Climate Change Adaptation in Human Settlements Using Integrated Water Resources Management Tools

Human Settlements

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Acronyms

ACSAD	Arab Center for the Studies of Arid Zones and Dry Lands
ACWUA	Arab Countries Water Utilities Association
ESCWA	Economic and Social Commission for Western Asia
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
IDF	intensity-duration-frequency
IWRM	integrated water resources management
MAR	managed aquifer recharge
MCM	million cubic metres
MDG	Millennium Development Goal
MENA	Middle East and North Africa
NRW	non-revenue water
PPP	public-private partnership
PSP	private sector participation
PV	photovoltaic
RCP	representative concentration pathway
RICCAR	Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region
SDG	Sustainable Development Goal
SSA	Storm and Sanitary Analysis
UN Environment	United Nations Environment Programme
UNICEF	United Nations Children's Fund
UNISDR	United Nations Office for Disaster Risk Reduction
WFP	water footprint
WHO/CEHA	World Health Organization Centre for Environmental Health Activities

CH. 1

Introduction

Cairo from plane. © Carol Chouchani Cherfane

CH. 1

Introduction

About the training manual

The training manual has been developed as part of the United Nations Development Account Project on developing the capacities of Arab countries for climate change adaptation by applying integrated water resources management (IWRM) tools. The project aims to provide a set of regionally appropriate IWRM tools for supporting climate change adaptation in five key sectors, namely agriculture, economic development, environment, health and human settlements. The training manual includes five modules, each on one of these selected sectors.

The project was led by the United Nations Economic and Social Commission for Western Asia (ESCWA), in cooperation with the United Nations Environment Programme Regional Office for West Asia (UN Environment), and was implemented in partnership with the following organizations for three out of the five modules:

- Agriculture module: Arab Centre for the Studies of Arid Zones and Dry Lands (ACSAD) and Deutsche Gesellschaft für Internationale Zusammenarbeit (German Agency for International Cooperation, GIZ);
- Health module: World Health Organization Centre for Environmental Health Activities (WHO/CEHA);
- Human settlements module: Arab Countries Water Utilities Association (ACWUA).

The Environment module and the Economic development module were prepared by UN Environment and ESCWA, respectively. This UNDA project builds on the results of the Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR) that is coordinated by ESCWA and implemented by the League of Arab States (LAS), United Nations organizations, and specialized partners.

Sector background

In the decades to come, climate change may make tens of millions of Arab urban residents, in particular the poorest and most marginalized, increasingly vulnerable to floods, landslides, extreme weather events and other natural disasters. City dwellers may also face reduced access to freshwater as a result of drought. Sustainable Development Goal (SDG) 11 on human settlements includes targets related to access to adequate, safe and affordable housing, basic services and transport systems. It also addresses water and sanitation services (target 11.1) and water-related disasters (target 11.5). Universal access to safely managed water and sanitation services under water-scarce conditions, including for vulnerable groups, are addressed in SDG-6. This demonstrates the cross-cutting nature of water issues within the SDGs and the need to consider the achievement of water-related goals and targets from a nexus perspective. Linkages that connect the human settlements-oriented SDG 11 to other goals, targets and indicators should be extracted and analysed.

Regional experience in data collection and reporting on the water-related indicators, for example in the context of the MDG+ Initiative, can inform Arab preparation and follow-up on the water-related SDGs. The MDG+ Initiative was launched by the Arab Ministerial Water Council in 2010 to monitor and report on water supply, sanitation and wastewater treatment in Arab States. It specifically aims to monitor and report on water consumption; drinking water quality; accessibility; affordability; continuity of supply; and sanitation-related indicators such as accessibility, affordability, and wastewater treatment, including types of treatment, and reuse. The challenges introduced by climate change will add more pressure on water supply, sanitation services and stormwater drainage systems, which will be particularly vulnerable to extreme weather events across urban areas of the Arab countries.

Climate change is expected to produce extreme weather events, such as increases in the intensity and frequency of heavy precipitation, floods and droughts. RICCAR outputs indicate that there will be lower precipitation rates, higher temperature degrees, and more frequent and more extended extreme events such as sand storms, heatwaves and flash rainfall storms across the Arab region. There are numerous physical risks associated with climate change that Arab urban settlements will have to confront and adapt to, including:

- Sealevel rise
- Heavy precipitation events and flooding
- Landslides
- Tropical cyclones
- Extreme heat events
- Sand storms
- Drought

Such extreme weather events induced by future changes in climate will certainly alter various livelihood aspects for residents of Arab cities.

The IWRM field provides a set of tools and measures that can help cities and urban centres to adapt to the impacts of climate change.

In this module, a set of IWRM measures and tools will be outlined and discussed, with a view to achieving a better adaptive capacity of Arab human settlements to extreme weather events and addressing the following key issues:

- Increasing resilience to water-related disasters, such as floods, stormwater management and droughts, which can affect the delivery of water supply and sanitation;
- Universal access to water and sanitation services under water-scarce conditions, including for vulnerable groups such as refugees, migrants and people living under occupation.

Training objectives and methodology

This training is designed to bring together, in a highly interactive setting, a group of 25-30 professionals (see below for targeted stakeholders), in order to develop the capacities of the Arab countries in the area of climate change adaptation, with a specific focus on the water sector, to protect human settlements.

The expectation is that participants taking part in the training have an acceptable understanding of IWRM. The material is designed to support a facilitated, multi-day

workshop that will empower participants to understand the tools and concepts needed to build programmes, direct staff and allocate resources as they develop and integrate IWRM as a concept for adaptation to climate change in the water sector in the Arab region. In addition, participants will have a comprehensive exposure on the water-related impacts of climate change on human settlements in the Arab region.

The training material presents basic facts on the relationship between the water sector and human settlements, IWRM tools and other modern tools needed to adapt to future conditions, prioritization of adaptation measures and implementation considerations. Case studies and exercises from the Arab region are incorporated so that trainees may learn from experiences of 'real world' projects and programmes. Specific objectives of this human settlements module are:

- To increase understanding of government officials and regional stakeholders of the impact of climate change on water resources;
- To frame the linkages between climate change, the water sector and human settlements;
- To review the vulnerability assessment protocols and indicators in the water sector;
- To enhance government capacity to incorporate IWRM tools into strategies, policies, plans and programmes of water management, in order to be better prepared for future climatic conditions (i.e. climate change adaptation);
- To present tools for adaptation in the water sector in order to protect human settlements;
- To review the governance framework and implementation mechanisms towards identifying the needed adaptation interventions for the sector.

Targeted stakeholders

With water resources intersecting many sectors, and given the myriad forms of governmental institutions dealing with policymaking, planning and implementation, this training module benefits a wide variety of officials from the public sector, academia, non-governmental organizations and the private sector. The module will also benefit those interested to learn about the different aspects of climate change impacts on water resources, the associated linkages to human settlements and the use of IWRM as a tool for climate change adaptation in these two sectors. The following target groups should find this module of particular interest:

- Decision makers and technical staff in the water and human settlement sectors who are concerned with the human settlements dimensions of climate change and with developing and implementing policies, programmes or projects;
- Decision makers and technical staff in other government sectors concerned with water and human settlements dimensions of climate change (such as spatial planning, environment, agriculture, food, disaster risk reduction, transport, industry, labour, education, etc.);
- Stakeholders involved in the development and implementation of national adaptation plans and national adaptation programmes of action, nationally appropriate mitigation actions and national communications;
- Representatives involved in the global United Nations Framework Convention on Climate Change process, such as negotiators and focal points;
- General human settlements and water sector staff and other professionals providing water and human settlement services;
- Professionals in the water and sanitation utilities field;
- Vulnerable population groups, including women;

- Civil society and local community representatives;
- Non-governmental organization experts active in the area of climate change and/or water and human settlements;
- Academics, scientists and researchers working on climate change adaptation in the water and human settlements sectors.

Module content

In addition to this introductory chapter, the module consists of the following chapters:

Chapter 2, on the current problems facing human settlements in the Arab region, whether due to water resources, population growth, urbanization or displacement, as well as problems with the physical infrastructure;
Chapter 3, on the impacts of climate change on human settlements, featuring an overview of vulnerability assessment and RICCAR indicators and outputs that feed into the identification of adaptation measures, with examples of impact assessment tools;
Chapter 4, on the adaptation measures available for combating ongoing or expected climate change impacts on human settlements, and a discussion of IWRM tools;
Chapter 5, on screening criteria for adaptation measures, adaptation planning at different levels and other issues pertaining to implementation of adaptation measures;
Chapter 6, on measuring and reporting progress of climate change adaptation.

The module ends with a list of the references that supported the preparation of this module and selected further readings that may be of interest.

CH. 2

Framing Sectoral Problems

Framing Sectoral Problems

Water resources, water supply and sanitation systems are directly impacted by climate change in most Arab human settlements. The management of these resources and services affects the vulnerability of ecosystems, socioeconomic activities and human health. Strategies and policies for managing water and sanitation should be adapted to new climate change realities.

Problems associated with water resources

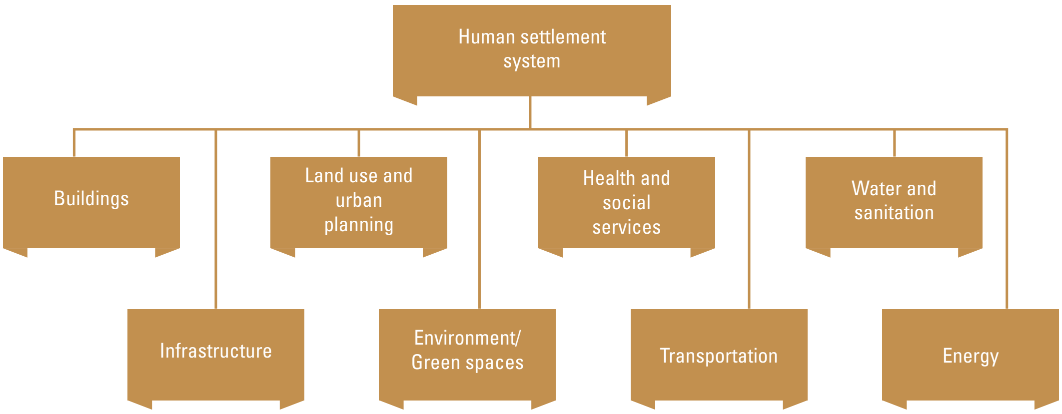
The Arab region is classified as arid to semi-arid and it is indeed the poorest in freshwater resources worldwide. As the population will continue to grow at high rates, a significant decline is projected in available freshwater resources per capita in all Arab countries.

Almost 75 per cent of the Arab population live under the water poverty level (1,000 cubic metres (m^3) per capita annually) and nearly half of them are under extreme water scarcity (500 m^3 per capita annually).

Box 1. Human settlement system in the Arab region

Even without the impacts of climate change, human settlements in the Arab region face many natural, governance and socio-economic problems, which differ in magnitude between and within countries. When considering the different components of the human settlements environment in a thematic way, one can represent the human settlement system as follows:

Representation of the human settlement system



In Egypt for example, the rapid growth of population is associated with a decline of the per capita availability of freshwater resources and the population already lives below the water poverty line of 1,000 m^3 per capita.

The water sector in the Arab region suffers from chronic problems, common to most countries, and faces many challenges in terms of water supply and sanitation services, including:

- Limited water resources, leading to a large gap between available resources and increasing demand for water due to the high rate of population growth, rapid urbanization and economic development;
- Impact of Political instability and conflict, leading to internal and external migration, an increased demand for water in host countries and damaged infrastructure;
- Centralized management of water utilities, especially in terms of planning, tariff determination, and laws and regulations of water utilities (as well as employment regulations);
- Increased shifting/move of professional staff from the public sector to the private sector within the same country or from one country to another;
- Limited financial allocations in many facilities for training and capacity-building, technology transfer, and limited financial resources for the implementation of mega projects in water supply and sewage treatment plants;
- Lending ceiling beyond which some Arab countries cannot structure any more loans to implement water projects;
- Very limited initiatives from the national private sector to finance strategic projects.

Problems arising from population growth and urbanization

The Arab region is one of the most urbanized. As of 2010, the Arab countries were home to 357 million residents, 56 per cent of whom lived in cities; by 2050, these countries will be home to 646 million people, 68 per cent of whom will live in cities (UN-Habitat, 2012).

The urban population in Arab countries grew by more than four times from 1970 to 2010 and will more than double again from 2010 to 2050. Most of the growth to date has taken place on the peripheries of each country's primary cities although, today, secondary cities are experiencing the fastest rate of growth (UN-Habitat, 2012).

Problems associated with infrastructure

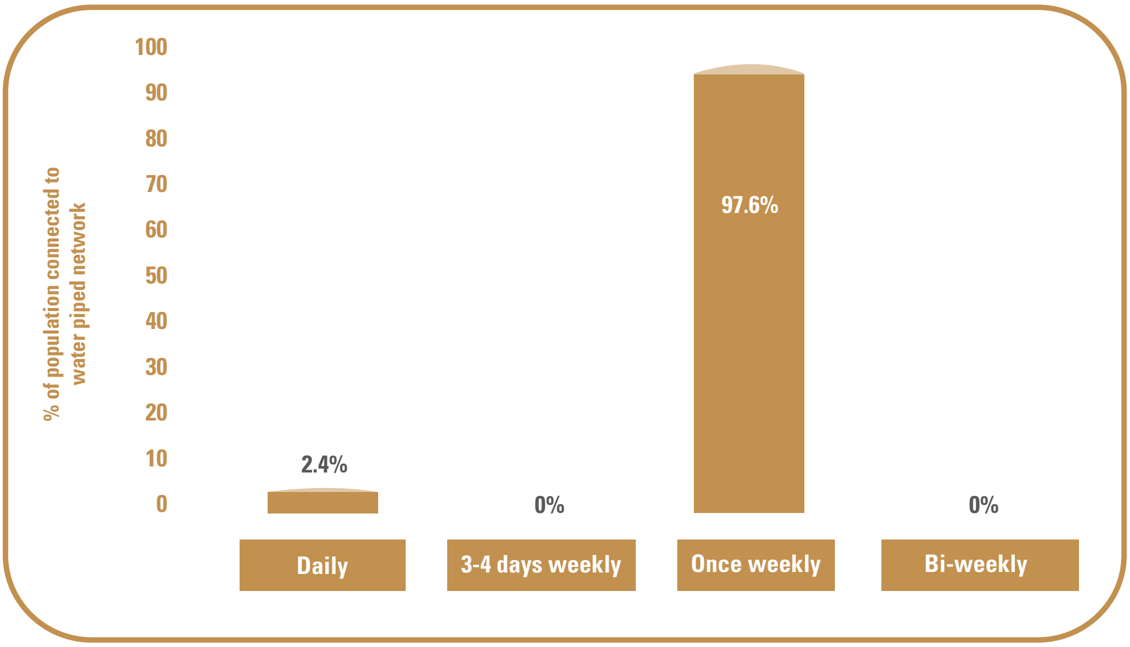
The following are examples of problems associated with the physical infrastructure in many countries in the Arab region.

