Do you expect fisheries in your region will be affected by climate change? What about aquaculture?

4.2.3 Water supply and human health

One of the greatest threats to human health is the lack of clean water. Despite progress made in the water supply and sanitation sectors, 1.1 billion people still lack an adequate water supply and 2.4 billion are without adequate sanitation (WHO/UNICEF/WSSCC, 2000). The majority of these people live in Asia and Africa (Figure 4.3). If water supply is stressed because of climate change, water availability for drinking and hygiene will be even further reduced. Lowering the efficiency of sewerage systems could lead to higher concentrations of micro-organisms in raw water supplies. Concentrations of pollutants will increase because of lowered dilution. Increased salinity because of lower stream flows and drying up of groundwater resources could force people to use contaminated surface waters. Higher rainfall, on the other hand, will put more pressure on sewerage systems and will result in more overflows, thus increasing the risk of spreading diseases. The incidence of water-borne diseases is further increased, because higher temperatures stimulate the spread of many diseases. Moreover, increases in temperature could also introduce new diseases into areas previously unaffected. Overall, the incidence of diseases is expected to increase (Kabat and van Schaik, 2003, Ludwig and Moench, 2009).

Figure 4.3: Distribution of the global population without access to an adequate water supply (left) and adequate sanitation (right)



Source: WHO/UNICEF/WSSCC, 2000

Table 4.2 summarizes climatic changes that, via their impact on water resources, affect human health (Kabat and van Schaik, 2003).

What is the general condition in your region with respect to water supply and sanitation? Will this be affected by climate change?

Table 4.2. Mediating processes and direct and indirect potential effects on health of changes in temperature and weather

Mediating process	**Health outcome**
Direct effects	
Change in the frequency or intensity of extreme weather events (e.g. storms, hurricanes, cyclones)	Deaths, injuries, psychological disorders; damage to public health infrastructure
Indirect effects	
Changed local ecology of waterborne and food-borne infective agents	Changed incidence of diarrhoeal and other infectious diseases
Changed food productivity through changes in climate and associated pests and diseases	Malnutrition and hunger
Sea level rise with population displacement and damage to infrastructure	Increased risk of infectious diseases and psychological disorders
Social, economic and demographic dislocation through effects on economy, infrastructure and resource supply.	Wide range of public health consequences: mental health and nutritional impairment, infectious diseases, civil strife.

Source: Kabat and van Schaik, 2003

4.2.4 Energy

Although many other sectors and economic activities will be affected by climatic changes as well (e.g. urban infrastructure, tourism, transportation), the energy sector in particular is susceptible to climatic changes. Hydropower generation is sensitive to the amount, timing and geographical patterns of precipitation, as well as to the direct impacts of (water) temperatures (Kabat and van Schaik, 2003). Hydropower production decreases with decreased flows. Moreover, during low flow periods, more user conflicts could arise (e.g. allocations for agriculture, nature). If water temperature exceeds a certain level, it will not be suitable anymore to be used for cooling purposes. For example, the 1997/1998 La Niña drought resulted in a drop in hydropower generation of 48 percent in Kenya, resulting in very high economic costs for the country. In the Colorado River (USA) a 10 percent decrease in run-off is estimated to reduce power production by 36 percent (Kabat and van Schaik, 2003).

How will your energy sector be affected by climate change? Are there also positive impacts?

4.2.5 Water infrastructure

> *Consider the following quotes:*
>
> *"Water management is all about managing climate variability. Climate change and increased climate variability will only transform boundary conditions for water managers." (van Beek, 2009)*
>
> *"In view of the magnitude and ubiquity of the hydroclimatic change apparently now underway, however, we assert that stationarity is dead and should no longer serve as a central, default assumption in water-resource risk assessment and planning. … The world today faces the enormous, dual challenges of renewing its decaying water infrastructure and building new water infrastructure. Now is an opportune moment to update the analytic strategies used for planning such grand investments under an uncertain and changing climate." (Milly et al., 2008)*

Water managers have, as a core of their function, managed climate variability for centuries. Basic ingredients of established design practice are the use of statistical analysis tools to derive design discharge or rainfall from long-term observations of those parameters. In dyke design, for instance, the derived design flood water levels are combined with a freeboard (a reasonable increase of the dyke) to arrive at the actual design defence level. The freeboard accounts for:

- Uncertainties in the hydrological analysis as well as in engineering;
- Wave run-up; and
- Subsidence.

The above quotes are taken here as two aspects of the current discourse of what implications climate change has on the planning and operation of hydraulic infrastructure. Some argue that the current statistical tools available are sufficient to accommodate the uncertainties of non-stationary conditions within the time series (imposed under climate change). Others argue that the lifetime of water infrastructure (in comparison to climatic time scales) allows for it to be adapted over time in a sequential manner. This, however, seems to imply that climate change is happening at a gradual or linear pace. This is far from certain. Regional shifts in climate, such as in average annual rainfall, may happen at a much faster pace than the global means.

If we look at the flood management case in weighing these aspects, it needs to be noted that the decision on what kind of design flood should be applied is based on a risk benefit trade-off, established not only on scientific principles but also event-dependent. A city or industrial complex will be protected with higher safety standard than an agricultural area. Flood management policy has already shifted in various places towards an approach beyond the largely politically driven myth of 'absolute safety from flooding'. Such 'integrated flood management' approaches recognize the value of flood protection measures, yet, also recognize its limits, such as the residual risks if for example, levees fail or are overtopped (WMO, 2004). This can be done by employing tools such as land use planning controls, flood-proofing of key infrastructure, flood forecasting, emergency preparedness planning for levee failure scenarios and risk sharing solutions (e.g. flood insurance schemes, catastrophe bonds, etc.) Such an approach is necessary, yet eventual political ramifications in terms of who takes part in decision-making within such a multi-sectoral scheme must be taken into account.

The drought case is of course more complex both in terms of its predictability, duration and the set of mitigation measures available. In particular, the design and operation of water storage infrastructure is an area of concern. Even under a climate variability scenario droughts receive far less attention than floods. The scientists who argue along the lines of the second quote (above) work on the assumption that a 'business as usual' approach in our current water infrastructure development practices may lead to severe consequences at a later stage, and that it is more cost-effective in the long run to take preventive or mitigation measures today. As the analytical tools currently available to develop and operate water infrastructure under non-stationary conditions may not be fully sufficient, and the societal demands on water managers for socially equitable and environmentally sustainable solutions increase, major efforts will be required in the research and development of alternative solutions that combine the strengths of various scientific disciplines.

4.3 Techniques for assessing impacts

A key component of any climate change adaptation effort, regardless of its scale, is to make a reasonably reliable assessment of potential impacts of climate change under different projected conditions, including those with and without the implementation of adaptation measures. To appreciate their significance, assessments of impacts have to be characterized by uncertainties inherent to different stages of the assessment process.

4.3.1 Climate change assessment frameworks

Assessing the impact of climate change on water resources is generally conducted within a larger framework. This should support the selection and formulation of adaptation policies and measures to enhance resilience and reduce vulnerability of water resource systems in the face of the impending climate change. The IPCC Working Group II Report (Carter et al., 2007) identifies five types of Climate Change Impact, Adaptation and Vulnerability (CCIAV) assessment frameworks (see Box 4.1), differentiated by their purpose and focus of assessment, available methods and approaches to deal with uncertainty. Generally, assessments are shifting focus from being mostly research-centred to supporting policy analysis and decision-making with emphasis on the involvement of stakeholders. Uncertainties are recognized as inher-

Box 4.1: CCIAV assessment frameworks

The IPCC (Carter et al., 2007) identifies five types of CCIAV assessment frameworks:

- **Impact assessment:** a first–generation, top-down scenario-based approach that still dominates the CCIAV literature.
- **Adaptation assessment:** a bottom-up approach that focuses on assessing measures to enhance the resilience of a system exposed to the risk of climate change.
- **Vulnerability assessment:** a bottom-up approach that is closely associated with the adaptation approach, but focuses more on the risks themselves to reduce their impacts.
- **Integrated assessment:** provides a platform to coordinate and represent interactions and feedback among different CCIAV assessment studies.
- **Risk management:** emphasizes the characterization and management of uncertainties and caters directly to policy and decision-making. Can be applied to facilitate the integrated analysis of mitigation and adaptation policies.

Source: Adapted from Department for International Development (DFID), 2006

ent features of the assessment process that need to be managed rather than reduced (see Chapter 5).

4.3.2 An overview of impact assessment methods

How useful are these methods to help you to manage your water resources on the ground? What type of information do you need from meteorologists?

The majority of the impact assessment studies found in the literature are based on the IPCC seven-step assessment framework as described in Table 4.3. In this top-down approach, scenarios are selected to represent a range of potential socio-economic conditions that are usually based on the IPCC SRES storylines (Figure 2.8). Corresponding scenarios of greenhouse gas releases are then run through GCMs to produce climate change scenarios that each contain a set of hydrological and meteorological variables necessary for simulating the given water resources system. Alternatively, these scenarios can be created using synthetic or analogue methods. A modelling tool is commonly used to assess the response of the water resources system to climate change scenarios.

Table 4.3: The seven-step assessment framework of IPCC

1	Define problem
2	Select method
3	Test method/sensitivity
4	Select scenarios
5	Assess biophysical/socio-economic impacts
6	Assess autonomous adjustments
7	Evaluate adaptation strategies

Source: Carter et al., 1994

The assessment process is conducted in several iterations to establish baseline conditions and to represent autonomous and planned adaptation. The performances of different adaptation measures and policies are assessed based on a set of criteria that reflects the priorities established by the planning agency. Ideally, those criteria should be chosen to strike a balance among the three key principles of IWRM: economic efficiency, environmental protection and social equity.

4.3.3 Types of climate change scenarios

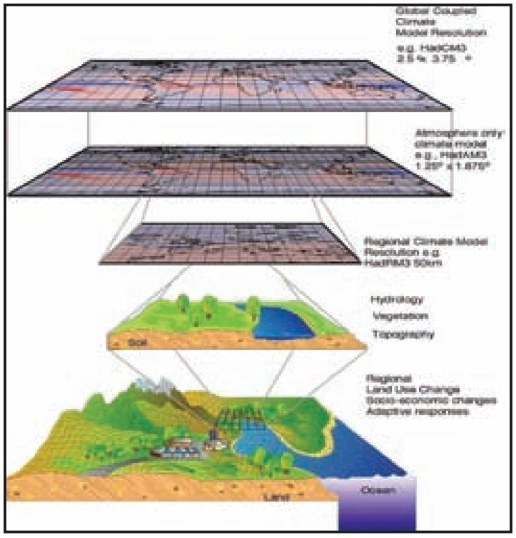
There are three main methods for generating climate change scenarios. The most common method is using output from Global Circulation Models (GCMs), simulated using greenhouse gas releases representing socio-economic scenarios. Synthetic scenarios can be created to represent a range of potential climate changes. Analogue scenarios can be created using historic observed conditions or those from another area (Feenstra et al., 1998).

Climate change scenarios based on Global Circulation Models

GCMs are computer applications designed to simulate the earth's climate system for the purpose of projecting potential climate scenarios. They range in complexity from simple energy models to the 3D Atmosphere-Ocean GCMs (AOGCMs; see section 2.2.2). In an impact assessment study, greenhouse gas conditions based on SRES are run through a GCM to produce climatic projections. They can be run based on equilibrium conditions, where both current and future climates are assumed to arrive at their greenhouse gas concentrations instantly. More representative, yet more expensive, GCMs can be run assuming that future climate is attained through a steady increase in greenhouse gas releases.

The *spatio-temporal resolution* of GCM output is much lower than that required for assessing hydrological conditions, making it unusable directly for hydrological modelling (see Figure 4.4). Output from GCM models can be used to run regional climate models (RCMs), which produce climate change scenarios of a resolution amenable to water resource models. Alternatively, output from GCMs can be statistically downscaled based on ground measurements.

Figure 4.4: Differences in spatial resolutions among climate and water resources models



Source: World Climate Programme, 2007

Synthetic climate change scenarios

Synthetic scenarios are based on combined incremental changes in meteorological variables. For example, synthetic temperature time series can be created by combining baseline data with a uniform temperature change. Precipitation synthetic data are usually created using a uniform percentage change. Synthetic scenarios are expensive and easy to apply and can be selected to represent a wide spectrum of potential climate changes. However, assumption of uniform changes in meteorological variables is not physically based, and synthetic variables may not be internally consistent with each other. For example, increased precipitation should be always associated with increased clouds and humidity.

Analogue climate change scenarios

Two types of analogue scenarios can be used. Temporal analogue scenarios are based on using past warm climates as scenarios of future climate. Spatial analogue scenarios are based on using contemporary climates in other locations as scenarios of future climate in study areas. However, the IPCC (Carter et al., 1994) has made recommendations against using the analogue scenarios. Since temporal analogues of global warming were not caused by anthropogenic emissions of greenhouse gases, thus no valid basis exists that spatial analogues are likely to be similar to those in the future.