Intermittent water supply

In many Arab countries such as Jordan, Lebanon, the State of Palestine and Yemen, water distribution systems and pipe networks serving human settlements are not flowing with water continuously, because of water scarcity and energy shortages. In Jordan, 97.6 per cent of the population connected to the water piped network receive water once per week (figure 1).

This results in inconsistent and higher pressures on pipe joints and valves, and consequently in more water losses as unaccounted-for water.

Figure 1. Continuity of water supply in Jordan



Source: League of Arab States, ESCWA and ACWUA, 2015.

Many urban areas in the Arab region deal with water scarcity by rationing/scheduling through intermittent supply. This implies the following:

- Need for water storage at the household level, which incurs financial burdens on the households due to:
  - Cost of underground cisterns, pumps and roof water cisterns ;
  - Extra cost for maintenance of the storage cisterns, pipes and pumps.
- Reliance on water tankers;
- Water quality problems associated with storage;
- Water quality problems associated with unknown sources of tanker water (illegal groundwater wells, for example).

Therefore, intermittent supply puts household water security at stake in many Arab cities, such as Amman and Sana'a.

Climate change will have an impact on the availability of water resources and water supply, which will increase the challenge of providing reliable water services in water-scarce Arab countries.

Cross-contamination is another consequence of intermittent supply. This results from the zero-pressure status when pipes are empty and exposed to inflow of polluted water through pipe cracks and bad joints. This problem can worsen during events of intense rainfall caused by climate change.

Elevated temperatures projected by RICCAR will also raise real concerns about chemical and microbiological quality of potable water supplies in storage reservoirs, elevated tanks and pipes. Algal growth should be expected in reservoirs under higher temperature scenarios. In water supply pipes, re-growth phenomena might be exacerbated and oxidation-reduction of water can be altered.

Water efficiency

Non-revenue water (NRW) is water that has been produced and lost before it reaches the customer. Losses can be real losses (through leaks, sometimes also referred to as physical losses) or apparent losses (for example, through theft or metering inaccuracies). High levels of NRW are detrimental to the financial viability of water utilities.

In Arab countries, the level of NRW is very high (table 1) and more so than in other parts of the world.Many Arab cities have adopted public private partnerships (PPPs) to shift water utilities from governmental administration to private sector, commercially based management. One main promise of this transformation has been to cut down on unaccounted-for water.

Table 1. Water losses in the water supply distribution system in selected Arab countries, 2005

Country	% of loss
Bahrain	15
Egypt	50
Iraq	50
Jordan	50
Kuwait	8-10
Lebanon	50
Oman	23
Palestine	40
Saudi Arabia	25-40
Syrian Arab republic	48
Yemen	30

Source: Food and Agriculture Organization of the United Nations (FAO), AQUASTAT. Available from http://www.fao.org/nr/water/aquastat/main/index.stm (accessed 24 January 2017).

Status of storm and wastewater infrastructure in Arab cities

While wastewater collection has largely improved in the Arab region, wastewater treatment varies significantly between Arab countries (table 2). In addition, the use of onsite wastewater disposal facilities, such as septic tanks and cesspits, is common practice in rural areas in the region and puts additional constraints on the collection, treatment and reuse of wastewater (League of Arab States, ESCWA and ACWUA, 2016).
Management and effectiveness of the water and sanitation infrastructure across the Arab region are not satisfactory. Many governments still wholly rely on foreign aid and loans to implement and maintain such crucial infrastructure, such as in Egypt, Jordan, Lebanon, Morocco and Yemen. Moreover, responsibilities for setting and regulating standards are split between different national authorities. There are no guidelines on the selection of the most cost-effective wastewater treatment techniques that are more appropriate for the regional arid and semi-arid climate conditions (for example, aerobic vs. anaerobic treatment). There are also no policies for systematic reuse of treated wastewater.

Oil-rich Gulf Cooperation Council (GCC) countries have been able to build impressive water infrastructure in most urban areas. However, even resource-rich cities such as Jeddah, face real challenges in terms of stormwater drainage infrastructure. In addition, the increase in impervious surfaces in urban settlements and inadequate stormwater drainage systems have overloaded drainage networks, which are unable to drain increased volumes during extreme rainfall events. Inadequate and ineffective operation and management of drainage systems result in an increased frequency of urban flood events, as witnessed in recent years in many Arab countries, such as Egypt, GCC countries, Lebanon, State of Palestine and Yemen. This has generated economic and environmental risks related to destroyed and damaged roads, vehicles, ports, houses, ecosystems and coastal areas.

Table 2. Proportion of population using sanitation systems, 2012 or 2013 (percentage)

Country	Sewerage systems		On-site sanitation facilities	
	Urban (%)	Rural (%)	Urban (%)	Rural (%)
Algeria (2013)	84.6	NA	5.4	NA
Bahrain (2013)	86.8	NA	13.4	NA
Egypt (2013)	91.9	29.5	8.1	70.5
Iraq (2012)	40.4	0	59.6	100
Jordan (2013)	70.1	NA	29.9	NA
Kuwait (2012)	98.4	NA	1.6	NA
Lebanon (2013)	DN	DN	DN	DN
Libya (2012)	56.3	46.7	43.7	53.3
Mauritania (2013)	0.6	0	99.4	100
Morocco (2013)	88.2	1.3	11.8	98.7
Oman (2013)	17.5	NA	82.5	NA
Palestine (2013)	63	2.1	37	97.9
Qatar (2012)	94.3	NA	5.7	NA
Sudan (2013)	DN	DN	DN	DN
Saudi Arabia (2013)	53.8	NA	46.2	NA
Tunisia (2013)	87.5	10.3	12.5	89.7
United Arab Emirates (2013)	DN	NA	DN	NA
Yemen (2012)	36.7	29.7	63.3	70.3

Abbreviations: NA, not applicable (urban values represent urban and rural i.e. national values); DN, data not available.
Source: Compiled from the League of Arab States, ESCWA and ACWUA, 2016.
Notes: It is assumed that populations using on-site sanitation facilities are those not reported as being served by sewerage systems. No data were available for the Comoros, Djibouti, Somalia and the Syrian Arab Republic.

Problems arising from displacement and forced migration

Urbanization is driven by economic development, migration to the oil-rich countries, drought and displacement due to conflict. As of 2010, there were 7.4 million registered refugees in Arab countries, most of them Palestinians and Iraqis living in Jordan and the Syrian Arab Republic; 9.8 million internally displaced persons, mostly in Iraq, Lebanon, Somalia, the Sudan, the Syrian Arab Republic and Yemen; and 15 million international migrants in GCC countries, living mostly in cities and representing one third of the subregion's population (UN-Habitat, 2012). Moreover, the impacts of climate change, including temperature increases and frequency of droughts, may lead to further rural-urban migration due to poverty. Migrants may lack the skills needed to earn a high salary that would enable them to live in built urban settlements. Thus, they end up living in informal peri-urban settlements with serious infrastructure problems, ranging from an unhealthy environment to difficult access to water, energy, transportation, communications and shelter. In some Arab countries, informal settlements and slum dwellings form isolated, marginalized pockets, while in others, 67-94 per cent of urban residents live under one or more housing deprivation. In some Gulf countries, for instance, housing conditions of low-income migrant workers are often very poor compared with those of the rest of the urban population (UN-Habitat, 2012).

Several Arab countries have been in political and security turmoil since 2011. Wars have resulted in massive destruction of urban infrastructure, such as in Iraq, Libya, the Syrian Arab Republic and Yemen, and in unprecedented waves of migrants, especially from Iraq and the Syrian Arab Republic. This will increase pressure on water supply and sanitation services in the host urban areas, such as in the cities of Jordan and Lebanon.

Provision of water, sanitation and wastewater treatment for refugees in camps and informal settlements has become increasingly problematic in several Arab countries. Measures should be adopted to respond to this pressure, such as expansion and improvement of water supply and wastewater sewage networks in host areas.

The following exercise will focus on water and sanitation in the Za'atari Syrian refugee camp in North Jordan. The aim is that trainees gain experience in the use of IWRM tools in emergency scenarios.

Exercise 1. Za'atari refugee camp

Za'atari refugee camp hosts around 80000 Syrians who have been forced to flee the war in the Syrian Arab Republic. More than half of these refugees are children. The size of the camp, now Jordan's fourth biggest city, is presenting huge challenges for the camp's infrastructure.

Oxfam currently works in 3 of Za'atari's 12 districts, supervising, water and sanitation, refuse management and the cleaning and maintenance of wash blocks. Oxfam also coordinates hygiene promotion activities, which are crucial in preventing the spread of disease. Oxfam is working with UNICEF and other international actors, to install a water network in the camp that will ensure refugees have safe access to water. When the water network has been completed, it will be the largest ever to be constructed in a refugee camp.

As the camp transitions into a semi-permanent city, refugees are struggling to find work and create a livelihood for themselves and their families. Many refugees are surviving on humanitarian aid or working illegally.

Conduct a guided discussion administered by the trainer on how to use measures of IWRM to help this refugee city adapt to both climate change impacts and the camp situation. The main points of discussion are:
1. Governance
2. Financing
3. Access to safely managed water supply and sanitation systems
4. Environmental and health aspects
5. NRW and reuse
6. Siting of camp relative to groundwater and surface water basins

CH. 3

Impacts of Climate Change and Vulnerability Assessment

CH. 3

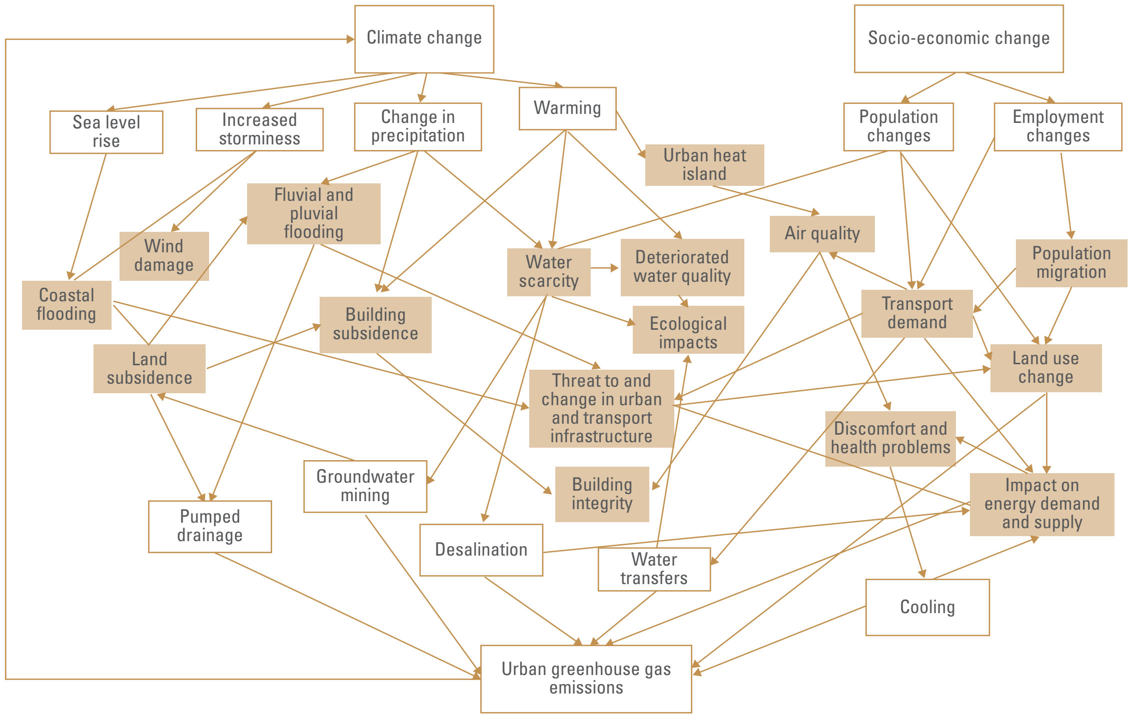
Impact of Climate Change and vulnerability assessment

> Water supply in Arab countries continues to face economic and governance challenges, in addition to the scarcity of the resource itself. Climate change will have an impact on the availability of water resources and eventually on the water balance and water supply, especially where water demand is rapidly increasing and the institutional system and water supply facilities are still insufficient.

Impacts of climate change on human settlements

Within human settlements, interactions occur through buildings, land use and infrastructure systems. Viewing human settlements as systems helps to avoid conflicts between the objectives of adaptation, mitigation, economic growth and sustainable development. Interactions between different human settlement functions and objectives occur at different physical scales and at a wide range of times cales. Figure 2 shows a sample of the processes whereby climate influences urban systems and urban functions interact. IWRM should take

Figure 2. Sample of interactions and interdependencies between climate change, adaptation and mitigation in cities



Source: Walsh and others, 2011, p. 79.

into account some of these complex interactions within a range of spatial and temporal scales to better address the problem of impact of climate change and vulnerability assessment.

Potential impacts of climate change on human settlements include the ones featured in table 3.

Table 3. Potential impacts of climate change on cities

Services provided by cities	Impacts of climate change
Coastal management	• Increased coastal erosion and inundation • Loss of private property/community assets • Loss of beach width • Changes to wetlands due to sea level rise, shoreline erosion and salt water intrusion • Loss of biodiversity linked to abduction of soil with natural habitats • Loss of areas affected by cultural heritage • Impacts on the infrastructure system for mobility and on coastal tourism
Stormwater/sewerage	• Inundation of stormwater and sewerage systems • Increased peak flows • Changes in groundwater levels • Changes in flood plains • Reduced dry weather sewerage flows • Reduced/unreliability of power supply for sewage pumping and treatment if existing • Electricity suppliers cannot maintain pace with long term changes in climate
Wastewater	• Changes in intensity of rainfall events impacting inflow and infiltration to wastewater • Network failure • Potential for blockages and dry weather overflows during dry spells
Water supply	• Changes in mean and peak stream and river flows • Uncertain water availability • Insufficient water supply in some areas • Increased potential for water contamination • Salinization of surface and groundwater supplies • Changes in availability of groundwater available for irrigation

Source: World Bank, 2011.

Additional sets of impacts are identified and assessed in the following sections.

Economic impacts

The expected extreme weather events will increase the vulnerability of urban economic assets and businesses. Climate change and extreme events will have direct and indirect impacts on city life in sectoral activities, such as:

- Industry and commerce;
- Tourism and recreation;
- Insurance: extreme weather events, such as heavy storms and flooding, could result in increasing demand for insurance while reducing insurability;
- Impacts on livelihood and ecosystem services.

Public health impacts

Climate change will increase the global and regional disease burden. At the city level, intense rainfall events and consequent flooding can raise public health concerns associated with flooded sewage collection and treatment infrastructure. Increased temperature can result in accelerated occurrence of algal blooms in water reservoirs and re-growth of pathogens within potable water pipe networks.

Social impacts

Slums and marginal communities are common in most Arab cities and these will unsurprisingly be the most vulnerable to climate change impacts. In addressing the social impacts in human settlements, issues that need to be investigated include:

- Poverty and unemployment;
- Gender issues;
- Concerns of specific age groups, such as children and the elderly;
- Concerns of ethnic and other minorities.

Exercise 2. Mapping potential climate change impacts at the country level

Step 1: Participants work in country groups as appropriate and draft a list of potential impacts in their countries, based on different climate change scenarios.

Step 2: Based on their observations, the same groups identify the potential governance and institutional weaknesses and gaps, and generate ideas for ways in which these gaps could be addressed and sensitivity and vulnerability could be strengthened.

Step 3: Groups prepare and present an example of climate change impacts from their countries using a news cutting, a story, a role-play, photographs, a map, or any other way to share their example. The learners will share their examples in small groups. Each participant should come up with a short title for his/her presentation and speak for 4-5 minutes. Each group is then asked to agree on one example to share in plenary. The plenary report should include a short description of the example, why they chose it and note anything participants have learned from sharing the examples. At the end of the exercise, when each group reports back, the short title for the example should be written on a card.

Displacement and forced migration

There are more and more "climate refugees" who have lost their homes or livelihoods due to environmental degradation, partially induced by climatic changes. This adds to the already high numbers of refugees in the Arab region that present a major challenge for many states in the region. What is more, many refugees are living in camps which, in turn, are highly vulnerable to extreme weather events that are increasingly occuring with climate change.

Vulnerability assessment

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as "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 variation to which a system is exposed, the sensitivity and adaptive capacity of that system" (IPCC, 2007).

ACSAD and others (2015) present an indicator-based approach to assess vulnerability by using regionally appropriate vulnerability indicators related to potential impact and adaptive capacity in the Arab region.

The indicators used under various components are classified using a scale of 1-10, with 1 indicating the most positive condition and 10 the most negative condition. Details of the methodology are found in ACSAD and others (2015). Understanding vulnerability to climate change requires therefore understanding its components: exposure to climate change, potential impacts (i.e. sensitivity and exposure) and adaptive capacity.

Exercise 3. Assessing vulnerability

Based on the observations of exercise 2, ask the learners to work in the same groups to assess the potential vulnerability, and identify how high vulnerability could be reduced, for example through strengthening adaptive capacity or reducing sensitivity. The learners will share their examples in small groups. Each participant should come up with a short title for his/her presentation and speak for 4-5 minutes.

RICCAR indicators and outputs that feed into the identification of adaptation measures

RICCAR outputs mainly outline a temperature rise and a reduction in the total rainfall amounts across the Arab region in the coming decades. Expected temperature changes to the middle of the century show an increase varying between 0.3 and 2.4°C in representative concentration pathways (RCP) 4.5, and 1.1 and 3.4°C in RCP8.5. The higher increases are expected to be witnessed in non-coastal areas, with the highest figures projected in the Sahara. Average monthly precipitation is expected to decrease in most of the Arab region.

Intense rainfall events, number of consecutive wet days and number of consecutive hot days are examples of parameters underlined by RICCAR outputs that human settlements

should deal with in their efforts to increase their capacity to adapt to climate change. The change in the summer days with T_{max}> 35°C for the period 2081-2100 from the baseline period 1986-2005 for RCP4.5 and RCP8.5 shows significant warming trends in both scenarios, reaching up to 80 days in the southern Arabian Peninsula and the western coast of Africa for RCP8.5 (United Nations and League of Arab States, 2015). The consequences of these results will be peaks of demand related to cooling systems and air conditioning.

Extreme weather events will mostly impact water and wastewater infrastructure in urban areas. In many Arab cities, flooding of sewer manholes is not uncommon due to several factors, including inefficient management and lack of funds to expand the sewage network at a rate close to the urbanization rate.

A set of tools within the IWRM field is available and should be used to help human settlements to adapt and reduce their vulnerability to extreme events under various scenarios of climate change. Such tools are detailed later in this module.

ACSAD and others (2015) present a methodology to assess vulnerability of key sectors to climate change impacts in the Arab region, such as changes in temperature, precipitation and run-off. It can also be adapted to examine droughts or flooding due to shifting rainfall patterns and extreme weather events.

Exercise 4. Mapping potential climate change scenarios at the country level

Ask the learners to work in country groups as appropriate and to draft a list of potential climate change scenarios in their countries based on different climate change indices using RICCAR outputs. Learners are then asked to prepare and present the observed climate change scenarios from their countries. Learners will share their examples in small groups.

Examples of regional impact assessment tools and initiatives available for the sector

Adaptation of human settlements will basically depend on enhancing resilience and reducing vulnerability of urban activities to extreme weather events. Robust infrastructure and abundance of resources can enhance adaptive capacity, as is the case in GCC countries. Moreover, awareness about climate change and its expected associated impacts is important for the adaption of all Arab cities. Related governance processes should be improved and bureaucracy reduced.

For decades, Arab countries have been investing in IWRM measures and tools to cope with water scarcity. Extreme events will impact almost all aspects of city life, notably transportation systems, telecommunications, public health, water and wastewater infrastructure and tourism.

The following are examples of regional impact assessment tools and initiatives that could be considered for human settlements.

Storm and sanitary drainage networks and their performance under assumed climate scenarios (RCP4.5 and RCP8.5)

A robust drainage network drains storm rainfall run-off in a safe way that prevents any undesirable implications, including floods, that may affect other physical components such as roadways, or even endanger the lives of inhabitants in a specific area.

A wellfunctioning sanitary network ensures the safe drainage of wastewater discharges into the desired endpoint (a treatment plant for example). Since wastewater is composed mainly of organic material and occasionally toxic material, its effects vary from aesthetic implications, including bad odours, to serious health threats, such as cholera epidemics.

There are two types of sewer networks:

- Combined network: a network system that collects both sewage discharge and surface run-off into one pipe;
- Separate network: a network system that collects sewage and run-off in two different pipes. The separate network type is the one recommended for water-scarce regions.

The main input parameters for the design of storm sewer pipe networks in urban cities are:

- Area of the drainage basin
- Run-off coefficient
- Rainfall intensity

The run-off coefficient depends on the imperviousness of the drainage basin. Therefore, it is a direct function of the level of urbanization in the city: the higher the level of urbanization, the higher the value of the run-off coefficient (ranging between 0 and 1).

Table 4. Example of RCP scenarios and the projected effect on precipitation and temperature per year at country level

	RCP 4.5					RCP 8.5				
	Year	Minimum	Medium	Maximum	Reference	Year	Minimum	Medium	Maximum	Reference
Precipitation (mm)	2035	-15.9	-8.2	9.2	-3.0	2035	-20.4	-12.9	-0.5	-12.9
	2055	-24.2	-15.4	0.7	-15.4	2055	-26.5	-15.0	-7.0	-12.9
	2085	-22.5	-13.6	-5.7	-12.0	2085	-38.0	-21.9	-10.9	-14.8
Mean Temperature	2035	0.9	1.2	1.8	1.2	2035	1.3	1.6	2.2	1.6
	2055	1.6	1.7	2.5	1.8	2055	2.1	2.6	3.4	2.6
	2085	1.8	2.1	2.8	2.5	2085	3.8	4.0	5.1	4.0
Maximum Temperature	2035	1.0	1.1	1.8	1.1	2035	1.3	1.5	2.3	1.5
	2055	1.6	1.7	2.5	1.7	2055	2.2	2.6	3.5	2.5
	2085	1.7	2.1	2.8	2.5	2085	3.8	4.1	5.0	3.9
Minimum Temperature	2035	0.9	1.1	1.7	1.3	2035	1.2	1.6	2.1	1.7
	2055	1.5	1.7	2.4	1.8	2055	2.0	2.5	3.3	2.7
	2085	1.7	2.0	2.8	2.5	2085	3.7	4.0	5.1	4.0

Source: Rabi, 2016.

Case study 1. Storm networks analysis during extreme hydrologic events

This case study aims to examine the performance of the designed storm and sanitary drainage networks when subjected to certain changes governed by the climate scenarios predicted for Jordan. The aim is to determine whether these scenarios have a visible impact on the two networks or not, and if there is an impact, to see whether the two networks maintain their capability to drain inflows, or fail to do so.

Irbid city is located north of Jordan and it has sanitary and stormwater drainage networks. Expected impacts of climate change include more intense rainfall events that will affect existing drainage infrastructure.

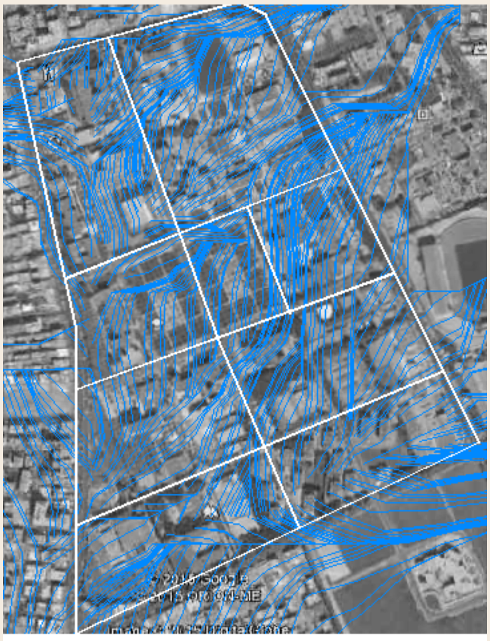
Part of the city network is analysed to examine its capacity to handle an extreme rain event, then it is re-designed to account for a hypothetical rainfall storm of higher intensity and less duration than the original design storm. The IDF curves inserted into the storm and sanitary analysis (SSA) software in the design phase were adjusted with respect to each scenario using the "IDF curves tab" in SSA as shown in the screenshot:

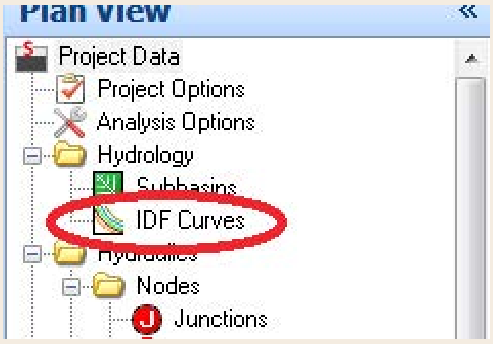
The AutoCad Civil 3D software is used to simulate the water flow in the network and provide visual representation, including videos of the progression of flooding inside the pipe network and service manholes.

The analysis of the network under assumed scenarios did not show any predicted failures in the designed network, neither when the IDF curves' intensity values were increased, nor when they were decreased.

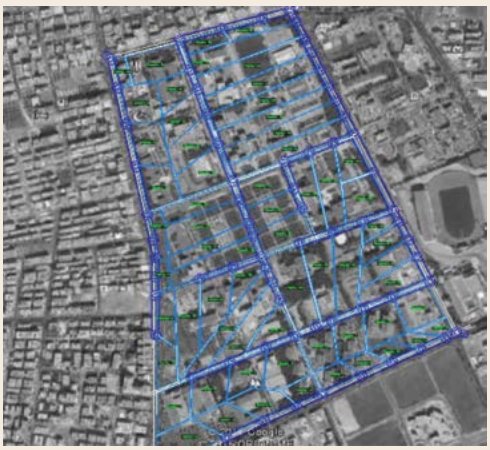
- The designed networks cannot be considered a perfect representation of the already existing networks, because the design aimed to get safe and functional networks, and a network on paper differs from a network in the field. The designed storm drainage network was safe under all the different scenarios, which may not be the case for a real existing storm drainage network.
- The assumed scenarios are based on small knowledge of what was found and understood concerning climate change, a science that is considered highly uncertain. Also, the assumed scenarios are based on present-day methods of design and analysis, while recent studies show that, to simulate the real effects of climate change, new methods should be adopted, such as new downscaled IDF curves. The results obtained cannot be considered conclusive of what will really happen, as they stem from assumed scenarios.