What is your opinion about the use of either one of these two climate change scenarios?

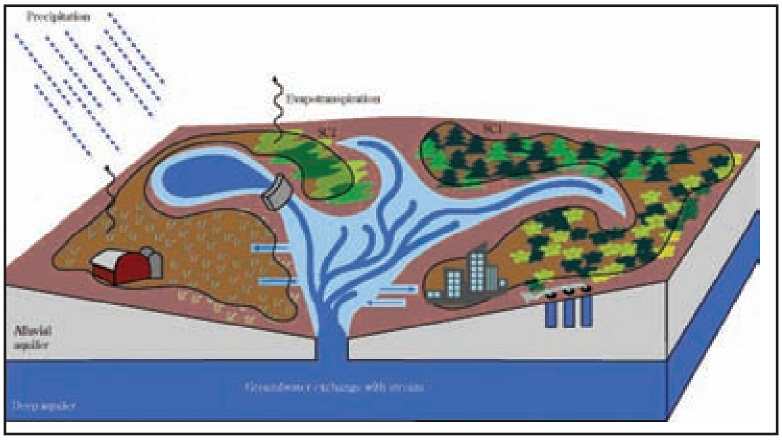
4.3.4 Assessing responses of water resources systems to climate stressors

In its broadest interpretation, a water resources system is composed of interlinked natural and social components (Figure 4.5). Climate change and variability have direct and significant impact on precipitation and evapotranspiration, which are the main drivers of hydrological responses that determine the potential of floods and droughts – the two main classes of water-related hazards. Through structural and non-structural measures, including for example dams, canals, floodplain zoning and regulations, societies manage water resources to secure clean water supply and provide flood protection.

Due to the complexity and highly variable nature of most water resources systems, it is generally a challenging task to assess their responses under changing climatic conditions. Several methods and tools have been developed to study the different components of water resources systems, including surface run-off, groundwater flow and water quality. However, most of these tools are applied individually, making it difficult to assess the overall behaviour of the system. However, a few integrated water simulation models have been developed to provide a holistic representation of water resources systems including those related to demand side and water regulation. Some also include support for economic and policy analysis features.

The following sections provide a brief overview of the types of water resources assessment methods.

Figure 4.5 Conceptual representation of a water resources system



Source: UNFCCC, 2005

4.3.5 Methods for assessing individual processes in water resources systems

Because of the complexity and wide range of the physical and social processes underlying water resources systems, the analysis and development of tools to simulate these processes has historically followed distinct lines of research. Consequently, many of the water resources assessment studies reported in literature have focused on one or only a few of the water resources sub-systems, mostly those related to physical processes. These include, for example, analysis of impact on a river as a result of changes in rainfall and snowmelt patterns, groundwater stocks in response to reduction of infiltration and water quality as a result of increases in temperature. A good overview of several modelling tools used in this type of climate change impact studies can be found in UNFCCC (2005). Although these studies are relatively straightforward and inexpensive to apply, they provide minimal consideration of the management and social aspects of water resources systems.

Methods for integrated assessment of climate change impact on water resources systems

A more recent approach that is being applied increasingly in climate assessment studies is based on a holistic integrated simulation of the physical, management and social aspects of water resources systems. This approach views water resource management not as a supply problem, but also as one where demand management and economic efficiency are important issues that need to be considered explicitly. In addition, great emphasis is placed on policy and decision-making analysis. Considering the challenging task of capturing all these elements in one integrated environment, few models have been successfully implemented (Assaf et al., 2008). Box 4.2 presents a list of some of the commonly used water resources management models.

Box 4.2: A list of water resources management models

UNFCCC (2005) compiled the following list of water resources management models:

- **WEAP:** water supply, demand management and policy analysis model;
- **SWAT:** a water balance and crop growth model mainly used to simulate agricultural activities;
- **HEC suite:** a set of models that simulate different components of watershed systems; and
- **Aquarius:** an optimization model with focus on economic efficiency.

One of the leading water resource system simulation models is the Water Evaluation and Planning (WEAP) Model. In contrast to most simulation models, WEAP explicitly represents water demand alongside water supply elements and provides an extensive policy and economic analysis tools. WEAP21 was applied as the principle tool in a major climate change impact assessment study authorized by the state of California (Purkey et al., 2008).

Summary

Climate change impacts on water resources at the global and the regional level, as well as on various water use sectors have been highlighted. An overview is given of frameworks to assess climate change impacts to support adaptation planning, most of which make use of GCMs and include socio-economic story lines.

5. DEALING WITH UNCERTAINTIES

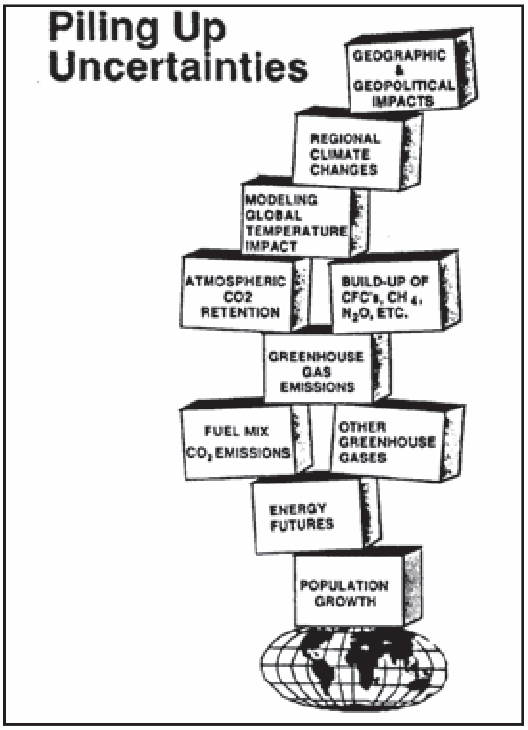
Goal

The aim of this chapter is to familiarize the participants with the uncertainties involved in predicting and adapting to the expected impacts of climate change.

5.1 Uncertainty and climate change

One thing is for certain: under climate change uncertainty will increase. When making climate change impact assessments, a 'cascade' of uncertainty arises (Dessai and van der Sluijs, 2007; see Figure 5.1 and Box 5.1). For example, there are uncertainties associated with future emissions of greenhouse gases and sulphate aerosols, uncertainties about the response of the climate system to these changes at global and local scales, uncertainties associated with the impact models and the spatial and temporal distributions of impacts. Climate change impacts such as changes in temperature, precipitation, run-off or heating-degree days are therefore characterized by uncertainties regarding their magnitude, timing and spatial distribution. Models may even show opposite signs (e.g. some projections show more precipitation, whereas others show less). In addition, uncertainties also exist when trying to understand current vulnerabilities to the impacts of climate change for the purpose of identifying adaptive responses.

Figure 5.1: Possible impacts of climate change are characterized by high levels of uncertainty



Box 5.1: Feedbacks

One factor that complicates climate science – and therefore leads to wide ranges of uncertainty – is the existence of feedbacks. These are interactions between different parts of the climate system in which a process or event sets off changes which in their turn influence the initial trigger. One example is the reduction of ice and snow, both on land and at sea. Ice, being white, reflects up to 90 per cent of the sun's radiation reaching its surface back out into space, preventing it from intensifying atmospheric warming. But when it melts it may expose earth, vegetation, rock or water, all of which are darker in colour and therefore more likely to absorb radiation instead of reflecting it. So the initial melting can cause a feedback which helps to quicken its pace. Another possible feedback is the thawing of the permafrost in high northern latitudes. As it melts, it could release large quantities of carbon dioxide and methane, which at the moment are retained below the frozen soil layer. If that happens, it will accelerate the warming that is already underway. Another expected feedback: higher temperatures of both land and ocean have the tendency to reduce their uptake of atmospheric CO2, increasing the amount that remains in the atmosphere. These are all *positive feedbacks* because they intensify the original process. Negative feedbacks, on the other hand, are changes in the environment that lead to a compensating process and mitigate the change itself.

Source: UNEP, 2009

5.2 Dealing with uncertainties in environmental management

The recognition that, when dealing with environmental issues, severe uncertainties and value-loadings exist has resulted in the development of new approaches to science. Precautionary or post-normal sciences deal with situations where facts are uncertain, values are in dispute, stakes are high and decisions are urgent (Ravetz, 2005). Also, water management is increasingly moving from a practice consisting of more or less straightforward tasks (e.g. ensuring a certain quantity and quality of water supply) to situations with large uncertainties, value-loading and various kinds of political and social issues (e.g. controversies around the building of dams, insufficiently accurate hydrological models). This leads to a situation where policies become based less on facts and more on guiding principles, which are expressed as advocations for the protection of certain interests. Traditional science and engineering cannot adjudicate among such conflicting values. It is principally a political task to weigh risks as a function of probability and expected consequence (including the prevailing uncertainties) in the political discourse with the wider public and the stakeholders. Such discourse also provides an opportunity to weigh the opportunities derived by accepting a certain level of (residual) risk, e.g. by allowing certain land uses in flood-prone areas. This is essential to arrive at a robust adaptation policy design that integrates a perspective on poverty reduction and livelihood security.

Clearly, this also applies to adapting to the impacts of climate change in water resources management. Uncertainty, variability and risk are probably the most important consequences of climate change (Aerts and Droogers, 2009). As seen earlier (Chapter 4), various climate change projections may be inconsistent or lack accuracy at regional and local scales. Traditionally, water management has been based on historical climate and hydrological data, assuming stationarity in weather and in the behaviour of water systems (Ludwig and Moench, 2009). With a changing climate, it becomes questionable if planning for variability and extremes can continue to be solely based on historical data. Experience from the past may no longer be a reliable guide for the future (Pahl-Wostl et al., 2007).

The challenges for the future lie in the improvement of climate predictions at the time and spatial scales required by water resources managers. However, it is also equally important to allow for a collaborative framework between the climate information community and the water resources management community to gain a better understanding of the respective information requirements and methods employed by each community. However, coping with future uncertainties also requires a more adaptive and flexible approach to realize a faster adaptation cycle that allows the rapid assessment and implementation of the consequences of new insights (Pahl-Wostl et al., 2007). Adaptive water management aims at institutional flexibility and a central role for stakeholders (cf. Aerts and Droogers, 2009). Its goal is to increase adaptive capacity to cope with uncertain developments, rather than trying to find optimum solutions (Pahl-Wostl et al., 2007).

How do you think climate change will affect the accepted approaches within IWRM?

5.3 Typology of uncertainties

Uncertainty can be classified on a gradual scale running from ‘knowing for certain’ to ‘not knowing’ (Dessai and van der Sluijs, 2007; see Figure 5.2). Three classes of uncertainty are explained in Box 5.2.

Figure 5.2 Uncertainty levels between determinism and total ignorance

Source: Dessai and van der Sluijs, 2007

Box 5.2: Levels of uncertainty

Statistical uncertainty concerns the uncertainties that can be adequately expressed in statistical terms, e.g. as a range with associated probability. For example, statistical expressions for measurement inaccuracies, uncertainties due to sampling effects, uncertainties in model-parameter estimates, etc. In the natural sciences, scientists generally refer to this category if they speak of uncertainty, thereby often implicitly assuming that the involved model relations offer adequate descriptions of the real system under study, and that the (calibration)-data employed are representative of the situation under study. However, when this is not the case, ‘deeper’ forms of uncertainty are at play, which can surpass the statistical uncertainty in size and seriousness and which require adequate attention.

Scenario uncertainty concerns uncertainties that cannot be adequately depicted in terms of chances or probabilities, but that can only be specified in terms of (a range of) possible outcomes. For these uncertainties, it is impossible to specify a degree of probability or belief, since the mechanisms that lead to the outcomes are not sufficiently known. Scenario uncertainties are often construed in terms of ‘what-if’ statements.

Recognized ignorance concerns those uncertainties that we somehow realize are present, but for which we cannot establish any useful estimate, e.g. due to limits to predictability and knowability (‘chaos’) or due to unknown processes. A way to make this class of uncertainties operational in climate risk assessment studies is by means of surprise scenarios. Usually there is no scientific consensus about the plausibility of such scenarios, although there is some scientific evidence to support them. Examples are the accelerated sea level rise, or the possible shutdown of the *thermohaline ocean circulation.*

Continuing on the scale beyond recognized ignorance, we arrive in the area of ***complete ignorance*** (‘unknown unknowns’) of which we cannot yet speak and where we inevitably grope in the dark.

Source: Dessai and van der Sluijs, 2007

5.4 Adaptation to climate change under uncertainty

Dessai and van der Sluijs (2007) put forth two distinct approaches in climate change adaptation: prediction-oriented and resilience–oriented approaches. The first focuses on characterizing, reducing, managing and communicating uncertainty, resulting in increasingly sophisticated modelling tools and techniques to describe future climates and impacts. The second approach accepts that some uncertainties cannot be reduced. The emphasis is on learning from the past. These two approaches are not mutually exclusive, but are best seen as complementary. Following are some examples of both approaches.