Catchment area used in case study





A storm network layout as appears in AutoCAD Civil 3d



- The software used for the analysis is based on available methods of design and analysis. Scientists are working to develop new software that would take into consideration the impact of climate change.

One important factor of the design of stormwater drainage networks is the land use features of the human settlements. Accelerating urbanization rates in Arab cities have resulted in flooded systems even without the impacts of climate change.

Source: Rabi, 2016.

Intensity-duration-frequency (IDF) curves for the catchment area is a basic tool of the design of the storm drainage basin, and is the one that most strongly reflects future climate change scenarios through the expected increased intensity of the design storm.

Therefore, the design procedure will focus, as is usual in engineering practices, onto the design inputs outlined above.

Climate scenarios can be described as a possible image of the future. They are considered "highly uncertain" and that is why many projected climate scenarios can be found at the global and regional levels. Choosing the scenarios depends on two parameters of concern, precipitation as the main parameter and temperature as the secondary parameter.

The effect of climate change on sanitary networks is not direct, i.e. the increase or decrease in precipitation or temperature will affect the daily water consumption rate and infiltration flow, which in turn may affect the performance of the sanitary network. Accurate data on how daily consumption and infiltration rates will be affected could not be found. Two scenarios based on precipitation and temperature data were thus assumed and examined:

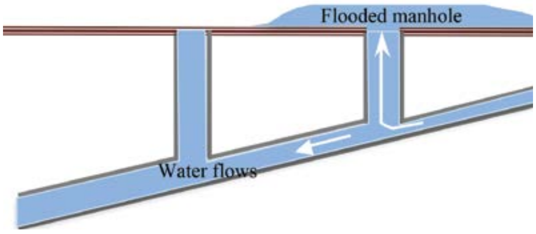
- The increase in water availability (due to a precipitation increase) and in temperature will raise people's daily consumption, while infiltration rates will increase due to higher precipitation levels. The assumed increase value was 50 per cent;
- The share per capita and infiltration will decrease due to a decrease in precipitation. The assumed value of decrease was 50 per cent.

The adjusted flows related to the first assumed scenario can be inserted into a water drainage specialized software to check if the pipes or manholes capacities would be exceeded, and the flows related to the second assumed scenario can be used to check if a violation to minimum velocity (0.6m/s) would occur.

Unlike the sanitary network, the storm network is directly impacted by climate change scenarios, as the parameter of concern used for analysing a storm network is precipitation. To simulate its effect, it can be assumed that an increase or decrease in precipitation is in the intensity of the design storm, and to simulate the assumed impacts, the IDF curves used at the design phase can be adjusted with respect to each scenario.

Two extreme cases were taken for each climate change scenario (RCP4.5 and 8.5), i.e. minimum and maximum projected precipitation values in the year of concern, resulting in four cases in total, as highlighted in table 4.

Figure 3. Flooded manhole under extreme rainfall event enabled by drainage software tools (left) and visualisation of a flooded area by a failed pipe as enabled by the software (right)



Source: Adapted from Google Earth 2016.

Expert system tool to evaluate the degree of flood risk of storm drainage networks

While software can be a helpful tool in determining hotspots of a stormwater drainage system, expert decision support systems can also be used to evaluate available alternatives in dealing with an emergency flooding scenario (Karnib, Al-Hajjar and Boissier, 2002).

Figure 3 depicts sample visualization outputs from available software tools to map results and to show the most overloaded areas and zones where stormwater is likely to overflow from the manholes and to flood the surface. During extreme events, surface flooding is inevitable, and such analysis results are not only necessary for city engineers to enhance preparedness but may also serve as an awareness-raising tool for policymakers and the public.

Expert systems can be used to estimate the degree of flood risk in human settlements due to loss and damage impacts on roads, cars and houses, in addition to the disruption of traffic and all economic activities in cities. “An expert system is defined as a computer system that consists of a knowledge base for the storage of information and knowledge obtained from experts and an inference engine for the utilization of this knowledge in problem solving” (Karnib, Al-Hajjar and Boissier, 2002).

The above-mentioned degree of flood risk could be evaluated as a function of the following variables (Karnib, Al-Hajjar and Boissier, 2002):

1. Density of population
2. Density of traffic
3. Density of public utilities
4. Density of land use (commercial, residential, industrial, etc.)

The system variables (density of population, density of traffic, and density of land use) are represented as fuzzy numbers of different levels (low, average and high). The risk degree is expressed by five levels (very low, low, average, high and very high) according to the vulnerability of urban areas to network failure. The system takes values between 0 and 1 and can be represented as shown in figure 4.

Table 5. Examples of rules to determine the risk degree

IF	THEN
Density of population is average and density of traffic is average	The risk degree is average
Density of population is high and density of commercial land use is average	The risk degree is high
....	....

Source: Karnib, Al-Hajjar and Boissier, 2002.

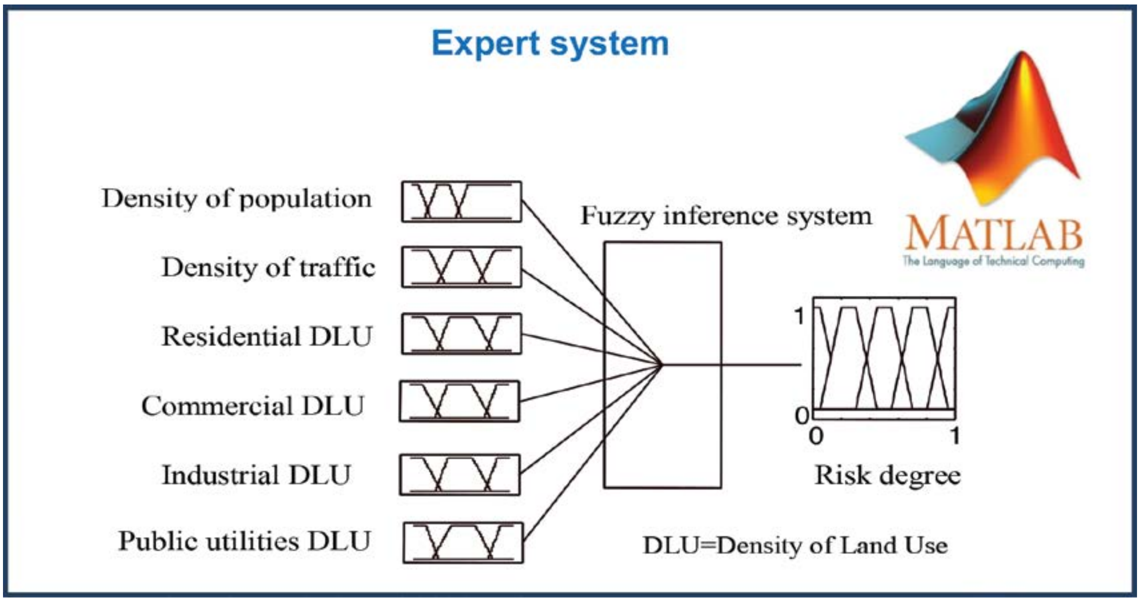
The different levels of the risk degree are defined as follows:

- Very low when there is no harm and no uncomfortable situation as a consequence of flooding;
- Low when there is an uncomfortable situation as a consequence of flooding;
- Average when there is an uncomfortable situation and possible damage as a consequence of flooding;
- High when there is an unbearable situation and possible damage as a consequence of flooding;
- Very high when there is an unbearable situation and extreme damage as a consequence of flooding.

After the determination of flooded areas using storm drainage software, the above-mentioned variables can be calculated for each flooded area. The use of geographic information system tools can be very useful in calculating these variables. Conditional rules can then be developed, such as those listed in table 5.

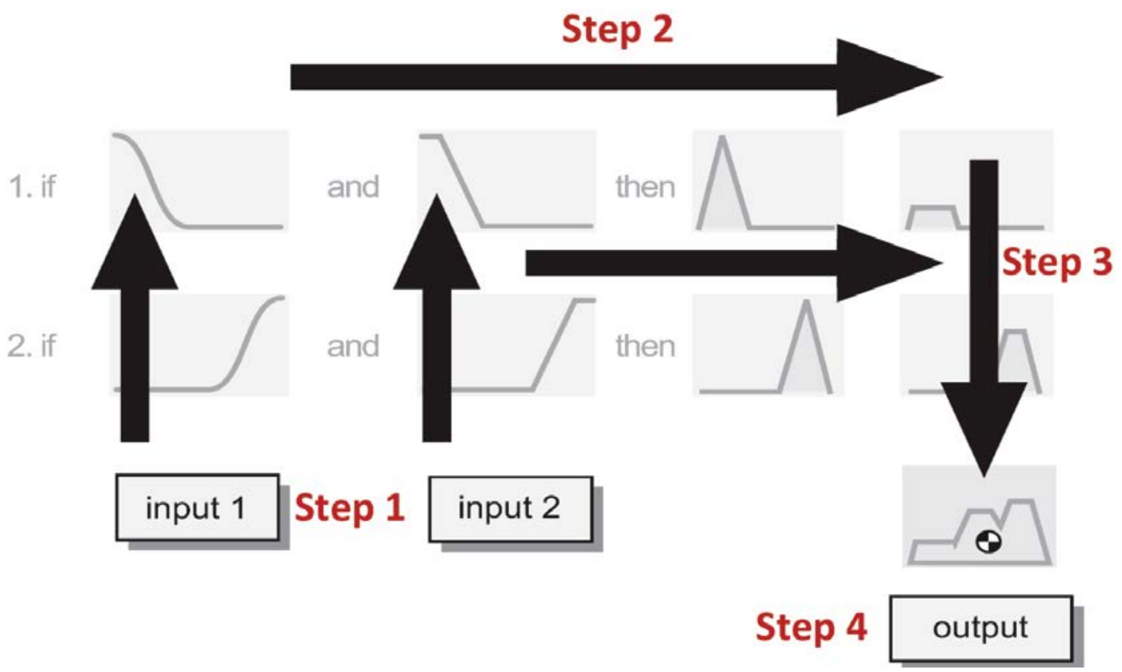
The fuzzy inference method can be used to calculate the risk degree based on the particular values of the system variables and the combination of the developed rules.

Figure 4. Structure of the expert system



Source: Karnib, Al-Hajjar and Boissier, 2002.

Figure 5. The fuzzy inference process



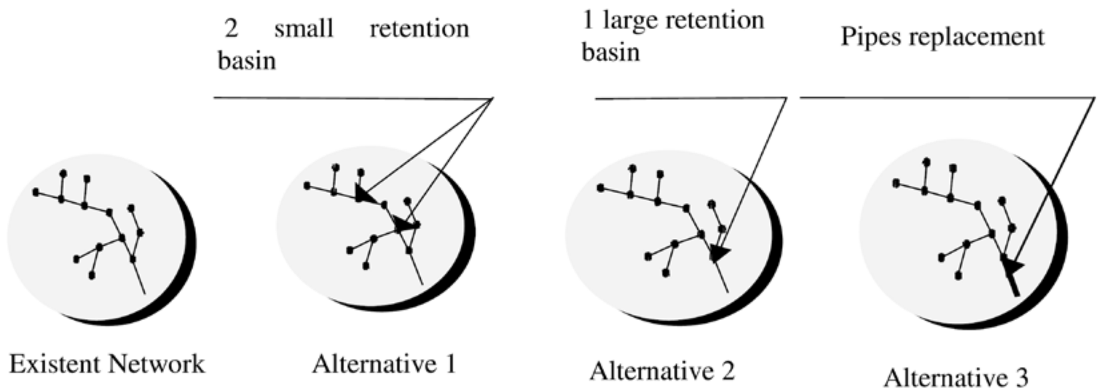
Source: MathWorks, Fuzzy Logic Toolbox. Available from https://www.mathworks.com/help/fuzzy/fuzzy-inference-process.html.

The fuzzy inference process is performed in four steps (figure 6):

1. Fuzzification of the input variables: Map the values of the input variables to values from 0 to 1 using a set of input membership functions (low, average and high).
2. Rule evaluation: Find the consequence of the rules by combining the outputs of step 1.
3. Aggregation of the rule outputs: Unify the outputs of all rules.
4. Defuzzification: Transfer the aggregate output fuzzy set into a single number.

The proposed system can be applied to an upgrading project of an existing storm drainage network where the capacity of the network will be exhausted due to the effects of climate change. Several alternatives of upgrading can be proposed as shown in figure 6.

Figure 6. Example of network upgrading alternatives



Source: Karnib, Al-Hajjar and Boissier, 2002.

Table 6. Example of a multi-criteria decision-making matrix

	Economic criterion (C)	Technical criterion (T)	Environmental criterion (E)	……	Risk degree criterion (S)
Alternative 1	C_1	T_1	E_1		S_1
……….	…	…	…	…	…
Alternative i	Ci	Ti	Ei		S_i
………..	…	…	…	…	…
Alternative n	C_n	Tn	En	…	Sn

Source: Author.

The input variables and rules of the system should be defined based on the opinion of experts. A drainage software tool will be used to perform the hydraulic simulation of the proposed alternatives and to identify the flooded areas. Based on the values of the input variables of the flooded areas, the resultant risk degree for each alternative can then be evaluated.

The evaluated risk degree could be used as a decision-making criterion, among other technical, economic and environmental criteria, in a multi-criteria decision support system when various alternatives to mitigate flooding are proposed. City authorities can use such a system to reach an appropriate response to expected flooding of drainage networks. Table 6 presents an example of such a multi-criteria decision-making matrix.

A practical application of the expert system on the upgrading project of the storm drainage network is given in Karnib, Al-Hajjar and Boissier (2002), where its applicability is discussed.

Impacts of climate change on sea level rise

Sea level rise resulting from climate change could lead to serious adverse impacts on future socio-economic development of coastlines. Rising sea levels could flood coastal infrastructure and contribute to the deterioration of groundwater quality.

The Environment Public Authority in Kuwait conducted an impact assessment of climate change on sea level rise (Al-Ahmad and Dimashki, 2016). Kuwait has 350 km of coastline and most its urban areas fall within 20 km of the coast. Most of the critical infrastructure (commercial buildings, port facilities, oil industries, road networks and recreational facilities) is located in coastal zones.

Assessing affected coastal zones from sea level rise showed that up to 419 km^2 of current land area would be inundated in the northern zone: this corresponds to over 2.4 per cent of the total land area of Kuwait and nearly 80 per cent of the inundated area in the highest sea level rise scenario (baseline sea level + 2 meters). Nearly all of the inundation, about 97 per cent, would take place from sea level rise of up to 1 meter. In the central zone, up to 76 km^2 of current land area would be inundated. Almost all of this land is heavily populated and occupied by commercial activities that greatly contribute to the Kuwaiti economy.

The impact assessment of climate change on sea level rise in Kuwait recommended enhancing coastal information systems by: (a) collecting data and information; (b) including patterns of human behaviour; and (c) raising awareness among the public, coastal managers and decision makers.

Case study 2. Jordan: climate change policy for a resilient water sector

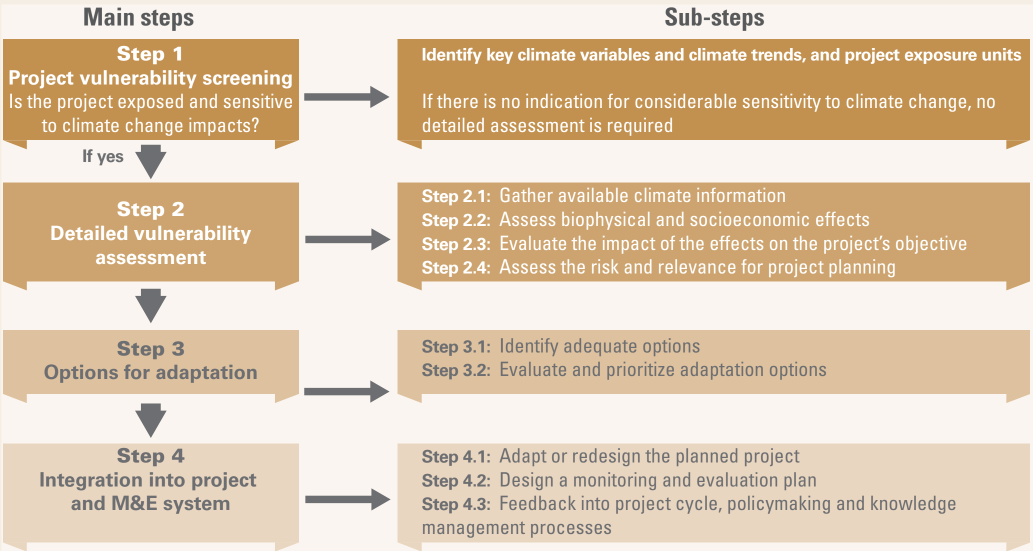
Given the large challenges resulting from climate change and other pressures, the rationale of Jordan's climate change policy is to provide a framework and methodology for strengthening the resilience of the water sector, based on existing IWRM approaches. It does so in a systematic way by (a) prioritizing solutions according to a combination of climate-specific and other already established criteria; (b) applying climate proofing steps to solutions or investments; and (c) monitoring and evaluating the results based on indicators derived from (a) and (b). These measures enable mainstreaming of climate adaptation and mitigation into the existing institutional framework.

This climate change policy is based on IWRM as a starting point. The proposed water-related solutions tackle infrastructure, economic and capacity-building aspects, including:

- Water storage;
- New water, water harvesting, water transfers, wastewater collection/treatment/reuse, desalination based on renewable energy;
- Water quality protection and improvement;
- Virtual water through imports of water-intensive products;
- Integrated water and land planning/management/zoning, water-smart land use, including urban planning to stop encroachment;
- Economic incentives for reducing water (and energy) use and for using more renewable energy in the water sector;
- Water (and energy) demand management: via technical and economic measures (such as water pricing) or awareness-raising and behavioral changes;
- Improvements in water use efficiency;
- Improved climate data collection, monitoring and early warning systems;
- Training and capacity development.

A climate proofing procedure is also proposed for implementing the climate change policy. It assesses the climate impacts for each solution or investment, the biophysical and socio-economic context, and resulting vulnerability and risks. It then identifies modifications and required additional actions (as shown in the figure).

Steps of the climate proofing process



Source: Eickhof, 2014.

Other case studies are available from the ESCWA website: https://www.unescwa.org/events/climate-change-adaptation-human-settlements-using-integrated-water-resources-management-iwrm.

Source: Jordan, Ministry of Water and Irrigation, 2016.

CH. 4

IWRM Tools for Identifying Adaptation Measures

CH. 4

IWRM Tools for Identifying Adaptation Measures

Adaptation measures build upon the information available on the observed and projected impacts of climate change, and are useful in the development of strategies and policies to limit adverse impacts on human settlements systems. Useful IWRM measures include rainwater harvesting, water reuse and water demand management. Prevention of water pollution is necessary to maintain a quality level that is appropriate for potable water supply.

In the decades to come, climate change may make hundreds of millions of urban residents, in particular the poorest and most marginalized, increasingly vulnerable to floods, landslides, extreme weather events and other natural disasters. City dwellers may also face reduced access to freshwater as a result of drought or the encroachment of salt water on drinking water supplies.

Stakeholders in the Arab region should go beyond traditional management of the water sector. Most of the water utilities are being operated in a centralized manner with reference to absolute laws and regulations. It is crucial for utilities and decision makers to adopt effective solutions and find proper environments to face these ongoing challenges. In this regard, community-based organizations could play an important role in raising awareness at all levels within utilities, especially at the top and middle management levels that have direct influence over decision makers. Evidence shows that meaningful involvement of civil society, particularly women, in water resources development, management and use can lead to the development of new policies, help governments to avoid poor investments and expensive mistakes, and ensure that infrastructure development yields the maximum social and economic returns (Bouman-Dentener and Devos, 2015).

While it is widely believed that urban centres are a major contributor to climate change phenomena, it is impossible to make accurate statements about the scale of urban emissions, as there is no globally accepted method for determining their magnitude. In addition, the vast majority of the world's urban centres have not been subject to attempts to conduct greenhouse gas emission inventories.

With rapid urbanization, understanding the impacts of climate change on the urban environment will become even more important. Evidence is mounting that climate change presents unique challenges for urban areas and their growing populations. These impacts are a result of the following climatic changes:

- Warmer and more frequent hot days and nights over most land areas;
- Fewer cold days and nights in many parts of the region;
- Increased frequency of warm spells/heatwave over most land areas;
- Increased frequency of heavy precipitation events over most areas;
- Increase in areas affected by drought;
- Increase in intense tropical cyclone activity in some parts of the world;
- Increased incidence of extreme high sea levels in some parts of the world.

The analysis of the projected climate parameters and the extreme climate indices has shown the following (United Nations and League of Arab States, 2015):

- There is a consistent warming trend with a general increase in the frequency of warm days and longer summer periods across the Arab region;
- The precipitation trends are more variable than temperature trends, and drier conditions are more dominant in the northern Maghreb;
- The occurrence of extreme precipitation reflects a stronger spatial variability than that shown in the temperature extremes.

Ragab and Prudhomme (2002) claim that, given the above-mentioned predictions, in order to meet the water demands for the next century, more dams and water infrastructure will have to be built in southern Mediterranean and Middle Eastern countries. Water use will have to be made more productive and a new paradigm will have to be adopted. They argue that two approaches will be needed:

- Increasing efficiency to meet current needs and improve water allocation among different uses;
- Increasing reliance on non-conventional sources of water supply, such as reclaimed or recycled water and desalinated brackish water or seawater.

Case study 3. Effects of severe droughts on rural livelihoods in the Syrian Arab Republic

Water is scarce across the region, with available water resources below 1,000 m^3 per capita per year in all Arab countries, except Iraq, Lebanon and the Syrian Arab Republic. However a major drought that hit the latter and lasted from 2006 to 2009 affected over a million people and led to a massive migration from rural areas to the outskirts of nearby urban centres and to Aleppo and Damascus. Farmers, herders and agriculturally dependent rural families from the countryside sought refuge in the cities, either permanently or semi-permanently. In 2009, the United Nations and the International Federation of Red Cross and Red Crescent Societies reported that over 800,000 Syrians lost their livelihoods as a result of the droughts. Over 1.53 million Syrian refugees have also been registered in Jordan and Lebanon, where water services are already stressed by scarcity and drought.

Threats to sustainability of resources are further exacerbated by regional conflicts. By October 2013, access to water supply services in the Syrian Arab Republic had decreased by 70 per cent on average since the beginning of the conflict. The figure has continued to decline due to a breakdown in services.

This situation has resulted in a massive undertaking among WASH (Water, Sanitation and Hygiene) sector partners to distribute chlorine, hygiene kits and generators throughout the country. Along the Euphrates river, decreased water levels and destroyed pipes have forced residents of Aleppo to use jerry cans to collect water from untreated surface water sources.

In June 2009, it was estimated that 36,000 households (200,000-300,000 individuals) had migrated from the Al-Hasakah governorate alone. In a region in which men are attributed primary responsibility as income earners, they were expected to leave the community to find alternative sources of income. This type of migration has contributed to the increase in the number of female-headed households in many areas, along with greater numbers of disabled males (caused by conflict), widowhood and higher divorce rates.

Sources: Sowers, Vengosh and Weinthal, 2011; Verner, 2012; United Nations World Water Assessment Programme, 2015; ACSAD and ISDR, 2011; Osman Elasha, 2010; and FAO, 2005.

Stocktaking of available climate change adaptation measures

The following are examples of several appropriate response measures that could be considered for human settlements:

Water harvesting

Water harvesting is recognized as an efficient and practical climate change adaptation measure. Rainwater harvesting can be implemented at the ecosystem, watershed, and urban and household levels. Benefits of rainwater harvesting include groundwater recharge, soil erosion control, flood control and improvement of water supply in the Arab region where water scarcity has been a challenge for development. According to data compiled from AQUASTAT, the region-wide total average amount of rainfall was estimated at 1,724 billion m^3 for 2014, while renewable water resources were estimated at only 289 billion m^3. The numbers show a great potential for rainwater harvesting at all levels in the Arab countries.

The present water supply and stormwater problems in most cities of the Arab region will rise in the future. The concept of integrated urban water management seems to be most appropriate, as it includes:

a. Water supply management: rainwater harvesting on urban buildings or other sealed surfaces offers new chances to cover the ever-growing urban water demand;
b. Water demand management: it can be achieved through a combination of behavioural changes and technological fixes such as watersaving devices;
c. Excess water management: it deals with stormwater and flood-plain management.

Harvesting may also be practiced at a small catchment level as well as at the basin level.

Water demand management

The following are examples of water demand management that could be considered for human settlements:

- Public awareness campaigns
- Installation of water-saving devices
- Programmes for water recycle/reuse for large water consumers (such as hotels)

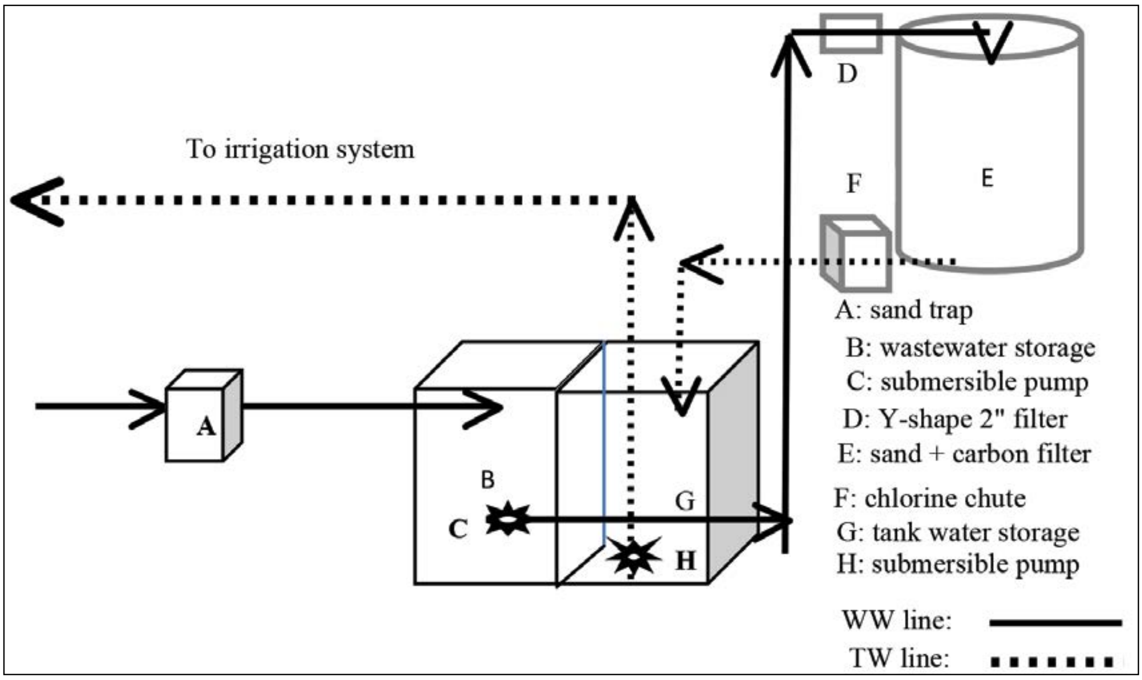
Reuse of grey water

Grey water is wastewater from showers, sinks, washing machines and dishwashers (any residential source other than toilets). Expanding grey water use in the Arab region can help to address acute water shortages and improve the water equation. The private sector can invest in the treatment and reuse of grey water as an alternative source of water. Although Arab countries have made strides in wastewater reuse over the past two decades, there is still room for improvement in terms of wastewater services.