5.4.1 Prediction-oriented approaches

The IPCC approach

The IPCC impact assessment method described in Chapter 4 provides an example of a prediction-oriented approach, which relies heavily on uncertain information by using climate change scenarios as drivers for impacts from which adaptation strategies are developed.

Risk approaches

A broad definition of risk assessment is the process of identifying, evaluating, selecting and implementing actions to reduce risk to human health and to ecosystems (Dessai and van der Sluijs, 2007).

Central to risk assessment is the management of uncertainties, which allows the risk of something to be determined (in its simplest form, this risk would be calculated as probability times consequence). Risk assessment and risk management have been widely applied to a number of environmental problems, but only very recently to climate change.

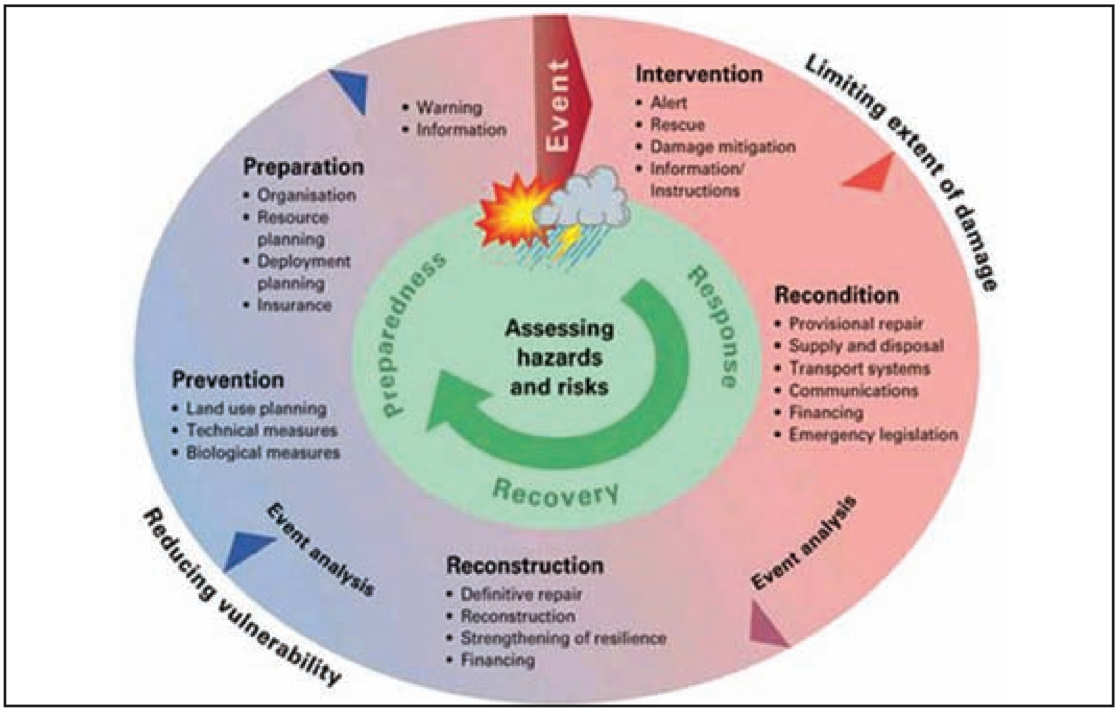
Dessai and van der Sluijs (2007) present an environmental risk assessment/risk management framework that includes the following steps:

1. Identify the key climatic variables affecting the exposure units being assessed;
2. Create scenarios and/or projected ranges for key climatic variables;
3. Carry out a sensitivity analysis to assess the relationship between climate change and impacts;
4. Identify the impact thresholds to be analysed for risk with stakeholders;
5. Carry out risk analysis;
6. Evaluate risk and identify feedbacks likely to result in autonomous adaptations; and
7. Consult with stakeholders, analyse proposed adaptations and recommend planned adaptation options.

While this framework is conceptually simple, it is difficult to implement due to the complexity of climate change. Like the IPCC approach, uncertainty is taken into account using climate scenarios (Step 2), but this particular risk approach is not completely scenario-driven. It is more dependent on stakeholder involvement and their definition of critical impact thresholds.

Safety chain and integrated risk management approaches

Figure 5.3: Integrated risk management



Source: PLANAT, n.d.

The safety chain, or hazard life cycle concept originates from the United States and includes four links: 1) mitigation, 2) preparedness, 3) response and 4) recovery (ten Brinke et al., 2008). In the Netherlands, this risk management approach has been adopted and slightly adjusted: instead of the mitigation link, two links are distinguished: pro-action and prevention. This allows for discrimination between risk reduction measures in spatial planning (pro-action) and measures such as dykes and storm surge barriers (prevention). A definition of the links used in this approach is presented in Table 5.1. A similar approach is used in Switzerland under the term ‘integrated risk management’ (Figure 5.3).

Table 5.1. The definition of the successive links in the safety chain

	Link	**Definition**
Risk management	Pro-action	Eliminating structural causes of accidents and disasters to prevent them from happening in the first place (e.g. by building restrictions in flood-prone areas)
	Prevention	Taking measures beforehand that aim to prevent accidents and disasters, and limit the consequences in case such events do occur (e.g. by building dykes and storm surge barriers)
Crisis management	Preparation	Taking measures to ensure sufficient preparation to deal with accidents and disasters in case they happen (e.g. contingency planning)
	Response	Actually dealing with accidents and disasters (e.g. response teams)
	Recovery	All activities that lead to rapid recovery from the consequences of accidents and disasters, and ensuring that all those affected can return to the ‘normal’ situation and recover their equilibrium.

Source: ten Brinke et al., 2008

Box 5.3: Examples of safety chain and integrated risk management approaches

Historically, **Dutch policy** focused on restricting the probability of floodings, i.e. protection by dykes (prevention). Nowadays, triggered by incidental high peak discharges of the River Rhine and the current debate on the effects of climate change, the possibilities are being explored also to take into account the consequences of a possible flooding. This can be achieved by more pro-active measures, by balancing protection levels and the values of the interests and the population size that have to be protected, and by additional efforts on preparation, response and recovery. In line with the recently adopted European Flood Risk Management Directive, these additional investments would broaden the historical flood defence strategy into a true risk policy by taking more into account the consequences of a possible flooding (ten Brinke et al., 2008).

In **Switzerland**, an approach is being considered where flood defence infrastructure is adjusted in order to retain their structural integrity during extreme events beyond the design criteria, combined with measures to reduce the residual risk to inundated areas such as spatial planning measures, warning and evacuation systems and flood insurance. An expert commission of the Swiss Water Resources Society (KOHS, 2007) defines its position on climate change and flood control. To date the basis for the assessment of flood hazards is, amongst other indicators, the documentation and evaluation of past events. The effect of climate change on future flood events in Switzerland can only be defined in terms of trends. The objective of protection measures is to prepare for an event of a certain magnitude – the design event – without any resulting damage. The design parameters can be determined by statistical evaluation of past observations. One of the main problems is that most record lengths are too short, so the reliability of predictions for extreme events is limited. Another problem is that the planning of flood control measures can only account for the variability of natural processes to a limited extent. Floods are always accompanied by erosion, sediment transport, and flotsam, which occur in numerous and sometimes arbitrary combinations. The precedent conditions of an event also have a relevant impact. For example, the saturation of soil due to antecedent precipitation has a significant influence on flood generation. Only a representative selection of process combinations – so-called 'scenarios' – has been used.

Dealing with natural hazards necessitates an integrative risk management involving a wide range of measures, such as urban and rural planning measures to avoid areas at risk, appropriate maintenance of water bodies, physical protection measures, alerting and evacuation, as well as insurance. However, f**ull protection against floods is not possible**. Extreme events can lead to the overloading of measures that were designed for a specific protection level. The associated residual risk has to be recognized and minimized with adequate provisions. Alerting and evacuation, individual object protection as well as insurance coverage are the main elements available to handle **residual risk**. Physical flood protection measures have to be robust and resistant to overloading. Thereby it is ensured that they do not suddenly fail and that a sudden increase in damage does not occur. Their behavior with regard to overloading is evaluated during the design phase. Additionally, the delineation of areas that are affected in the event of overloading serves as the basis for the assessment of the residual risks.

Source: Dessai and van der Sluijs, 2007

Integrated assessments

Climate change is characterized by a multitude of different impacts on different sectors. In order to formulate a well-designed policy it is necessary to have a complete overview on all impacts and their uncertainties. This can be done by making a model in which all of these impacts (and uncertainties) are integrated. Integrated assessments can address real-world problems that lie across or on the intersection of various scientific disciplines. They can help understanding complex phenomena. In risk management they can contribute to, or form, a central part of risk assessment, response assessment, goal and strategy formulation, implementation, evaluation and monitoring (Toth and Hizsnyik, 1998).

Are risk approaches in your country focusing more on prevention, or towards response/ recovery?

Various approaches have been developed, like the Environmental Vulnerability Index, the Social Vulnerability Index and the Flood Vulnerability Index (for websites, see below). Sullivan and Meigh (2005) introduced a Climate Vulnerability Index (CVI) that can help to identify those human populations most at risk from the impacts of climate change (see Box 5.4).

Box 5.4: The Climate Vulnerability Index (CVI)

The 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 below.

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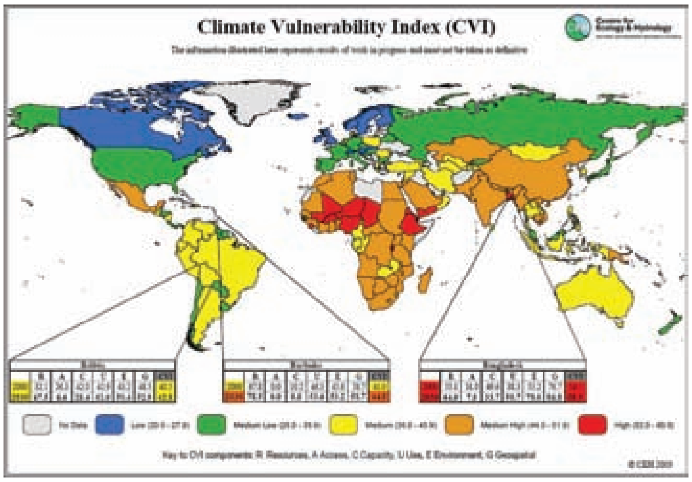
Are you aware of the application of any of these integrated assessments approaches in your region? What would be more appropriate, a focus on floods, droughts, or both?

CVI component	Sub-components/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 land slips ● degree of isolation from other water resources and/or food sources ● deforestation, desertfication and/or soil erosion rates ● degree of land conversion from natural vegetation ● deglaciation and risk of glacial lake outburst



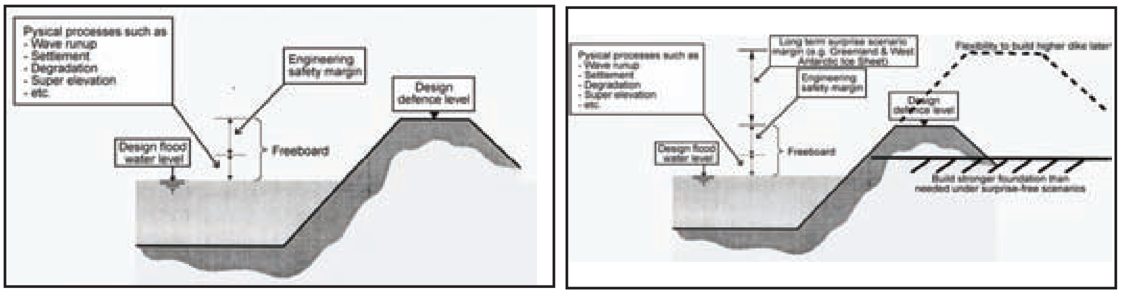
Source: Sullivan and Meigh, 2005

5.4.2 Resilience-oriented approaches

Engineering safety margin and anticipating design

In the design of dykes, it is common practice to apply an engineering safety margin on top of the design flood level. This is to compensate for physical processes not foreseen in the design water level (e.g. overtopping by waves) and for uncertainty in the prediction of design flood levels (e.g. accuracy in the flood estimation (Figure 5.4). These safety margins mainly account for statistical uncertainty and unrecognized ignorance; scenario uncertainty is only accounted for in the design flood. A safety margin based on observed variability does not seem to be a good way to cope with recognized ignorance such as the unknown probability of high-impact events and possible surprises (e.g. accelerated sea level rise from the Greenland ice sheet and West Antarctica). Thus, there is a need for mapping the unknowns – experience from the past may no longer be a valid base for decisions, especially when changes go beyond natural variability.