Grey water can be recycled using individual treatment units within the homes that produce it, with no need to channel it to large treatment plants, and it can be easily treated and reused in households for irrigation and other purposes. Countries should consider grey water as a source of water that can bridge the gap between supply and demand.

Commercially available grey water systems are too expensive for individual households. Therefore, a low-cost, low-maintenance treatment system could be designed, constructed, and operated by households (figure 7).

Figure 7. Simple treatment line for grey water reuse at a small scale



Abbreviations: WW, wastewater; TW, treated water.
Source: Ahmad and others, 2011.

Table 7. Suggested distribution of grey water application/reuse split

Application	Percentage
Toilet flushing	54
Irrigation and gardening	36
Outdoor use and cleaning	5
Laundry	2.5
Infiltration	2.5

Source: Pidou and others, 2007.

Table 8. Distribution of household domestic water use

Application	Percentage
Toilet flushing	35
Wash basin	8
Shower	5
Bath	15
Laundry	12
Dishwasher	4
Outside Use	6
Kitchen sink	15

Source: Pidou and others, 2007.

The advantage of recycling grey water is that it is a large source with low organic content. Grey water represents up to 70 per cent of total consumed water but contains only 30 per cent of the organic fraction and from 9 to 20 per cent of the nutrients. Moreover, in an individual household, it has been established that grey water could support the amount of water needed for toilet flushing and outdoor uses, such as car washing and garden watering (table 7). For example, on average, toilet flushing and outdoor use represent 41 per cent of total domestic water usage, whereas grey water from shower, bath, hand basin, laundry and dishwasher correspond to 44 per cent (table 8).

Water footprint tool

Water footprint (WFP) assessments can assist water managers, government officials, scientists and the private sector in understanding the quantities and types of water (such as blue, green and grey water) involved in the production of specific products, and in assessing the impact of

products or whole production sectors on the actual water demand and water resources available. This may in turn contribute to improving productivity and the sector's overall water efficiency.

Public awareness is crucial in helping various sectors of human settlements to understand the challenges associated with climate change, especially large water-consuming establishments such as hotels and factories. Water reuse and recycling within factories and hotels should be promoted.

Case study 4. Grey water treatment in Oman

Oman is an arid country where the pressure on freshwater sources is severe. Increasing water availability by treating and reusing wastewater for irrigation is a government policy. Experience from arid and semi-arid countries indicates that grey water can be a cost-effective alternative source of water. Grey water includes water coming from baths, washing water, washing machines, showers and bathroom sinks. Grey water has lower quality than potable water, but has higher quality than black water. Studies have shown that 80 per cent of water used in Omani households is grey water.

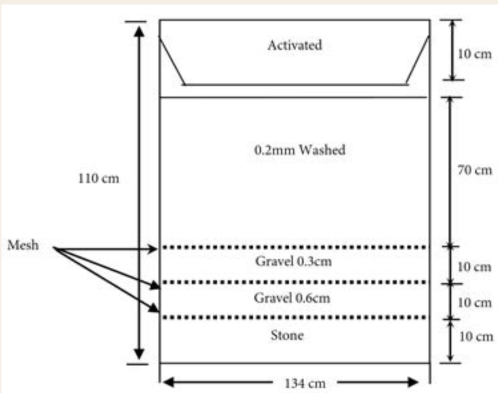
A research project was accomplished at Sultan Qaboos University in Oman to quantify grey water production, characterize water quality parameters, and design simple treatment systems combining aeration, sand filtration and chlorination to meet the existing reuse standards.

A low-cost and low-maintenance treatment plant was constructed and operated at Al Hail mosque in Oman.

Al Hail mosque lawn irrigated with treated grey water

The water is sent through a sand trap to allow settlement of soil particles. Since the sand trap is shallow, periodic cleaning of this trap is easy. Subsequently, the water is conveyed by gravity to the water storage tank, and dropped from near soil surface to the water level, aerating on its way. Water lifted by the pump is sent through an irrigation filter. This prevents floating matter from proceeding further. Subsequently, water enters a filter unit, which consists of an activated carbon tray (10 cm deep), 0.2 mm washed beach sand (70 cm deep), gravel 1/8 mm (10 cm deep), gravel ¼ mm (10 cm deep) and stones (10 cm deep) (as shown in the figure).

Design of sand and activated carbon filter (drawing not to scale)



Following filtration, the water passes through a chlorination chute. Filtered water mixed with chlorine is then dropped into the treated water storage tank.

A commercial unit is installed at Sultan Qaboos University mosque, which is much larger. This system performs well and produces water that satisfies the existing Omani standards for reuse.

Source: Prathapar and Al-Adawi, 2011.

It is strongly advised to propagate the culture of WFPs in human settlements. Establishments, institutions, urban farms, hotels and others should be introduced to the significance of preparing reports on the WFPs of their activities. With water tariffs used as an effective tool for water demand management, assessing institutions' WFPs becomes relevant and feasible.

Reducing non-revenue water

In the Arab region, the level of NRW is relatively high, thus endangering the financial viability of water utilities. Under climate change scenarios, water utilities should continue trying to reduce NRW, which typically entails:

- Reducing physical losses
- Using advanced and innovative sensors (acoustic and water borne) to detect leaks
- Investing in better governance with a goal of minimizing response time
- Investigating, reducing and resolving administrative non-leak losses

New advances in leak detection technology and sensors can and should be used in order to reduce NRW in all Arab urban areas, especially in the GCC subregion where water supply relies on desalination to cover at least 50 per cent of the demand.

Case study 5. NRW reduction in Jordan

Jordan has moved into privatization of water supply and sanitation services since 1999, when the first management contract (PPP) was enacted for Amman. Other governorates followed, such as Aqaba and Irbid, where private sector companies manage these services. One main challenge that seems to persist is the real reduction of NRW.

The case study uses a guided discussion that focuses on both the physical losses in the supply system and the administrative component of the NRW. Effectiveness of reduction practices in dealing with the NRW problem are discussed and analysed during the exercise.

To support the guided discussion, below is a listing of the NRW reduction practices that were used and applied in Jordan.

Replacing the deteriorated small size network pipes and the galvanized type service connection: This practice is common in Jordan, due to the fact that most of the leakage occurs in the small sized pipes and galvanized service connection. Therefore, all utilities are replacing these pipes with polyethylene types.

Water meter replacement programme: The water meter replacement programme has an important effect on NRW reduction. More than 90 per cent of the customers' water meters are class B type. Studies have shown that this type of water meter will not be able to read low flows (less than 30 litres per hour) after a certain time, causing an underestimation that has an important impact on NRW. Jordan has established a policy that all water meter nominal diameters (DN) 15, 20 and 25 that passed 2,000 cubic meters of water or which are five years old (whichever comes first) should be replaced.

Micro private sector participation (PSP) practice in Jordan: Micro PSP is a relatively new practice in Jordan. It was proposed as an accelerated option to achieve service improvements in the processes related to the management contracts in Amman and the Northern Governorates Water Administration. The creation of a market for local private companies to support the reform process in the water sector was perceived as a fundamental economic objective in Jordan, in addition to other objectives related to cost reduction, management innovation and performance improvements.

Individual service connection survey: This method is not internationally established yet, but was developed by the NRW team in Jordan based on their experience. It was specifically suited to the Jordanian situation. The idea behind this survey is that, in addition to surveying main lines for leaks, it is necessary to check every service connection and customer meter for possible illegal connections and leaks.

Establishment of a district metered area: Under the current NRW situation in Jordan, priority should be given for countermeasures if any district metered area is found to have a baseline NRW of 25 per cent or more, as it would require more effort to reduce NRW by the same extent in such areas in comparison with other areas that have a much lower NRW baseline.

Licensing system for service connection installation: It is a common fact that most of the leakage cases happen along service connections. Major causes are generally derived from aged failed pipes, poor skills during pipe installation, use of low-quality pipe materials and improper trench preparation for protecting pipes from damage. Some of these causes may be avoided if contractors work according to the approved instructions, and if utilities carry out strict supervision on the contractors during the installation of the service connections. This will ultimately contribute to the reduction of NRW.

Pressure management: As in many other Arab countries, intermittent water supply is widely practiced in Jordan due to water resources scarcity. The mountainous nature of the service areas in Jordan and the intermittent water supply increase water pressure in the networks, thus increasing the number of bursts in the pipes, in addition to the negative direct impact on water meters. Pressure control in areas of excessive pressure helps in overcoming many negative effects caused by an intermittent supply system. To deal with this type of problem, a large investment in the procurement of pressure reducing valves, zoning, hydraulic modelling and construction of new reservoirs, among others, is required (as is the case in Amman and other water utilities in the major cities).

Source: Sustainable Water Integrated Management (SWIM), 2013.

Updating urban planning policies

According to RICCAR outputs, more intense rainstorms are expected across the Arab domain. Urban areas and human settlements should thus be prepared to build resilience to cope with expected flood events, such as Cyclone Guno that hit Oman in 2007.

Urban planning policies have to be reviewed and updated to enact measures, including:

1. Avoiding flood plains when locating institutional and economic enterprises such as emergency administration buildings and hospitals.
2. Upgrading existent stormwater drainage and sewage collection networks to handle expected surges in flow.
3. Providing capacity-building and training for technical staff to consider climate change scenarios in the design process in water and sanitation infrastructure.
4. Building awareness especially among middle and high-level decision makers on the gravity of expected climate change impacts on urban infrastructure.

Wastewater treatment and reuse

Aerobic wastewater treatment processes decompose organic matter by microorganisms in the presence of oxygen. Anaerobic treatment is a biological process that is carried out in the absence of oxygen; it is sensitive to low temperatures, and the process should be implemented

in temperatures ranging between 25°C and 35°C (Metcalf and Eddy, 2003). This is important when pursuing climate change adaptation or appropriate technology transfer arrangements in the warmer climates of the Arab region. Energy recovered from wastewater treatment plants is almost non-existent in the Arab region, even though the best-performing wastewater treatment plants

Box 2. Aerobic versus anaerobic wastewater treatment

Most wastewater treatment plants in the Arab region are based on aerobic treatment processes that are commonly found in cooler climates (Europe and the United States of America). Anaerobic wastewater treatment plants are more suitable for the warmer climate of the Arab region and are more energy efficient, because they do not require energy for aeration to maintain the oxygen levels needed for aerobic bacterial growth. In addition, anaerobic processes can produce biogas, which can fuel the treatment facility. Besides, digested sludge can be processed into safe, high quality agricultural fertilizers. Sanitation climate adaptation measures thus present opportunities for biogas production in some Arab countries, based on the future climate warming in the region.

Source: Karnib, 2014.

Table 9. Volume of collected wastewater, wastewater treatment and reuse, 2012 or 2013 (MCM/year)

	Collected wastewater	Primary treatment	Secondary treatment	Tertiary treatment	Reused	Reused (% of treated)
Algeria, 2013	1570.36	0.00	275.24	0.00	19.32	7%
Bahrain, 2013	122.80	0.00	0.00	122.80	38.07	31%
Egypt, 2013	3572.20	924.70	2585.00	62.50	DN	DN
Iraq, 2012	620.40	0.00	415.70	0.00	0.00	0%
Jordan, 2013	130.83	0.00	130.83	0.00	130.83	100%
Kuwait, 2013	DN	0.00	57.97	250.31	308.28	100%
Lebanon, 2013	DN	DN	DN	DN	DN	DN
Libya, 2012	291.10	0.00	45.84	0.00	14.67	32%
Mauritania, 2013	0.65	0.00	0.65	0.00	0.12	18%
Morocco, 2013	144.18	38.18	0.14	6.10	DN	DN
Oman, 2013	26.20	0.00	0.00	26.20	20.40	78%
Qatar, 2013	176.83	0.00	0.00	158.79	115.92	73%
Saudi Arabia, 2013	1317.17	0.00	580.22	736.95	237.09	18%
State of Palestine, 2012	60.971	0.300	45.262	0.001	0.001	0%
Sudan, 2013	18.04	18.04	0.00	0.00	0	0%
Tunisia, 2013	235.00	0.00	222.03	6.62	44.11	19%
United Arab Emirates, 2013	615.70	0.3	11.7	593.6	397.2	65.6%
Yemen, 2012	159.37	58.13	42.24	22.02	DN	DN

Abbreviations: DN, data not available; MCM, million cubic metres.
Source: League of Arab States, ESCWA and ACWUA, 2016.
Note: The "reused" column represents the volume of safely reused secondary and tertiary treated domestic sewerage in MCM/year, and the last column represents the percentage reused as a share of wastewater treated at the secondary or tertiary level.

can produce more energy than is needed for treatment (United Nations World Water Assessment Programme, 2014).

Reuse of treated wastewater is an indispensable tool for enhancing adaptive capacity to climate change impacts. Reuse has been a practice in most major Arab cities before climate change concerns became commonplace. It has long been perceived as an important element of wise water management whereby treated effluents are used in restricted irrigation schemes, leaving scarce freshwater available for domestic supply. Table 10 shows the amounts of wastewater produced, treated and re-used in selected Arab countries (League of Arab States, ESCWA and ACWUA, 2016).

A summary of selected guidelines and mandatory standards for reclaimed water use in a variety of jurisdictions is presented in table 11. Some minor differences are apparent: for example, some measure faecal coliforms, while others measure total coliform. The use of total coliforms is more restrictive than that of faecal coliforms alone, without necessarily being a more expensive testing

Table 10. Standards for reuse of wastewater adopted by selected countries, areas and entities

Country/region	Faecal coliforms (CFU/100 ml)	Total coliforms (CFU/100 ml)	BOD5 (ppm)	Turbidity (NTU)	TSS (ppm)	DO (% of saturation)	pH	Chlorine residual (ppm)
Australia (New South Wales)	<1	<2 150	>20	<2	-	-	-	-
California (USA)	-	2.2	-	2	-	-	-	-
Cyprus	50	-	10	-	10	-	-	-
France	<1 000	-	-	-	-	-	-	-
Germany (g)	100	500	20	1-2 (m)	30	80-120	6-9	-
Kuwait (crops not eaten raw)	-	10 000	10	-	10	-	-	-
Kuwait (crops eaten raw)	-	100	10	-	10	-	-	1
Oman 11A	<200	-	15	-	15	-	6-9	-
Oman 11B	<1 000	-	20	-	30	-	6-9	
South Africa	0	-	-	-	-	-	-	-
Tunisia	-	-	30	-	30	7	6.5-8.5	-
United Arab Emirates	-	<100	<10	-	<10	-	-	-
United States Environmental Protection Agency (g)	14 for any sample, 0 for 90%	-	10	2	-	-	-	1
WHO (lawn irrigation)	200 (g) 1 000 (m)	-	-	-	-	-	-	-

Abbreviations: CFU, colony forming units; BOD, biochemical oxygen demand; PPM, parts per million; NTU, nephelometric turbidity unit; TSS, total suspended solids; DO, dissolved oxygen.
Source: Adapted from the United States Environmental Protection Agency (EPA), 2012.
Notes: (g) signifies that the standard is a guideline; (m) signifies that the standard is a mandatory regulation; 11A and 11B in the case of Oman refer to the two categories of reuse rules that are in place in the country, based on application limitations common to many countries.

method. Other indicators of sufficient treatment are also often measured, such as filtering or otherwise removing suspended particles that could serve as bacteria substrates: BOD5 and turbidity or TSS. It is also useful to measure chlorine residuals as evidence of disinfection.

Obstacles to wastewater reuse implementation in Arab countries can be summarized as follows:

- Technology and infrastructure availability
- Water resource management frameworks
- Regulations and recycled water quality
- Sociocultural beliefs and religious practices
- Public perceptions and terminology

In the Arab region, social acceptance of reclaimed wastewater remains an issue, which can be overcome via public awareness, carefully designed media messages and careful selection of vocabulary.

Case study 6. Sustainable water security and wastewater reuse in Saudi Arabia

There is a global trend in increasing dependence on the reuse of wastewater as a sustainable non-conventional water resource for solving the rising global water stress, especially in arid countries.

The approximate volumes of renewable water resources available for use in Saudi Arabia are about 5,000 MCM, and the average water share from renewable resources is about 220 m^3 per capita in 2013. According to the scarcity index, the country suffers from extreme water scarcity. Current water supplies consist of desalinated water, which is expensive to produce, and groundwater, which is a non-renewable or slowly renewable resource. The growth in population in Saudi Arabia will significantly increase water demands and wastewater flows. The increase in coverage by water distribution systems and sanitary sewer systems will add to these increases. The significant amount of additional effluent expected to be generated provides an important opportunity for reuse to offset water demands for non-potable uses. The use of reclaimed water for cooling by industries or commercial enterprises, and possibly by public buildings, could increase due to the high expense and environmental costs of using desalinated water or groundwater for such purposes.

Wastewater will play a major role for water supply in Saudi Arabia, along with groundwater. Wastewater reuse, in a scarce-water country such as Saudi Arabia, has become an inevitable mean, and an integral part of IWRM to achieve sustainable water and food security. This climate adaptation measure represents one of the most cost-effective and energy-efficient alternative water resources, compared with desalination and long distance water transportation. Energy-efficient, advanced water recycling plants are producing recycled water of drinking quality, with a relatively low energy footprint. Reuse of water can contribute to the saving of valuable freshwater resources and electric power, in particular when freshwater has to be transported over long distances or further water treatment is required, for example production of potable water from desalination of brackish water or seawater. The generation of recycled water only requires a fraction of the energy needed for the desalination of seawater.

Biosolids are another renewable resource that can be recycled, but are currently being disposed of by landfilling or at designated locations. There is little indication that biosolids are beneficially reused. Requirements for the use of biosolids in agriculture exist, but there is little awareness among farmers of the benefits of using sludge in agriculture. Therefore, an investment in raising awareness of the value of these resources is needed, along with the significant infrastructure capital investment planned to meet the service goals for 2025.

Source: Abderrahman, 2014.

Water tariffs

Pricing policy is one of the main driving factors for water reuse or lack thereof. Water tariffs are set based on a number of formal criteria defined by law, as well as informal criteria. Formal criteria typically include one or more of the following:

- Financial criteria (cost recovery)
- Economic criteria (efficiency pricing based on marginal cost)
- Environmental criteria (incentives for water conservation)

Social and political considerations are also important in setting tariffs. Tariff structures and levels are influenced in some cases by the desire to avoid an overly harsh burden on poor users or by other political considerations. Water tariffs should be easy to understand for consumers. This is not always the case for the more complex types of tariffs, such as increasing-block tariffs and tariffs that differentiate between different categories of users.

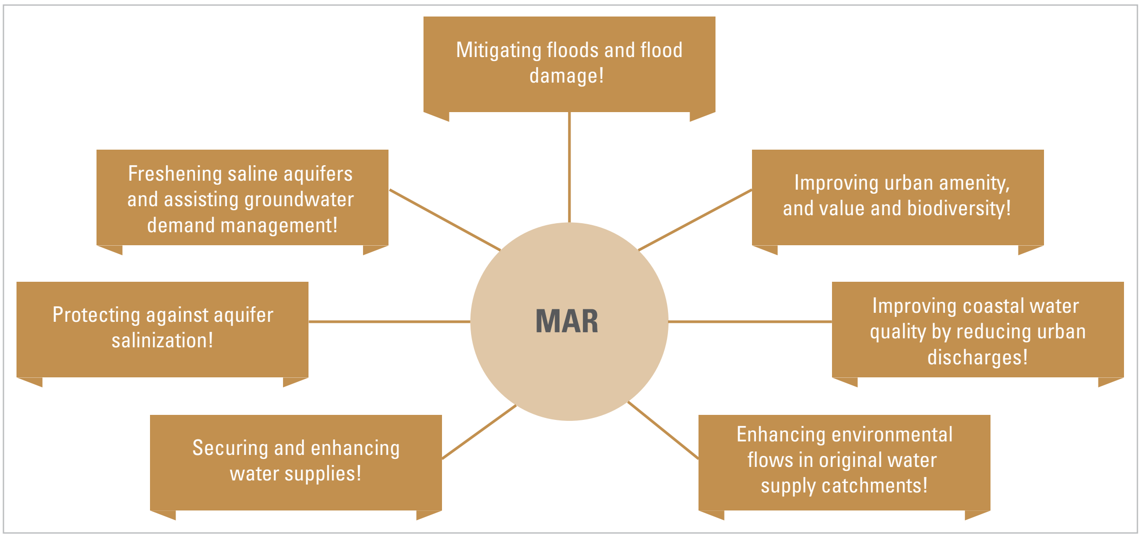
Managed groundwater recharge: aquifer recharge and recovery

A variety of different types of water are stored or treated in managed aquifer systems, including:

- Reclaimed water
- Potable water (including desalinated water)
- Surface water (treated to varying degrees)
- Stormwater
- Raw groundwater (inter-aquifer systems)

Managed aquifer recharge (MAR) was defined by Dillon and others (2009) as the intentional banking and treatment of water in aquifers. The term *managed aquifer recharge* was introduced as an alternative to *artificial recharge,* which has the connotation that such use of the water was in some way unnatural. MAR projects, particularly in urban areas, have

Figure 8. Objectives of MAR projects in urban areas



Source: Dillon and others, 2009.

many purposes in addition to water supply, and they vary from site to site (figure 8). All of the economic, environmental and social benefits and costs of projects should be taken into consideration in project selections.

MAR includes a variety of techniques, some of which are applicable to effluent storage and treatment. Aquifer storage and recovery is an important MAR technique, which aims to store water in a suitable aquifer during times when water is available, and the recovery of the water from the same aquifer during times when it is needed. Aquifer storage and recovery systems offer the following advantages for reclaimed water storage:

- Much lower costs than surface storage options
- Very large storage capacities that are typically available at no cost
- Much lower land requirements than surface reservoirs
- No water losses due to evapotranspiration
- Less severe environmental impacts due to small system size
- Potential improvement in water quality through the natural attenuation of concentrations of pathogens and chemical contaminants
- Minimal adverse aesthetic (such as visual, odour) impacts

Case study 7. Managed aquifer recharge as an integrated water resource management approach for preventing seawater intrusion in Hazmieh (Beirut area), Lebanon (ACCWaM pilot project)

Most coastal areas in countries of the Middle East and North Africa (MENA) are affected by population growth, urbanization and the impacts of climate change. Hence many coastal aquifers suffer from overexploitation, seawater intrusion and deteriorating water quality.

Beirut and its surrounding area are no exception. They are witnessing: (a) steadily growing water demand; (b) shrinking of the natural groundwater recharge in the watershed area; and (c) increase in surface run-off.

To explore the potential of artificial aquifer recharge using an IWRM approach, a feasibility study was commissioned by the GIZ programme "Adapting to climate change in the water sector in the MENA region (ACCWaM)" in 2013, implemented in partnership with ACSAD. First findings indicate that: (a) in Lebanon presently about 740 MCM/year of water are flowing unused to the Mediterranean Sea and a good share of it enters the sea around Beirut; (b) seawater intrusion has progressed further inland than expected; (c) the emptying of the coastal aquifers is not only due to overextraction, but to reduced recharge in the mountainous parts of the watershed (caused by decline in precipitation, reduction of snow cover, more settlements, deforestation, etc.) and in urban areas (sealing of the ground by buildings, parking lots, etc.); and (d) solutions to the problem have to include supply-side (such as groundwater recharge, rainwater harvesting) and demand-side measures (awareness campaigns, water metering, etc.).

The implementation of a remediation project will depend on a close cooperation of State organs, non-governmental organizations and the public, while the high costs involved will lead to seeking the involvement of an international donor.

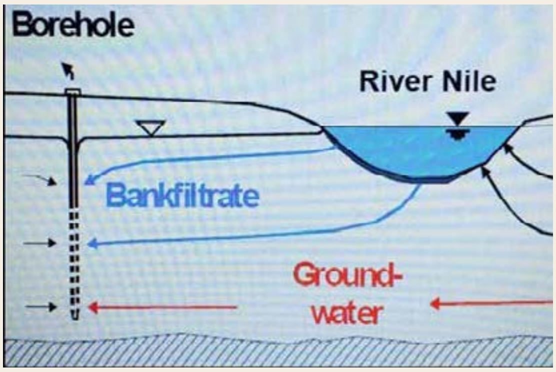
Source: ACCWaM website, available from http://www.accwam.com/IAP/3/Lebanon.html (accessed 17 July 2016).

Case study 8. Water abstraction through bank filtration to improve drinking water supply in Upper Egypt

Throughout the Egyptian water sector reform process, the responsibilities of governorate-owned and run enterprises have been increasingly transferred to the newly established utilities for water supply and wastewater disposal. These new enterprises have been gradually consolidated, but there are still deficits in carrying out services in an economic and efficient manner.

The objective of the GIZ programme dealing with drinking water supply in Upper Egypt is therefore to improve water and wastewater management services in that area.

Schematic illustration of the bank filtration technology



Investigations revealed that the use of riverbank filtrates was an interesting option to secure water supply to a number of cities along the Nile river, which presently use surface water for their domestic water supply. Surveys in recent years indicated a significantly higher water quality of bank filtrates when compared with water abstracted directly from the river. The utilization of bank filtrates within the GIZ programme is still in its early stages, but it became evident that concerted efforts are required to put into practice the full potential of bank filtration in Egypt and to understand the processes involved.

Source: GIZ, available from http://www2.giz.de/wbf/4tDx9kw63gma/F11_Water_Abstraction_through_Bank_Filtration.pdf (accessed 17 July 2016).

Desalination by renewable energy

Desalination has become the most important source of water for drinking and agriculture in several Arab countries. The Arab region accounts for about 38 per cent of the global desalination capacity, with Saudi Arabia being the country with the largest desalinating capacity (International Energy Agency-Energy Technology Systems Analysis Programme (IEA-ETSAP), and International Renewable Energy Agency (IRENA), 2012).

Freshwater sources will become scarcer in the Arab region due to the impacts of climate change and increasing demand for natural resources. Desalination of seawater and brackish water can be used to boost the growing demand for freshwater supplies.

Renewable technology prices continue to decline, thus making renewable energy a viable option for desalination. Desalination by renewable energy represents a feasible measure of planning for climate change and reducing greenhouse gas emissions.

There are two broad categories of desalination technologies. Thermal desalination uses heat to vaporize freshwater, while membrane desalination (reverse osmosis) uses high pressure from electrically powered pumps to separate freshwater from seawater or brackish water, using a membrane. Policymakers need to consider these different technology choices for desalination and base their decisions on locally available renewable energy sources. For example, solar

Box 3. Solar power desalination, Morocco

Morocco has commissioned a solar powered desalination facility at the Green Energy Park of Ben Guerir near Marrakech, which has a capacity to produce 5 m^3 per hour. The project was developed as a pilot that facilitates solar and new energies research in the country. The pilot facility involves the use of both photovoltaic (PV) and thermal solar technologies, including 57 solar PV panels with a combined capacity of 10 kW and 18 solar thermal panels with 14 kW of cumulative power capacity. Designed to be mobile and modular, the plant was equipped with reverse osmosis and membrane distillation technologies, which carry out purification of water. Combination of dual desalination and dual solar technologies has increased water processing capacity for the facility and brought down its brine discharges to the minimum. While water purification through reverse osmosis is powered by the PV cells, the solar thermal panels back the membrane distillation process.