Figure 5.4: Engineering safety margin for a dyke (a) and flexible design, anticipating imaginable surprises (b)



Source: Dessai and van der Sluijs, 2007

An innovative way to take uncertainty of the type 'recognized ignorance' into account in the design of dykes is anticipating design. 'Surprise-free' scenario's can be used to choose the design flood level. The uncertainty related to the possibility of a substantial higher sea level rise can be included in the design by building a foundation that is strong enough to carry a dyke for a design flood level corresponding to that upper boundary, but dimensioning the dyke itself using the design flood level. This provides the flexibility to construct a higher dyke later with lower costs, if needed (Figure 5.4b). Similarly, dykes can be protected against erosion to cater for overload where appropriate. This creates a situation where the inflow into the floodplain during and extreme event can be reduced substantially. Such measures should ideally be part of an integrated risk management approach that would identify the most desirable locations for overtopping, adjusting the land use behind the levee at those locations, maintain an early warning and emergency response system, and consider the use of insurance and flood proofing options there.

Summary

A short introduction is given on the various aspects that add to the uncertainties when dealing with climate change and how this can be included in environmental management approaches. Prediction- and resilient-oriented approaches are presented as two different options for climate change adaptation. They have been illustrated with some examples.

Websites for vulnerability indices

- Climate Vulnerability Index: http://ocwr.ouce.ox.ac.uk/research/wmpg/cvi/
- Environmental Vulnerability Index: www.vulnerabilityindex.net
- Flood Vulnerability Index: www.unesco-ihe-fvi.org
- Social Vulnerability Index: http://webra.cas.sc.edu/hvri

6. INSTRUMENTS AND MEASURES FOR ADAPTATION

Goal

The aim of this session is to familiarize participants with the range of adaptation measures for a number of projected climate change impacts and to discuss indicators for their applicability in given climatic and socio-economic environments.

6.1 Introduction

Water managers' routine activities include water allocation among multiple and often competing uses, minimization of risk and adaptation to changing circumstances such as variability in water storage levels and water demand due to seasonal effects and/or population growth. A wide range of adaptation techniques have been applied over many decades, including: capacity expansion (e.g. building new reservoirs), changing operating rules for existing water supply systems, managing water demand and changing institutional practices. Within this context, historical climate and hydrological records provide the basis for the determination of reliable water yields and assessment of flood and drought risk. Underpinning these investigations is the assumption that the statistical properties (e.g. averages and standard deviation) of the climatic and hydrological variables remain constant over time. The prospect of climate change means that the key climate and hydrological variables will vary, as will water demand. Climate-induced effects may be nonlinear and carry the potential for surprises beyond those already incorporated in water supply system designs and existing water management strategies (Kabat and van Schaik, 2003).

Prevent mitigate ... ... **and** adapt!

6.2 Adaptation measures

Forecasts of climate change may remain debatable for some time; evidence of increased climate variability is incontestable, and the severity of that variability demands urgent responses from water managers. The reassuring aspect of this argument is that adaptation options for coping with climate variability now will also help to reduce the impact of climate change in the future. These measures include the conventional technological elements of water infrastructure – such as storage reservoirs, boreholes, recharge wells and sand wells – but with an emphasis on techniques for boosting the yield of available resources (rainwater harvesting, water recycling/reuse, desalination). Adaptation benefits enormously from improved forecasting and climate modelling. This stresses the need for strengthening of data-gathering initiatives. (Many hydrological stations in developing countries have become defunct over the years through lack of investment). Risk-sharing and access to credit for affected families are among the financial mechanisms that are being adapted to be responsive to floods and droughts. On a more structural level, modification of land-use patterns, crop selection and tillage practices can also be considered.

6.2.1 Classification and overview of relevant climate change adaptation measures

According to IPCC (IPCC, 2007c: 869), adaptation can be defined as “Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities”. This term refers to changes in processes, practices, or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate. It involves adjustments to reduce the vulnerability of communities, regions, or activities to climate change and variability. It thus differs from mitigation, which can be defined as “An anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks” (IPCC, 2007c: 878).

Adaptation is nothing new (see Box 6.1) and the majority of adaptation measures occur spontaneously, depending on the individual needs and capacities of a given sector of society – this is termed autonomous adaptation. Planned adaptation, on the other hand, results from decisions that have been made based on the awareness that conditions have changed, or are about to change (UNFCCC, 2006).

Box 6.1: Adaptation is nothing new!

Raised beds and *waru waru* cultivation, Peru. This technology is based on modifying the soil surface to facilitate water movement and storage, and to increase the organic content of the soil to enhance its suitability for cultivation. The technology is a combination of rehabilitation of marginal soils, drainage improvement, water storage, optimal utilization of available radiant energy, and attenuation of the effects of frost. This system of soil management for irrigation purposes was first developed in 300 BC, before the rise of the Inca Empire. It was later abandoned as more technically advanced irrigation technologies were discovered.

Have you heard of completely new adaptation measures and approaches? Before discussing the adaptation measures for climate change, do you think we have done our homework under climate variability in a sufficient manner so far (e.g. in establishing flood and drought early warning systems in developing countries)? What are the implications?

There are various other ways of classifying adaptation options (UNFCCC, 2006). Adaptation can be reactive or anticipatory. The first occurs after the impacts of climate change have become manifest, while the second takes place before impacts are apparent. Table 6.1 (UNFCCC, 2007a) lists an overview of reactive as well as anticipatory sectoral adaptation options and responses as provided by developing countries in their communications to UNFCCC.

Table 6.1: Adaptation measures in key vulnerable sectors highlighted in national communications of developing countries

Vulnerable sectors	Anticipatory adaptation	Reactive adaptation
Water resources	● Better use of recycled water ● Conservation of catchment areas ● Improved water management system ● Water policy reform (pricing, irrigation policies) ● Flood control, drought monitoring	● Protection of groundwater resources ● Improved management/maintenance water supply systems ● Protection of catchments ● Improved water supply ● Ground- and rainwater harvesting, desalinization
Agriculture and food security	● Development of tolerant/resistant crops ● Research and development ● Soil-water management ● Diversification/intensification of food/plantation crops ● Policy measures (tax incentives, subsidies, free markets) ● Early warning systems	● Erosion control ● Dams for irrigation ● Fertilizer use and application ● Introducing new crops ● Soil fertility maintenance ● Planting and harvesting times ● Different cultivars ● Education and outreach on soil/ water conservation and management
Human health	● Early warning systems ● Improved disease/vector surveillance/monitoring ● Improvement of environmental quality ● Changes in urban/housing design	● Public health management reform ● Improved housing/living conditions ● Improved emergency response
Terrestrial ecosystems	● Creation of parks/reserves, protected areas, biodiversity corridors ● Identification/development of resistant species ● Vulnerability assessment of ecosystems ● Species monitoring ● Development/maintenance of seed banks ● Including socio-economic aspects in management policy	● Improvement of management systems, incl. deforestation, reforestation, aforestation ● Promoting agroforestry ● National forest fire management plans ● *Carbon storage* in forests
Coastal zones and marine ecosystems	● Integrated coastal zone management ● Coastal planning and zoning ● Legislation for coastal protection ● Research and monitoring of coasts and coastal ecosystems.	● Protection of economic infrastructure ● Public awareness for protection of coastal and marine ecosystems ● Building seawalls and beach enforcement ● Protection of mangroves, coral reefs, sea grasses and littoral vegetation.

Source: Adapted from UNFCCC, 2007a

Another distinction can be made with respect to the system in which adaptation takes place: the natural or human system. Within the human system, a distinction can be made between public (governments at all levels) and private (individual households, commercial companies) interests (Table 6.2).

Table 6.2: Matrix showing five prevalent types of adaptation to climate change, including examples of adaptation

		Anticipatory	Reactive
Natural systems			Changes in length of growing season Changes in ecosystem composition Wetland migration
Human systems	Private	Purchase of insurance Construction of houses on stilts Redesign of oil rigs	Changes in farm practices Changes in insurance premiums Purchase of air conditioning
	Public	Early warning systems New building codes, design standards Incentives for relocation	Compensatory payments, subsidies Enforcement of building codes Beach nourishment

Source: Klein, 1998 and Smit et al., 2001 in UNFCCC, 2006

Finally, when getting into technologies for adaptation, a distinction can be made between soft and hard technologies (UNFCCC, 2006). Soft technologies include insurance, crop rotation and setback zones, as well as information and knowledge. Hard technologies could be seawalls, drought-resistant seeds and irrigation technology. In many cases, successful adaptation will include a mixture of soft and hard technologies. UNFCCC (2006) further classifies these into traditional, modern, high and future technologies.

It is questionable whether society can rely on autonomous adaptation to deal with the expected impacts of climate change and increased variability. Thus, it is widely acknowledged that there is a need for anticipatory planned adaptation, which could take the following forms (Klein and Tol, 1997, Huq and Klein, 2003, in UNFCCC, 2006):

1. Increasing the ability of infrastructure to resist impacts of climate change (e.g. reinforcing dykes);
2. Increasing the flexibility of vulnerable systems managed by humans (e.g. changing management practices);
3. Enhancing the adaptability of vulnerable natural systems (e.g. reducing other stresses);
5. Reversing trends that increase vulnerability (e.g. reducing human activities in vulnerable areas, preserving natural systems that reduce vulnerability); and
4. Improving public awareness and preparedness (e.g. early warning systems).

Kabat and van Schaik (2003) give an overview of options for adaptation grouped according to the following categories (Tables 6.3a–c):

- Robust policies;
- Technological and structural measures; and
- Risk-sharing and spreading.

Robust policies

Over centuries, societies and ecosystems have adapted to climate variability and climate change in an evolutionary way. Today, the rapidity of changes in hydrological regimes requires more immediate and more concerted efforts. Policies and operating rules focused on optimum exploitation of available water resources need to be adjusted. Sea level rise, shrinking natural lakes and desertification all force changes of land-use and livelihoods. The increasing susceptibility of flood plains to extreme events means that governments have to consider more rigid spatial planning as a coping option. Resettlement is neither popular nor desirable, but it may eventually become inevitable where the risk associated with a particular place may start to outweigh perceived benefits and therefore may become unacceptable to society.

The policy concepts and processes directly related to, and considered applicable for the purpose of adaptation planning include IWRM (GWP, 2000), Integrated Flood Management (WMO, 2004), and Integrated Coastal Zone Management (UN, 1992). All these concepts are adaptive in nature and consider management options in broad development contexts. This is essential for the robustness of policies in the natural resource management context. Observers of the international water policy development process are aware that certain specific issues tend to ‘flare up’ and dominate the agenda for a certain time, mostly driven by current events such as floods, droughts, food prices, biofuels, etc. It is essential to realize that policies that are developed in such an event context have a very limited lifetime. If, for example based on an extreme flood event, the floodplain use is severely restricted or resettlement programmes are implemented without consideration of the floodplain benefits, such policy may have negative impacts on food and livelihood security. Similarly, if ecosystem conservation or pollution control leads to narrowly aimed policies that prevent the necessary investments in water resources development, there are often unconsidered consequences for water availability under climate variability and change, as well as for food and livelihood security. Robust policies should therefore be based on the broad aims and principles of IWRM, Integrated Flood Management and Integrated Coastal Zone Management. The processes suggested by those concepts provide the means for mediating different interests and competing uses of water resources.

A fundamental aspect of any coping strategy therefore must be mainstreaming of climate issues into national water management policy. To implement such policies there is the need to have a legal and institutional framework in place, in order to allow all stakeholders to become part of the process and manage the resources according to agreed rights, powers and obligations. An overview of policy instruments that can be used is presented in Table 6.3a.

Table 6.3a: Compendium of policy instruments for adaptation

<table>
<tr><th>International</th><th>National</th></tr>
<tr><td>International conventions on Climate Change (UNFCCC);
International trade (particularly WTO)
Polluter-pays principle influences ODA/Funds.</td><td rowspan="3">National Poverty Reduction Strategies;
National strategic interests;
National Water Policies and IWRM Plans;
National Adaptation Plans of Action;
Disaster Management Policies;
National Drought Preparedness and Mitigation Plans;
Economic instruments and water markets;
Risk management cross-cutting in development plans;
Strengthened functions of River Basin Authorities;
Integrated catchment management;
Non-water planning, e.g. urban areas, refuges;
Adaptive spatial planning and resettlement;
Livelihood diversification (in particular for highly climate dependent sectors such as rain-fed agriculture).</td></tr>
<tr><td>Regional</td></tr>
<tr><td>Regional Adaptation Plans of Action;
Regional Strategic Action Plans for IWRM;
Transboundary plans and inter-State cooperation;
Informal bi-national cooperation
Regional institutions.</td></tr>
</table>

Source: Adapted from Kabat and van Schaik, 2003

Technological and structural measures

The list of coping options in Table 6.3b may seem like a catalogue of water management infrastructure and operating techniques. It is true that coping with climate change does not involve many entirely new processes or techniques, perhaps with the exception of advances in the structure, quality and resolution of climate information products such as seasonal or inter-annual climate predictions. It should, however, be made clear that this is not an argument for 'business as usual'. Existing instruments, methods and measures may need to be introduced at a faster pace, and applied in different locations, at different scales, within different socio-economic context and in new combinations.

For example, if we expect an increased occurrence of flash floods in Europe, strategies, methods and techniques from countries that have had to deal with a high frequency of flash floods for decades should be considered to accelerate the adaptation process. This is not expected to be a rapid or smooth transition. But the message that there may be adaptation solutions for the water sector found in places that have experienced climatic conditions in the past, and that are now expected to become common place elsewhere, should be a driving principle of adaptation planning.

Table 6.3b: Compendium of technological and structural adaptation options

<table>
<tr><th>Storage and recirculation</th><th>Early warning systems</th></tr>
<tr><td rowspan="3">Large reservoirs;
Small reservoirs;
Groundwater
Artificial recharge;
Borehole drilling;
Sand dams;
Scavenger/gallery wells;
Related options
System maintenance;
Supply leakage control;
Irrigation equipment maintenance;
Irrigation canal leakage;
Rainwater harvesting;
Water reuse/recycling;
Desalination.</td><td>Near real time (hours to days);
Short-term (days to weeks);
Medium-term (month to season);
Long-term (years to decades);
Communicate forecasts to end-users.</td></tr>
<tr><th>Operations/system improvements</th></tr>
<tr><td rowspan="3">Reservoir operations rules;
Integrated, optimised reservoir systems;
Retrofitting existing structures;
Irrigation scheduling;
Water demand management;
Indigenous coping strategies;
Precipitation enhancement;
Soil conservation and tillage practices;
Crop varieties.</td></tr>
<tr><th>Flood/storm surge control</th></tr>
<tr><td>Structures (levees, dykes, diversions, *detention basins)* ;
Preventative operations.</td></tr>
</table>

Source: Adapted from Kabat and van Schaik, 2003

What it also means is reviewing existing operations in the light of very different hydrological circumstances. Basin infrastructure is essential to protect against, and reduce the impact of, water-related disasters along with new civil works like disaster shelters in risk-prone areas. It can be very practical to improve existing infrastructure, such as roads, drains, natural ponds and lakes, dams and reservoirs, and processes like soil conservation of steep slopes and sediment control into reservoirs. However, proper skills for operation and maintenance and the financial means to carry them out are equally important.

As far as specific management measures are concerned, as a general rule, reservoirs provide the most robust, resilient and reliable mechanism for managing water under a variety of conditions and uncertainties. However, other combinations of non-structural measures (e.g. demand management, agricultural conservation practices, pricing, regulation, relocation) may provide comparable outcomes in terms of gross quantities of water supply, but not necessarily in terms of system reliability. The choice of alternatives depends on the degree of social risk tolerance and perception of scarcity, as well as the complexity of the problem.

The possibilities for coping with the uncertainties of climate change and variability are manifold – both in the number of strategies and in the combinations of management measures that comprise a strategy. There is no single ‘best’ strategy. Each depends on a variety of factors, e.g. economic efficiency, risk reduction, robustness, resiliency or reliability. However, adaptation strategies need to be developed, implemented and monitored through participatory cross-sectoral policy processes such as IWRM or Integrated Flood Management. Only if this succeeds, the resulting solutions to adapt practices in the water management and planning domain will have a chance to be socially equitable, economically efficient and environmentally sustainable. Furthermore, such process would need to be employed to minimize the risks that adaptation measures are counterproductive to the climate change mitigation agenda.

The hydrological rules have changed. Continually updated assessments of meteorological and hydrological data need to be an integral part of water resources planning and management. Continued efforts are required from the climatological and hydrological research communities to absorb those data and transform them into results adequate for adaptation planning.

Can we cope without additional storage under more variability? What is the role of existing storage facilities? How are we rating in terms of maintenance and safety of those facilities?

Risk sharing and spreading

Disaster insurance is a classic means for dividing risks and losses among a higher number of people over a long-time period (Table 6.3c). Payouts on natural disasters are potentially massive, and very much higher than any single small or medium-sized insurance company could bear. For this reason, there is an active market in re-insurance. The cost of premiums can be very high for major infrastructure, and many governments do not take out insurance cover, choosing instead to bear the replacements cost of the partial losses that inevitably occur from their capital budgets. Provided long-run costs of replacement remain less than the cost of premiums, this is a sensible approach – for societies, this approach relies on government investment into replacement. A major problem arises when a disaster is of such magnitude that it overwhelms the capacity of an economy to bear the cost from the national recurrent budget. Recognizing that climate-related hazards are not only inevitable, but are likely to continue increasing, insurance mechanisms are seen to have a role in sharing and spreading risks.

Table 6.3c: Compendium of risk sharing and spreading options

Insurance	Finance
Primary insurers; Re-Insurance; Micro-insurance.	Development banks; Private; Micro-lenders.

Source: Adapted from Kabat and van Schaik, 2003

6.3 Adaptation focus themes

In the following section selected examples are presented to illustrate a range of adaptation focuses that might be taken in view of particular national or local expected impacts.

Adaptation focus 1: Integrated water resources development and management

Integrated water resources management is widely recognized as the most effective way to optimize water availability for all uses, although the institutional strengthening it demands poses challenges to many developing countries. With IWRM and its extension to integrated catchment management comes an increased flexibility to cope with large fluctuations in rainfall and river flows (Kabat and van Schaik, 2003). Agricultural and irrigation technology have made it possible to continue feeding a world population that has tripled in the past century. On the negative side, many water management systems and policies are not well adapted to responding to the modern paradigm of water management that calls for managing the resource in a sustainable manner under conditions of uncertainty. The degree to which IWRM approach can be implemented and put into practice depends on the adaptive capacity of countries' institutions.

Increasing the production efficiency of water by improving irrigation efficiency is the simplest answer to water scarcity and climate variability. The initial step is to improve the water available within irrigation and drainage systems.

Adaptation focus 2: Integrated flood management

Adaptation measures in the flood management context should involve a best mixture of structural and non-structural measures, with the aim of minimizing the losses of life from flooding and maximizing the net benefits derived from the floodplains (WMO, 2004). This approach is also referred to as Integrated Flood Management or flood management within the context of IWRM.

- Structural measures include for instance dams, levees, diversion channels, detention basins, flood proofing, etc.
- Non-structural measures include flood forecasting and warning systems, spatial planning, source-control, emergency preparedness and response procedures, insurance, flood risk awareness programmes, etc.

In recent years, a number of countries have developed adaptation strategies to deal with more extreme flood events. Those strategies involved as a first step detailed scientific assessments of observed and projected change of climate variables and their expected impact on the water resources of the specific country. The strategies are generally based on the precautionary and risk management principles. Some countries have given consideration to adjust flood defences by introducing design factors or allowances to account for expected changes to river discharge, sea level, wave activity, etc. Other countries are recommending a more diversified approach in the form of a combination of measures to allow flood defences to be overtopped during an extreme event without compromising their structural integrity, and at the same time to minimize the residual flood risks through spatial planning, emergency preparedness and response programmes, as well as flood insurance.

River flood, flash flood or tidal flood: flood forecasting and warning systems are considered baseline systems for the protection of life and property in the context of climate variability and climate change. Many countries are lacking substantial capacity in that field and climate change places the establishment or improvement of such systems in a priority position. Such systems can be considered part of no-regret adaptation options, meaning their establishment is beneficial within a climate change scenario, but also when climate does not change.

Flood forecasting needs to encompass all stages and aspects of floods, such as rainfall and coastal sea levels (meteorological predictions), water levels in rivers and floodplains (hydrological predictions), and projections of, for example, the damage to agriculture and infrastructure (economic or impact predictions). Long-term hydrological forecasts typically have a lead-time of a month or more. These can only give a general indication whether there would be a risk of increased flooding, and if the predicted floods are likely to be average, below or above average. This information can, however, be of great value to reservoir operators in semi-arid regions. These hydrological predictions depend very strongly on forecasting accuracy for weather and climate on seasonal time scales. Medium-term hydrological forecasts have a lead-time of a week or so, and should provide more accurate estimates of the flood conditions. These forecasts mainly depend on the quality of rainfall forecasts and information from the upper watersheds, additional short-term climate information, and the quality of a distributed hydrological model used to calculate run-off and river flows. Finally, short-term hydrological forecasts, with a lead-time of a few days, focus on river water levels and the extent and depth of inundation areas. This forecast is derived from a real-time observation of rainfall and river flows in the upper watershed, combined with hydrological and hydraulic models, which calculate or estimate water levels in the river and water storage in the inundated areas (Kabat and van Schaik, 2003).

Adaptation focus 3: Drought preparedness and mitigation

There are both traditional (indigenous) and technological approaches to coping with the risk of drought. Any technological management of drought requires medium- (seasonal) to long-term (annual to decadal) climate forecasts and, therefore, the appropriate modelling tools. This information then has to be translated into early warning and response mechanisms.

Supply-side drought protection measures include the following:
- Supplies of water should be augmented by exploiting surface water and groundwater in the area. However, intensive groundwater withdrawals for drought management, is not a sustainable remedy.
- Transfers can be made from surface water sources (lakes and rivers) and from groundwater, if socio-economically and environmentally acceptable.
- Storage of water can be increased. Groundwater reservoirs (aquifers), which store water, when available, can be more advantageous than surface water storage, despite the pumping costs, because of the reduction in evaporation losses.

In recent years, the emphasis in action plans to combat drought has increasingly shifted from supply-side management by provision of water resources in required quantities to effective demand-side management of the finite and scarce freshwater resource.

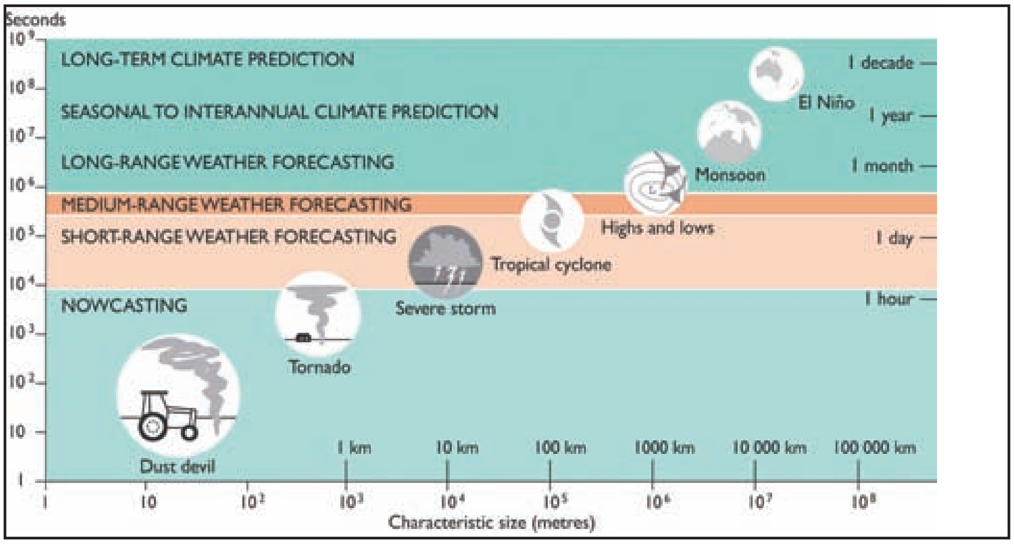
Possible demand-side measures include:
- Improved land use practices;
- Watershed management;
- Rainwater/run-off harvesting;
- Recycling water (e.g. use of treated municipal wastewater for irrigation);
- Development of water allocation strategies among competing demands;
- Reduction of wastage;
- Improvements in water conservation via reduction of unaccounted water; and
- Water pricing and subsidies.

Drought contingency planning also requires thorough consideration, including:
- Restrictions of water use;
- Rationing schemes;
- Special water tariffs; and
- Reduction of low-value uses such as agriculture (Kabat et al., 2003).

Adaptation focus 4: Weather and climate information

Climate prediction and weather forecasting are vital elements in the coping strategies. Meteorologists are getting better at tracking and forecasting extreme weather associated with cyclones and typhoons with reasonable accuracy over periods of a few days or weeks. Increasing understanding of the El Niño/La Niña phenomena and other climate anomalies means that predicting seasonal climate variations for specific regions is also becoming more accurate. In this context, Regional Climate Outlook Forums (RCOFs) have been instrumental in providing consensus seasonal climate outlooks before the onset of the rainy season to support climate adaptation in various sectors.

Figure 6.1: Weather and climate information products with corresponding spatial and temporal scales



Adapted from: J.W., Zillman, WMO Bulletin 48 (2) April 1999).

Figure 6.1 provides an overview of weather and climate information products reaching from nowcasting to climate predictions with their characteristic spatial and temporal scales. Strengthening the provision of weather and climate information products is considered an essential tool for adaptation to climate variability, and in the long term to climate change. Investment in climate and weather information products should be considered a priority as the benefits arising are immediate and materialize under any climate change scenario.

Adaptation focus 5: Ecosystem maintenance

Policy decisions at the governmental level for protecting the natural ecosystems from the adverse impacts of climate change need special attention. Effective responses depend on the understanding of the likely regional changes in the climate and ecosystem. Monitoring of those changes is essential to adjust management practice and can be considered no-regret options. The current state of knowledge suggests that the impacts on ecosystems from unmitigated climate change would be disastrous and unprecedented in human history, and that adaptation measures for ecosystems would only be effective for lower levels of climate change. Existing policies to protect and preserve the natural ecosystem would also be useful in the climate change regime. Reducing the present stresses on the natural ecosystems such as habitat fragmentation and destruction, overexploitation, pollution and introduction of alien species will provide various ecosystems with some space and time to adjust within specific limits, and therefore need to be recognized as adaptation measures.

Some of the adaptation measures to protect natural ecosystem are (GWSP, 2005):

- Conservation of wild biodiversity: strengthening of Protected Area Network;

- Sustainable improvement in traditional agriculture to protect forest and meadows;
- Protection of the marine ecosystems;
- Protection of the coastal zones; and
- Protection of freshwater wetlands.

Ecosystem services such as water purification, livelihood provision (particularly in a subsistence livelihood context), or flood mitigation may be negatively affected by climate change; however, the impact of climate change on those services is subject to ongoing research and may hold various surprises as climate change proceeds. The IPCC AR4 (Fischlin et al., 2007) indicates that ecosystems in drylands, mountain and Mediterranean regions may be most vulnerable. The IWRM process, based on the involvement of all stakeholders and the principles of environmental and ecological sustainability has the potential to integrate the fate of vital terrestrial and aquatic ecosystems for life support of future generations under climate change.

Summary

The ‘best mix’ and sequence of adaptation measures should be established as part of a risk assessment process. No-regret and low-regret options that provide benefits even under a climate variability scenario are preferred options. The adaptation challenge is not merely a technical challenge but a societal process with strong requirements to broad stakeholder engagement. Adaptation options have to be developed in a highly localized context and with significant uncertainty concerning the future state of the local resource.

Suggested reading

CPWC (2009) Environment as Infrastructure. Perspective Paper on Water and Climate Change Adaptation. The Co-operative Programme on Water and Climate (CPWC): Den Haag, The Netherlands. http://www.waterandclimate.org/index.php?id=5thWorldWaterForumpublications810
CPWC (2009) IWRM and SEA. Perspective Paper on Water and Climate Change Adaptation.
CPWC (2009) Producing Enough Food. Perspective Paper on Water and Climate Change Adaptation.
CPWC (2009) Water Industry. Perspective Paper on Water and Climate Change Adaptation.
CPWC (2009) WASH Services Delivery. Perspective Paper on Water and Climate Change Adaptation.

7. ADAPTATION TO CLIMATE CHANGE IN WATER MANAGEMENT

Goal

The aim of this module is to familiarize the participants with the way adaptation to climate change can be incorporated into water resources management at all levels.

7.1 Introduction

As water quality and availability are substantially affected by climate change manifestations such as severe droughts or excessive flooding, there is a need to change the way water is being used and managed. The question is how is that change going to be brought about?

Integrated water management aims to ensure that communities are provided with access to sufficient resources, that water is available for productive use, and that the environmental function of water is secured. On all three levels, management is challenged by climate variability manifestations and they have to be considered when setting out management strategies.

To do so, adaptation to climate variability has to be incorporated into water resources management planning.

7.2 How can IWRM help?

Management measures have to be feasible, effective and acceptable (GWP n.d.). Measures for climate change adaptation through IWRM should form part of wider adaptation strategies and in the broader context of sustainable water management. Development policies have to be reviewed in relation to new climatic developments and it needs to be assessed whether these policies still hold. At the local and national levels, capacities to cope with or adapt to climate variability can be addressed in the context of planning for IWRM. As GWP (n.d.) puts it: “The best way for countries to build capacity to adapt to climate change is to improve their ability to cope with today’s climate variability”. In other words, improving the way we use and manage water today will make it easier to address the challenges of tomorrow (Box 7.1).

Box 7.1: Why is it important to address climate change manifestations in water management?

- Impacts of climate change on freshwater systems and their management are mainly due to the observed and projected increases in temperature, evaporation, sea level and precipitations variability.
- The number of people in severely stressed river basins is projected to increase significantly (3 to 5 times in 2050 as compared to 1995).
- Semi-arid and arid areas are particularly exposed to the impact of climate change on freshwater.
- Higher water temperatures, increased precipitation intensity and longer periods of low flows will lead to more pollution and impacts on ecosystems, human health and water system reliability and operating costs.
- Climate change affects the function and operation of existing water infrastructure as well as water management practices.
- Adaptation procedures and risk management practices for the water sector are being developed in some countries and regions that recognize the uncertainty of projected hydrological changes.
- The negative impacts of climate change on freshwater systems outweigh its benefits.

Source: IPCC, 2007

What changes are actually expected that have a direct impact on water availability and management? In quantity terms, precipitation is expected to increase or decrease by 20 percent. Also expected are more intense and more frequent floods and droughts. These changes will have direct impacts on the way people use and manage their water resources.

What contribution could water management make to address immediate issues in flooded rural communities?

Adaptation strategies through water management will need to combine 'hard' (infrastructural) with 'soft' (institutional) measures (see Chapter 6). The three main challenges are:

- Establishing dynamic organizations that are able to respond strategically and effectively to changing circumstances;
- Making decisions based on predictions rather than historical data; and
- Securing funding.

7.3 Possible management measures

What are possible management actions that can address the challenge?

In a situation of water stress

Water stress, indicated by the ratio of withdrawal to availability over a particular period, is high in much of northern Africa, southern Africa, western and central Asia, the Indian subcontinent, northern China and Mongolia, Mexico and northern areas of Central America, the western coastal regions of South America, as well as particular areas of Argentina and Brazil, and southern Thailand (IPCC 2007a, UNDP 2007). Here sustained rainfall deficits and increased water demand potentially increase water stress. When measuring water stress, not all aspects of vulnerability are captured, as it does not consider climatic variability. The most vulnerable areas in terms of climate-related water shortages are semi-arid and low-income countries with high annual variations and seasonal concentration of precipitation. Within these areas, people whose access to water supply is linked to rainfall, surface run-off and recharge of water bodies are the most vulnerable.

Adaptation interventions will consist of the following measures to increase water availability:

- Reduce water waste;
- Increase efficiency in agriculture – 'more crop per drop'; and
- Save water in domestic use.

Measures to achieve these goals include:

- Water pricing (controversial as it may affect poor people's access to water);
- Seasonal water rationing during times of shortage;
- Adapt industrial and agricultural production to reduce water wastage;
- Increase capture and storage of surface run-off;
- Reuse or recycle wastewater after treatment;
- Desalination of salty or brackish water (costly);
- Better use of groundwater resources (risk: siltation); and
- Rainwater harvesting.

In a situation of water quality risks

Climate change affects water quality. Increases in frequency and severity of storms and floods put water distributions systems at risk of damage. Inadequate drainage systems in many urban areas are likely to fail as a result of increases in the frequency of intense rainfall events (see Chapter 2). In lakes and reservoirs, increase in water temperatures resulting from anthropogenic warming will affect water quality as a result of impacts on water chemistry. Increased temperatures in rivers reduce the oxygen content and therefore the capacity of rivers to purify themselves. Increase in rainfall may result in more nutrients, pathogens and toxins being washed into water bodies.

Interventions will focus on reversing water quality effects associated with climate change, such as algal blooms as a result of higher temperatures, or contamination because of higher precipitation.

What could be some special measures during seasons of high precipitation?

Possible measures are:

- Improvements to drainage systems;
- Upgrading or standardizing of water treatment;
- Better monitoring; and
- Special measures during high precipitation seasons.

Adaptation interventions in water will require a combination of good practice and longer-term measures to address specific climate change drive impacts on the resources.

Table 7.1: Possible short- and long-term benefit measures

Interventions with short-term benefits	Interventions with long-term benefits
● Rainwater harvesting; ● Increased use of drought orders and water rationing during periods of low rainfall, backed up by promotion of water-saving measures and monitoring and enforcement measures; ● Public awareness campaigns to encourage voluntary reductions in water use and increases in water use efficiency, particularly during periods of high water stress; ● Reuse of wastewater in processes not requiring potable water (e.g. irrigation, industrial use) ; ● Improved monitoring of water quality, particularly during high-risk periods (e.g. drought, temperature extremes, intense precipitation events) ; ● Water quality warnings and advice to public on water treatment during low-quality episodes; ● Use of seasonal and shorter-term forecasts to plan water use; ● Introduction of water pricing schemes, with safeguards to ensure access for poor and vulnerable groups (e.g. pricing only applicable above certain usage per capita/household/business, or above certain ratio of water use to productivity for businesses).	● Incorporation of information on potential future changes in water availability into policy and planning frameworks; ● Integration of rainwater harvesting systems in domestic and commercial buildings; ● Minimum standards for water use efficiency in new buildings; ● Investment in less water-intensive industries; ● Strategic importation of water-intensive products; ● Concentration of certain water-intensive activities in wetter seasons; ● Upgrading of water treatment infrastructure; ● Improved water quality monitoring systems; ● Separation of drainage and wastewater systems, improved run-off management; ● Upgrading of water distribution systems (reduce leakage, evaporation) ; ● Mainstreaming of climate and weather forecasts in water management sector; ● Construction of desalination plants, use of groundwater from aquifers (but note cost and sustainability issues) ; ● Development of international mechanisms for management of shared water resources.

Source: UNDP – not published

7.4 Climate change in IWRM planning

Historically, at the core of water management has been its adaptive capacity and capability. Previously, management practices responded to particular situations or needs arisen from changing circumstances that could be brought on by natural causes, institutional changes, political priorities, and other factors. From that perspective, adaptation and coping strategies for climate change are not new or devoid of basic water management practice principles.

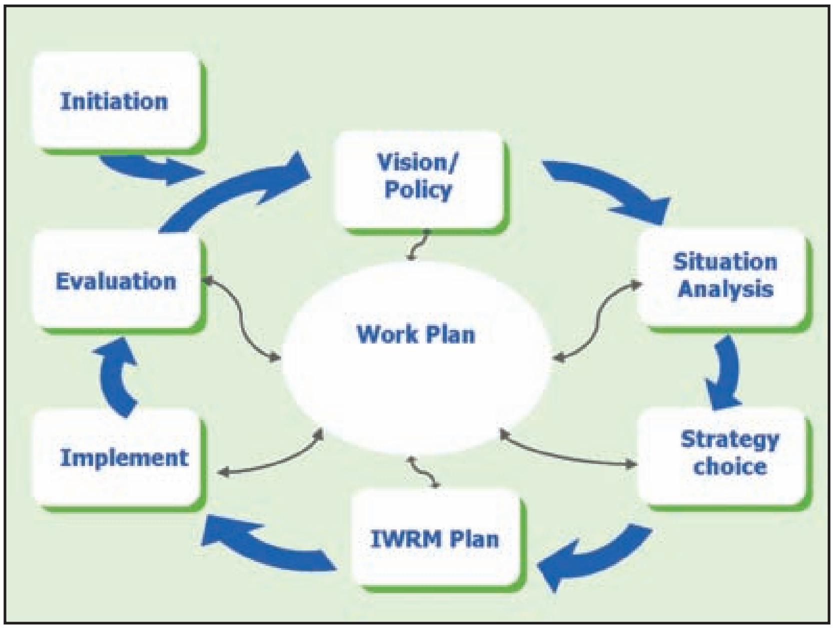
Which interventions are more effective, with short-term or with long-term benefits? Why is that?

Management options for adaptation to climate change are not unique or specifically different from those already employed for coping with contemporary climate variability. The only substantive difference is whether one adopts a more conventional and incremental 'no-regrets' approach, or a more anticipatory and 'precautionary' approach. This is one argument for the use of IWRM as an instrument for adaptation. Perhaps more important is that IWRM is a response to the question, how to work through water management to achieve the Millennium Development Goals? In this context, it has been rightly suggested that while energy habits are the focus of climate change mitigation, IWRM should be the focus of adaptation (Jonch-Clausen, 2007)

How to incorporate the climate change dimension into national IWRM plans?

At the World Summit on Sustainable Development in 2002, countries committed to the development of national IWRM and water efficiency plans that were included in the Johannesburg Plan of Implementation (UN, 2002). This has been instrumental in taking the development and implementation of IWRM forward in national agendas, and many countries have initiated or further strengthened national processes for the development of such plans.

The Cap-Net Training Manual and Operational Guide on Integrated Water Resources Management Plans (Cap-Net, 2005b) presents the process in seven sequential steps as outlined in Figure 7.1.



Source: Cap-Net, 2005b

Figure 7.1: The IWRM planning cycle

When viewing the IWRM planning process as instrumental for adaptation to changing climatic conditions, the following may be considered:

At which stage of the cycle would it be most opportune to introduce adaptation measures as part of IWRM?

- In the 'Initiation' step, climate change impacts need to be integrated in the planning process. In advocacy towards policy makers, the argument can be brought up that this will be instrumental for decision makers to advance demand management strategies, which otherwise might be politically difficult to implement.
- During the 'Vision/policy' phase, climate change adaptation is an additional element, not a replacement of IWRM goals. The overall aims of IWRM will remain the same.
- In the 'Situation analysis' step, the use of climate information and impact analysis needs be incorporated. Further, the adaptation/mitigation theme can be brought out to suggest that the IWRM process should reduce the risk of adaptation options negatively impacting on the mitigation targets, and vice versa.
- In the 'Strategy choice' phase, the anticipatory or 'precautionary' approach can be introduced as the basis for strategies for IWRM.
- Consider the roles of local authorities and river basin organizations (RBOs) in adaptation strategies when drafting an IWRM plan.
- Legal frameworks, economics and health, and other variable conditional elements that have been analysed from the corner stone for implementation of IWRM and are decisive in how it contributes to climate change adaptation.
- During evaluation, results must be measured against indicators, taking into consideration the adaptation measures proposed in the plan.
- Throughout the process, stakeholder involvement is essential so that the results of the impacts assessment and strategic choice are owned by the implementing agencies.

The range of solutions and strategies has been broadened over time by improvements in technologies. What has changed is our understanding and implementation of the integrated ensemble of water management measures that conform to modern principles and policies. A catchment is composed of many users, who reside upstream and downstream of each other.

The integrated approach considers the catchment as a whole and considers the impacts that changes in the catchment or the distribution of water will have on the other users. Water resources managers no longer start with the presumption that certain structural measures (e.g. dams, levees) are the single best solutions. Rather, they begin planning by asking what the objectives of management are. These usually include such factors as social and community well-being, women's roles in water user groups and environmental restoration. IWRM should be advocated as the encompassing paradigm for adaptation to contemporary climate variability, and it is the prerequisite for coping with the consequences of global warming, climate changes associated with it and their repercussions on the water cycle.

7.5 Within the institutional context of river basin management

Water management and climate issues are often addressed in different institutional settings. Water management may fall within a ministry of water or department for water affairs, whereas climate change is usually addressed within a ministry of environment. Equally at the river basin level, climate change measures may be the responsibility of environmental agencies, whereas the river basin organization is usually concerned with allocation and pollution control (Cap-Net, 2008). The challenge is to prepare river basin organizations to take up responsibilities in addressing climate change adaptation, together with local authorities and environmental agencies.

Typical functions of river basin organizations are:

- Water allocation;
- Pollution control;
- Monitoring;
- Basin planning;
- Economic and financial management;
- Information management; and,
- Organization of stakeholder participation.

In implementing these functions at the basin level, river basin organizations have practical instruments to properly address climate change manifestations. As such the possible adaptation measures mentioned earlier in this chapter fall within the mandates and responsibilities of the RBOs. In the table below, we match some of the possible measures with functions of the RBO.

What are key river basin organization functions that would help to assist municipalities and communities to address climate change effects?

Table 7.2: Some possible adaptation measures and functions of river basin organizations

Possible adaptation measures	RBO function	Anticipated effect
Water pricing, cost recovery, investment	Economic/ financial management	Reduced per capita consumption Improved efficiency
Seasonal water rationing, re-allocation, managing water use	Water allocation Pollution control	Availability and access improved Uninterrupted flow Purification function secured
Flood and drought risk mapping, infrastructure, scenario development	Basin planning	Reduced impact of extreme events
Possible adaptation measures	**RBO function**	**Anticipated effect**
Increase capture and storage of surface run-off	Basin planning	Improved availability Reduced polluters in the system
Reuse and recycle, better regulation, pressure for improved sanitation	Pollution control Water allocation Basin planning	Improved availability Reduced groundwater pollution
Groundwater usage	Water allocation Basin planning	Improved availability
Rainwater harvesting, warning systems	Water allocation Stakeholder participation	Improved availability Reduced drainage damage
Improving drainage systems and water treatment	Pollution control Basin planning	Reduced pollution Improved availability and recovery
Better monitoring.	Information management Monitoring	Improved action responding to real needs.

7.6 Adaptation at the appropriate level

Developing countries are likely to suffer most from negative impacts of climate change. In developing countries, the climate-sensitive sectors such as agriculture and fisheries are economically more important than in developed countries. Reducing vulnerability of these sectors and societal groups needs to be at the centre of adaptation strategies, ensuring that livelihoods are sustained. Limited human, institutional and financial capacities to anticipate and respond to direct and indirect impacts, particularly at community level, makes it essential that strategies are developed and implemented at the appropriate level.

Local authorities play a crucial role in addressing poverty, improving access to basic water services and sustainable management of water resources. However, they often lack the knowledge and capacity to reach these expectations. They are the most decentralized representative governance structures that have responsibilities for providing basic services. In this context, they are the first responsible authorities to ensure that the needs of vulnerable sectors and players are addressed in adaptation strategies and their livelihoods protected.

Can you think of other desirable or less desirable effects of proposed adaptation measures?

Local authorities are expected to provide or facilitate water and sanitation services, but they are also increasingly being expected to use participatory approaches to maximize stakeholder inputs to planning, management decisions and stakeholder responsibility for water demand management. Local authorities have roles in river basin water management agencies, both as users and as community representatives, and they will be expected to endorse regulatory approaches that support sustainable management of water resources, including environmental and ecosystem protection. With increasing decentralization, local authorities have been charged with greater responsibilities, yet often have widely varying competence, experience and capacity. Their effectiveness influences development, poverty, environment and health, yet they remain one of the most challenging institutions to reach with assistance for improved water management.

User associations, environmental NGOs, interest groups and others have an important role in mobilizing stakeholders for the development of adaptation strategies and to ensure their participation in implementation. In the framework of planning for adaptation in the context of IWRM, consultation with, and participation of, stakeholders is central to the process. They ensure that gender equity issues are properly addressed and that the most vulnerable sectors and water users are adequately considered when strategies are developed.

In this context, a distinction can be made between private and public adaptation. Private adaptation is initiated and implemented by individuals, households or other private entities and usually serves the interests of those who implement it. Public adaptation is initiated and implemented by public authorities and should usually serve the interest of the community. Ideally, the public authority solicits the inputs of individuals, interest groups, or other representatives of private entities to develop a strategy that meets public interests based on private requirements. However, that demands a substantial capacity by the public authority to organize participation and translate inputs in strategic policies and implementation. Local parties also have to be informed of and sufficiently familiar with adaptation scenarios and the tools and techniques at their disposal. Substantial capacity-building efforts directed towards local authorities and civil society representatives will be required.

Suggested reading

Cap-Net (2005) Integrated Water Resources Management Plans: Training Manual and Operational Guide. Cap-Net: Delft, The Netherlands.

Cap-Net (2008) Integrated Water Resources Management for River Basin Organisations: Training Manual and Facilitators' Guide. Cap-Net: Pretoria, South Africa.

CPWC (2009) Planning Better WRM. Perspective Paper on Water and Climate Change Adaptation. The Co-operative Programme on Water and Climate (CPWC): Den Haag, The Netherlands. http://www.waterandclimate.org/index.php?id=5thWorldWaterForumpublications810

CPWC (2009) Small Island Countries. Perspective Paper on Water and Climate Change Adaptation.

CPWC (2009) Transboundary Water Management. Perspective Paper on Water and Climate Change Adaptation.

CPWC (2009) Water Resources and Services. Perspective Paper on Water and Climate Change Adaptation.

Global Water Partnership (2009) Better Water Resources Management - Greater Resilience Today, More Effective Adaptation Tomorrow. Perspectives on water and climate change adaptation. GWP: Stockholm, Sweden.

If local authorities, communities and interest groups are essential for adequate adaptation to climate change and the needs of vulnerable groups are to be addressed, how is this to be considered in scenarios and strategies developed by central governments?

Part 2

Facilitator's 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	**IWRM principles and concepts are introduced and the way IWRM may help addressing climate change adaptation will be discussed in this session.** **Presentation is followed by group discussion.**
13:30 – 14:30	Understanding drivers and impacts of climate change – Drivers	**Introduction and discussion** *The physical science basis of climate change and the associated drivers are introduced.*
14:30 – 15:30	**Group discussion**	**Random groups – report back**
16:00 – 17:30	**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.**

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	Strategy development and planning for adaptation	*Introduction and discussion* What basic principles can be employed for adaptation planning in the water context? Processes that have been developed for preparing adaptation strategies and projects, and examples of adaptation planning are discussed.
11:00 – 12:30	Exercise	Groups formed according to 4 cases – define ToRs 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.
15:30 – 17:30	**Exercise**	Same groups as previous session discuss impacts on: Case 1 – agriculture and rural floods Case 2 – navigation and agriculture Case 3 – infrastructure and urban floods Case 4 – ecosystems and fisheries.

Day 3

Time	Topic	Content
08:30 – 09:00	Recap of previous day	
09:00 – 10:30	Techniques for assessing impacts	*Introduction and discussion* Building on the previous session, new techniques for assessing the identified impacts will be introduced.
11:00 – 12:30	Dealing with uncertainties	*Introduction and discussion* Introduction to the various aspects that add to the uncertainties when dealing with climate change and how this can be included in environmental management approaches. Includes a presentation of prediction and resilient oriented approaches as two different approaches in 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	The 4 groups design and plan a risk assessment dealing with uncertainties strategy using the climate vulnerability indices for their respective cases.
11:00 – 12:30	Instruments and measures for adaptation	*Introduction and discussion* Overview of adaptation measures and their typology.
13:30 – 15:00	Exercise	The 4 groups propose adaptation measures for their respective cases.
15:30 – 18:00	Role play	

Day 5

Time	Topic	Content
08:30 – 09:00	Recap of previous day	
09:00 – 10:30	Adaptation to climate change in water management	*Introduction and discussion* The session addresses water resources management instruments available and how they can help addressing climate change. It considers the phases in a planning process and where adaptation can fit in. It also matches adaptation measures with water resources management functions
11:00 – 12:30	Exercise	The 4 groups are challenged to strategize and incorporate adaptation in water resources management planning.
13:30 – 14:30	- cont'd -	Working groups
14:30 – 15:30	- cont'd -	Reporting back and discussion
16:00 – 16:30	General discussion	Lessons to be taken home
16:30 – 17:30	Course evaluation and closure	

SESSION OUTLINES

Session 1

Title: Introduction to integrated water resources management (IWRM) and climate change

Learning objectives
At the end of this session, participants will:
Be able to describe the meaning of IWRM and its main principles;
Understand the main reasons for taking an IWRM approach;
Be aware of 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 the question 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: 1 hr 30 minutes

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

Having gone through the basic principles of IWRM, you will probably be able to assess the situation in your own country when it comes to implementation of IWRM. Some of the questions you may want to answer are:

- What is the evidence of commitment to IWRM in your country?
- Is there any adoption of water management principles in your country?
- How are men and women affected differently by changes in water resources 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;
- Be aware of the language used by IPCC to communicate confidence and uncertainty;
- Understand the basis behind the Special Report of Emission Scenarios;
- Be able to identify climate change impacts on the water cycle, ecosystems and water use.

Needs/requirements for the session
Computer and projector
Breakout space

Short summary
It is imperative to understand the physical science basis of climate change and the associated drivers before looking into their possible consequences. Water, as the life-giving resource and the one that will be most affected by climate change, needs special attention. Water managers need to understand how climate change is going to impact water resources and ecosystems and how this may affect water use.

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?
- What do you think will be future changes and how might they 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;
- 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
The session sheds light on the question of which basic principles can be employed for adaptation planning in the water context. Also explored are the processes that have been developed for preparing adaptation strategies and projects. The session will further explore and discuss an example of adaptation planning, especially how those principles can be transposed to a national adaptation project context.

Time allocation
Presentation: 40 minutes
Discussion: 20 minutes
Exercise: 120 minutes
Total: 3 hrs

Exercise
Group exercise and presentation to plenary.

- See exercise description and sample solution.

Session 4

Title: Impacts of climate change on water use sectors

Learning objectives
At the end of this session, participants will:
- Understand the implications of climate change for water resources by world region;
- Be able to explain the expected consequences of climate change for major water use sectors;
- Understand the different CCIAV frameworks;
- Understand various methods to generate climate scenarios.

Needs/requirements for the session
Computer and projector
Breakout space

Short summary
Impacts of climate change are not expected to be uniform and will vary over different geographic regions. The session discusses the climate change impacts on water resources at global and the regional levels. The expected impacts for various water use sectors are also highlighted.

The IPCC identified several frameworks to assess climate change impacts, organized collectively under the umbrella term Climate Change Impact, Adaptation and Vulnerability Assessment (CCIAV). In the majority of CCIAV studies, climate scenarios are projected using General Circulation Models (GCMs) based on socio-economic storylines. Climate scenarios are then processed via different models to assess the impact on water resources systems to support adaptation planning.

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
Case descriptions are provided in the exercises section. The participants will be split in four groups following descriptions of the cases. The groups will then 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 5

Title: Dealing with uncertainties

Learning objectives
At the end of this session, participants will:
- Understand the various types of uncertainties involved in dealing with climate change;
- Be aware of the consequences uncertainty has for environmental management;
- Be able to explain the differences between prediction- and resilience-oriented approaches and to illustrate this with examples.

Needs/requirements for the session
Computer and projector
Breakout space

Short summary
A short introduction is given on the various aspects that add to the uncertainties when dealing with climate change and how this can be included in environmental management approaches. Prediction- and resilient-oriented approaches are presented as two different ways to addres climate change adaptation. They are illustrated with some examples.

Time allocation
Introduction and discussion: 90 minutes
Exercise and plenary presentations combined with exercise on techniques for assessing impacts: 90 minutes
Total: 3 hrs

Exercise
Based on the 4 cases, the same groups will carry out a risk assessment, using the CVI presented below in the next section. They will then identify major uncertainties.

Session 6

Title: Instruments and measures for adaptation

Learning objectives
At the end of this session, participants will be able to:
- Understand the concept of adaptation to climate change and variability;
- Explain the difference between adaptation and mitigation and provide arguments for why adaptation to climate change and variability is necessary;
- Distinguish various typologies of adaptation options;
- Identify possible adaptation measures for various sectors and climate change impacts.

Needs/requirements for the session
Presentation equipment
Flip charts or other group exercise reporting tools (e.g. laptops)
Breakout space

Short summary
The session will provide the participants with an overview of adaptation measures and their typology. In a group exercise they will propose realistic adaptation measures for selected cases (provided) or, alternatively, within their own country/region.

Time allocation
Presentation: 40 minutes
Discussion: 50 minutes
Exercise: 90 minutes
Total: 3 hrs

Exercise
Group discussion and presentations. Use the same groups as in earlier exercises to consistently work with different aspects of one case per group. The groups propose suitable instruments and measures for adaptation as presented for their respective cases.

Session 7

Title: Adaptation to climate change in water management

Learning objectives
At the end of the session participants will be able to:
- Understand the water resources 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
IWRM aims to ensure that communities are provided with access to sufficient resources, that water is available for productive use and that the environmental function of water is secured. On all three scores, management is challenged by climate variability manifestations and these have to be considered when setting out management strategies.

To do so, adaptation to climate variability has to be incorporated into water resources management planning.

The session addresses water resources management instruments available and how they can help address climate change. It considers the phases in a planning process and where adaptation can fit in. It also matches adaptation measures with water resources management functions. Finally, the participants are challenged to strategize and incorporate adaptation into water resources 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.

EXERCISES

Session 3: Strategy development and planning for adaptation

Exercise 1

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 laid 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 resources planning;
  - Operation of water infrastructures, and
  - 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 from 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 (Inter-ministerial Coordination Group) and develop mechanisms to obtain inputs from other sectors. The Working Group will be responsible for providing following climate information for use by other groups:
(i) GCMs Scenarios/database;
(ii) Downscaling and Regional Climate Models;
(iii) Climate and ocean interaction modelling for sea roughness;

(iv) Seasonal climate outlooks;
(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 compiling of available data;
(ii) Assessment of data needs;
(iii) Building platform for data sharing and management;
(iv) Assessment of data gaps; and
(v) Recommendations on strengthening monitoring network for future needs and monitoring 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 the 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 following actions to study impacts of climate change on groundwater:

(i) Groundwater recharge and its quality;
(ii) Groundwater/freshwater interface in the 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 the Working Group 1 (Climate Information Group) and Working Group 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 mechanism and inputs for mainstreaming the climate risk information generated in:

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

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 the lakes;
(iv) Outlets of rivers and lagoons;
(v) Coastal erosion;
(vi) Impacts on coastal protection works; and
(vii) Infrastructure in costal areas.

Working group 8: System Operation and Maintenance Group

Terms of Reference: The Group will be responsible for assessing the sensitivity of following water infrastructure structures to impacts of climate change in water availability:
(i) Dams;
(ii) Infrastructure (barrages, bridges, pump houses, etc.); and
(iii) Canals; and
(iv) Drainage systems.

Working group 9: Information and Awareness Group

Terms of Reference: Working Groups 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 users associations to achieve the above.

Working Group 10: Inter-ministerial Coordination Group

Terms of reference: The Group will be responsible to interact with 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.

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				

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 of 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 losses 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 a deviation of development funds 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), with generally 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 mega city 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 of some lower parts of the city. This has resulted in overflow of sewer systems and 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, forcing further developments in high-risk areas.

Case 4:

A river basin is situated in a tropical developing country in SE 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 important 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.

Session 4: Impacts of climate change on water use sectors

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 5: Dealing with uncertainties

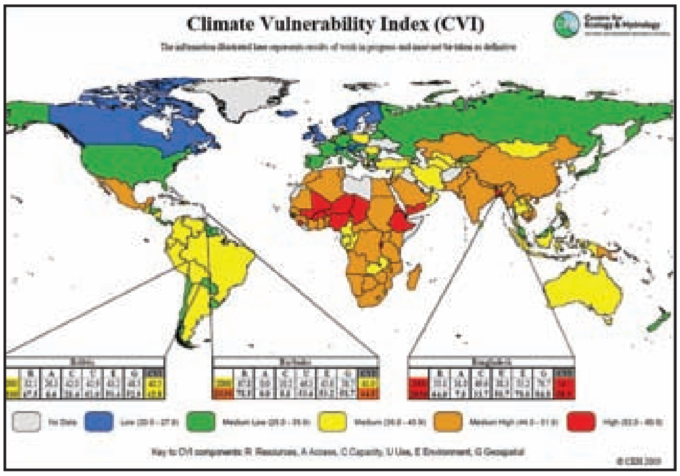
For the four cases the same groups will carry out a risk assessment, using the Climate Vulnerability Index (CVI). Identify major uncertainties.

The Climate Vulnerability Index

The 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 below.

CVI component	Sub-components/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 land slips ● degree of isolation from other water resources and/or food sources ● deforestation, desertfication and/or soil erosion rates ● degree of land conversion from natural vegetation ● deglaciation and risk of glacial lake outburst



Source: Sullivan and Meigh, 2005

Session 6: Instruments and measures for adaptation

Each group is assigned to one of the case studies (above) 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. Use these impacts to define a set of measures that need to be considered in adapting to the projected impacts and explain for each measure what should be the intended effect. This set of measures preferably should exist of a combination

of policy measures, technological measures and measures aiming at risk sharing.

3. Classify these measures according to Table 2 (lecture notes): 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.

Session 7: Incorporating Climate Change Adaptation in Water Resources Management Planning

Description:
The working groups of the previous exercises are expected to elaborate further 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 IWRM plans (2005)

Role Play: Lake Naivasha

Please read the following description of Lake Naivasha, Kenya from Wikipedia (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 km²; 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 km², and is surrounded by a swamp, which covers an area of 64 km², 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 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 northeast 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[1]: 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 as an observer. The responsibilities are presented in Table 1 below.

Table 1: Roles and responsibilities of the participants

Role	Responsibility
Stakeholder	● Prepares goals and a strategy for the meeting together with 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 strategy, 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 realises that they are acting.

Based on the information in Table 2[2] 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 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. The 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).

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[1] 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, Nairobi and Lake Naivasha Riparian Association, Naivasha. 78 pp.

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

Table 2: The characteristics of the stakeholders

Stakeholder	Characteristics[3]
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 ● Over-confident ● Wants to leave the meeting with an agreement
Small-scale farmers' association	● Know the area very well, lived there for generations ● Realize the need for restrictions ● Feel restrictions should mainly (if not only) apply to the floriculturists ● Do not like the floriculturists and feel that these foreign-owned companies do not care about the lake at all ● Believe 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 the LNRA ● Thinks the large industries should not abstract water from this vulnerable ecosystem (floriculturists) ● 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 they are '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 sensitive 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 ● Feel overlooked
KMFRI	● Has a permanent station on the lake ● Economic and scientific interest ● Lake offers good potential for international research cooperation ● Knows that the floriculturists are close to potential European donors (EU, Dutch government) ● Historical link to the fisheries ● Very worried about the potential effects of climate change on the ecology of the lake

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 suggestions on slips of paper, and hand these to their respective stakeholders. The 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.

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[3] Are fictive and do not always reflect reality

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.

PLANNING A WORKSHOP AND DEVELOPING TRAINING SKILLS

Content:

- What to consider when planning a workshop
- Dynamics and energizers
- Icebreaking
- 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 to do 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 opportunity 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. Following 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 working

group sessions, layout of the meeting room, access to internet, air conditioning, 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 as part of the learning process.
- Plan daily recaps to evaluate the activities and understanding by the participants, 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 basin level making use of the programme and materials of the training just conducted on IWRM and climate change.
3. You need to identify:
    - Target group;
    - 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;
    - Prepare a presentation to share in plenary.

Some icebreaking / 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.

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, like lake, river, rain, spring, etc. You can use colours or other references. You can also give the participants a chocolate or candy with 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 person (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.

Animal card (30 minutes)

You can distribute cards with images of animal in pairs, or use opposite cards and ask to the participants to meet with the other person who has the matching card. Each one has to introduce the other participant to the plenary telling 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 to the participants to give you something that must be important to them; avoid pencils or pens and instead suggest eyeglasses (in their case), driver’s license, rings, watches, etc. When you get all the treasures in the bag, draw one and ask to the owner to say his or her name and to 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 and colourful ball to toss around and to ask the participants to stand up and present themselves one by one, as they catch the ball. Assure that all the participants receive the ball. You can also use the same exercise when the people 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 person next to the beginner 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 put them on a large paper sheet on the wall, assigning a number to each picture and prepare a big envelop on the side; keep them there until the last day. The participants must identify each of the participants from their baby picture, 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 counter-clockwise.” 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. When 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 have everyone 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!

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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.

Aquifers
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 and ozone (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 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 carbon dioxide (CO_2) from large point sources such as fossil fuel power plants. In this way, the carbon dioxide 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 the United Nations Framework Convention on Climate Change (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 a 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 hydrologic 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 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. The Intergovernmental Panel on Climate Change (IPCC) concludes that anthropogenic greenhouse gases are responsible for most of the observed temperature increase since the middle of the twentieth 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 greenhouse gases, or to the enhanced (anthropogenic) greenhouse gases, which results from gases emitted as a result of 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), carbon dioxide (CO_2), nitrous oxide (NO_2), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. The Kyoto Protocol (see below) addresses CO_2, N_2O and CH_4, and also the greenhouse gases sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) (see Chapter 2 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 or moving water; it may be harnessed for purposes such as commercial electric power.

Hydrosphere
As defined in physical geography, the zone continuing 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 Conference of the Parties (COP) to the UN Framework Convention on Climate Change (UNFCCC) in 1997 in Kyoto, Japan. It contains legally binding commitments, in addition to those included in the UNFCC. Countries included in Annex B of the Protocol (most member countries of the Organization for Economic Cooperation and Development (OECD) and those with economies in transition) agreed to reduce their anthropogenic greenhouse gas 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 characterise 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 United Nations International Strategy for Disaster Reduction (UNISDR), non-structural measures are defined as any measure not involving physical construc-

tion, 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 0ºC.

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, and 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 practiced 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.

Acronyms

AOGCM	Atmosphere-Ocean Global Circulation Models
APF	Adaptation Policy Framework
Cap-Net	International Network for Capacity Building in Integrated Water Resource Management
CCIAV	Climate Change Impact, Adaptation and Vulnerability
CFCs	chlorofluorocarbons
CH_4	methane
CO_2	carbon dioxide
CVI	Climate Vulnerability Index
δD	deuterium
DFID	United Kingdom Department for International Development
FAO	Food and Agriculture Organization of the United Nations
GCMs	Global Circulation Models
GHG	greenhouse gases
GWA	Gender and Water Alliance
GWP	Global Water Partnership
H_2O	water
HEC	Hydrologic Engineering Center
IFM	Integrated Flood Management
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resources Management
LDCs	Least Developed Countries
LOSU	level of scientific understanding
MDGs	Millennium Development Goals
MFW	marine and freshwater
N_2O	nitrous oxide
NGOs	non-governmental organizations
NAPAs	National Adaptation Programmes of Action
ppm	parts per million
PR	Polar Regions
RBO	River Basin Organization
RF	radiative forcing
SRES	Special Report of Emission Scenarios
SWAT	Soil and Water Assessment Tools
TER	terrestrial
UN	United Nations

UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNESCO-IHE	United Nations Educational, Scientific and Cultural Organisation Institute for Water Education
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children’s Fund
WEAP	Water Evaluation and Planning
WHO	World Health Organization
WMO	World Meteorological Organization