Source: Water-technology.net website, available from http://www.water-technology.net/news/newsmorocco-commissions-first-solar-power-desalination-plant-4773751 (accessed 17 July 2016).

energy, in particular heat from thermal desalination and electricity from solar photovoltaic and concentrated solar power for membrane desalination, is a key solution in arid regions with extensive solar energy potentials (such as the MENA region), while wind energy is of interest for membrane desalination projects in coastal and island communities.

Desalination is still costly. However, the declining costs of the deployment of renewable energy technology are expected to reduce desalination costs in the coming years. Remote regions and islands with small populations and poor infrastructure for freshwater and electricity transmission and distribution will particularly benefit from these developments.

Mapping water needs and renewable energy sources is a strategic tool for planning new desalination systems. Renewable energy-powered desalination could be a key enabler for continued growth, especially in those countries that rely on desalinated water for sustaining local communities and productive uses such as irrigation. As such, renewable energy generation should be seen as a valuable economic investment that reduces external, social, environmental and operational costs. Policymakers may therefore wish to take the evolving market opportunities and long-term impacts of technology options into consideration when planning their capacity, infrastructure and sustainable water supply needs (IEA-ETSAP and IRENA, 2012).

IWRM modelling methods

Planners in the human settlements sector must identify and evaluate alternatives for climate change adaptation objectives and plans on the basis of their economic, ecological, technical, environmental, and social or political impacts. Once objectives and various alternatives have been identified, IWRM models can be developed and used to help stakeholders to identify specific alternative plans that best meet those objectives.

Some objectives may be in conflict, and in such cases IWRM models can help to identify the efficient trade-offs among these conflicting objectives. If the objectives are the right ones (that is, they are what the stakeholders really care about), such quantitative trade-off information should be of value during the debate over what decisions to make.

There are several mathematical optimization and simulation modelling approaches commonly used to study and analyse climate change adaptation in the human settlements sector. The modelling approaches are illustrated by their application to some relatively simple climate change adaptation planning and management problems. The purpose here is to introduce some commonly used methods of (or approaches to) IWRM modelling. Additional details on optimization models and simulation methods can be found in Louks and others (2005), on which this section is based. More realistic and complex problems usually require much larger and complex models than those developed in this module, but regardless of size or complexity, the models are often based on the principles and techniques introduced here.

Mathematical models include variables that are assumed to be known and others that are unknown and to be determined. Known variables are called parameters and unknown variables are usually called decision variables. Models are developed for the main purpose of identifying the best values of the decision variables. These decision variables can include design and operating policy variables of various climate change adaptation components.

Design variables can include the dimensions or flow capacities of canals and pipes, the active and flood storage capacities of reservoirs, the efficiencies of wastewater treatment plants, the pumping capacity of pumping stations, the targets for water supply allocations, the heights of levees, and so on. Decision variables can include measures of system performance, such as concentrations of pollutants, net economic benefits, ecological habitat suitability values or deviations from particular ecological, economic or hydrological targets.

IWRM models describe the system under analysis in mathematical terms, and the conditions that the system has to satisfy. These conditions are usually called constraints.

While the components of simulation and optimization models include system performance indicators, model parameters and constraints, the process of model development and use includes interested stakeholders. When a mathematical model is being used, one important consideration is that it must provide the information in a form that the interested stakeholders can understand.

Plan formulation

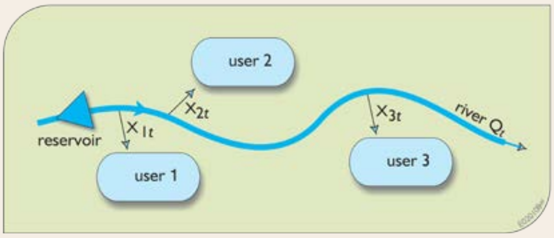
Building an IWRM model to define alternative climate change adaptation plans or policies involves three main steps:

1. The first step is to clearly identify the issue or decision(s) to be made. What are the important objectives and possible climate change adaptation alternatives? Such alternatives in the human settlements sector might require defining allocations of water from different water sources, the technology, level and location of wastewater treatment, and the level and reliability of flood-plain protection from levees. Each of these decisions may affect system performance criteria or objectives. Often these objectives include economic measures of performance, such as costs and benefits. They may also include environmental and social measures not expressed in monetary units (Karnib, 2004). For example, consider the problem of designing a water tank where the criterion to be used to compare different feasible designs is the construction cost. The goal in this example is to find the least-cost shape and dimensions of a tank that will hold a specified volume V of water that is one of the model parameters. The model of this problem should relate the unknown design variables to the construction cost of the tank. For a cylindrical tank shape, for example, the design variables are the diameter D

Exercise 5. A simple planning example (from Louks and others, 2005)

Consider the case of a potential reservoir releasing water to downstream users (see figure). A reservoir and its operating policy can increase the benefits each user receives over time by providing increased flows during periods of otherwise low flows relative to the user demands. Of interest is whether or not the increased benefits the water users obtain from an increased flow and more reliable downstream flow conditions will offset the costs of the reservoir.

Reservoir-water allocation system to be simulated



Describe the simulation process to solve the planning problem in a simulation modelling approach and provide a flow diagram of the reservoir-allocation system simulation process.

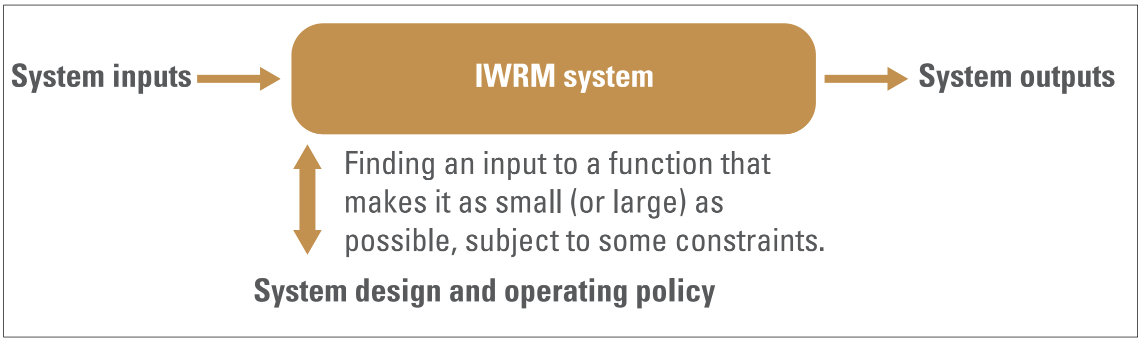
and height *H* of the tank. The objective of this problem is to find the combination of *D* and *H* values that minimizes the total construction cost of providing a minimum tank capacity *V* of water.

2. The second step of model building is to specify all the relations among the objectives, function and decision variables and parameters, including all the conditions that must be satisfied (constraints). It is often appropriate to first state these relationships in words. The result is a linguistic model. Once that is set, mathematical notation can be used to build a mathematical model. For example, the model for the tank design problem mentioned above is to minimize total construction cost where: (a) total cost equals the sum of the costs of the foundation, the base, the wall and the top; and (b) costs of the foundation, base, wall and top is the cost-per-unit area of these elements. Using the mentioned notations already defined, a mathematical model of the total cost that includes the costs of the foundation, base, wall and top can be written.
3. In the third step, a sensitivity analysis should be performed on the uncertain parameters or assumptions. In general, these assumptions could include the values of the parameters and the relationships expressed in the model. The sensitivity analysis should clarify how much any decision variable changes with respect to changes in some parameter values.

Selection of a climate change adaptation plan

Assume that *P* alternative climate change adaptation plans have been identified. For each plan, a number of decision variables exist. Together, these variables and their values define the specifics of each plan. The task, in this case, is to find the particular plan *p*, defined by the known values of each decision variable that maximizes a certain objective derived from the plan. One example is an upgrading project of an existing storm drainage network where the capacity of the network will be exhausted due to the effects of climate change. Several alternatives of upgrading could be proposed, such as building numerous small retention basins, one large retention basin or pipe replacements. One can assume that the decision variables (which are criteria, in this case) are related to technical, economic and environmental aspects.

Figure 9. Representation of the optimization process



Source: Adapted from Louks and others, 2005.

Four IWRM methods are commonly used:

A. Optimization methods

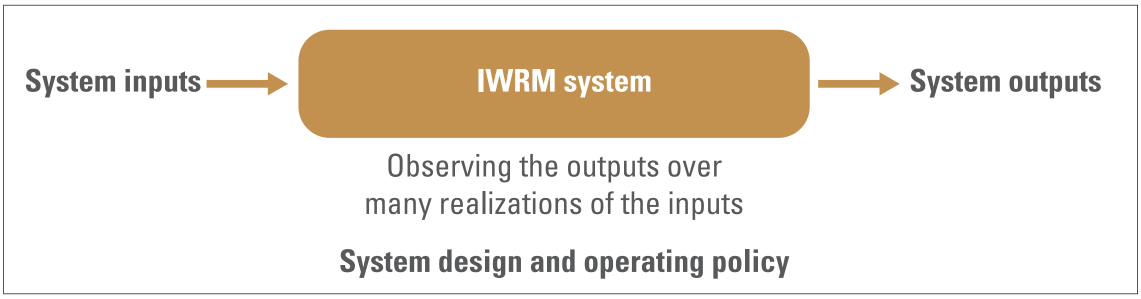
Optimization methods are used to provide the best values of system design and operating policy variables, i.e. values that will lead to the highest levels of system performance. In this type of method, an overall performance objective is expressed as: maximize an objective equation. The values of each decision variable that meet this objective must be feasible; in other words, they must meet all the physical, legal, social and institutional constraints.

There are various approaches to finding the best plan, or best set of decision variable values. Except for relatively simple problems, the use of these optimization models and methods is primarily for reducing the number of alternatives that need to be further analysed and evaluated using simulation methods. Optimization is generally used for preliminary selection of alternatives before more detailed analyses are carried out (figure 9).

B. Simulation methods

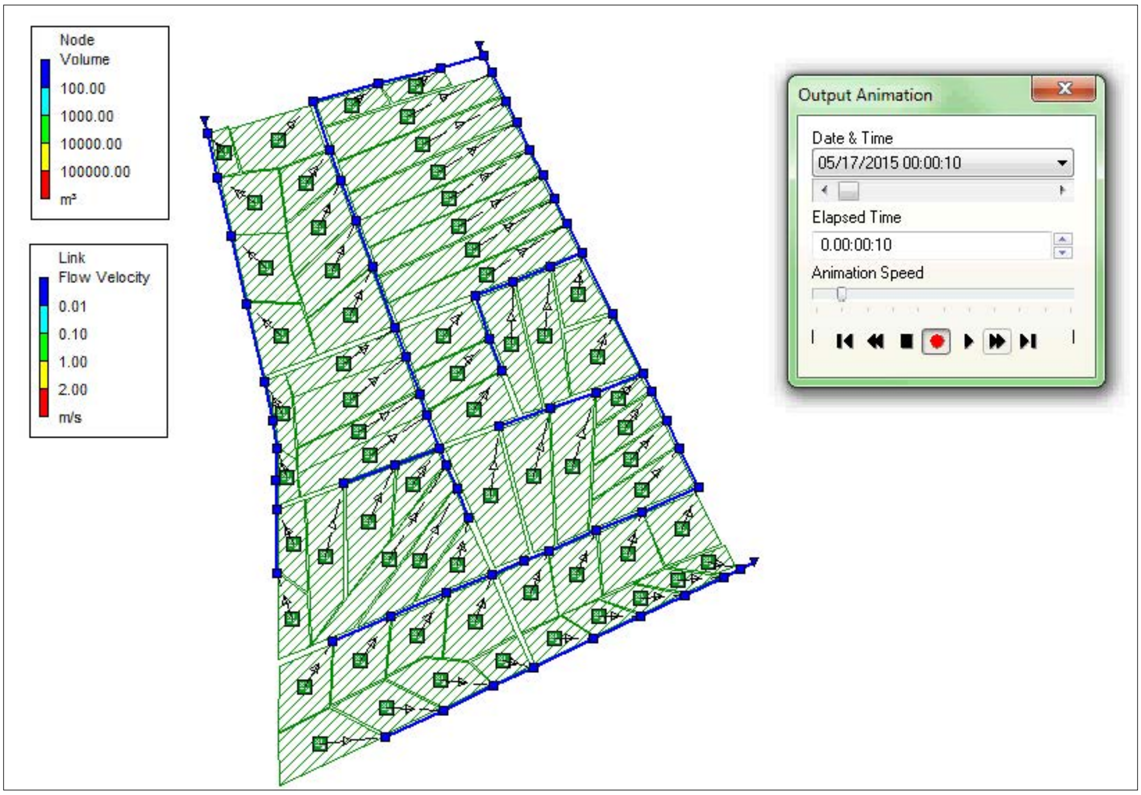
Simulation is the imitation of the operation of a system over time, it addresses the "what if" questions. Simulation requires that a model be developed that represents the key characteristics or behaviours/functions of the selected climate change adaptation system. The model represents the system itself, whereas the simulation represents the operation of the system over time.

Figure 10. Representation of the simulation process



Source: Adapted from Louks and others, 2005.

Figure 11. An animation in the entire network using SSA during a specified storm



Source: Rabi, 2016.

Computer software capable of simulating a wide variety of water resources systems is becoming increasingly available. Simulation software is designed with interfaces that facilitate the input and editing of data and the display of output data (figure 10). Their input data define the components of the water resources system and their configuration. Inputs include hydrological and other technical data and design and operating policy data. These general simulation programmes are now becoming capable of simulating water infrastructure systems, surface and groundwater water flows, storage volumes and qualities under a variety of system infrastructure designs and operating policies. Figure 11 presents an animation in a storm drainage network using SSA during a specified storm.

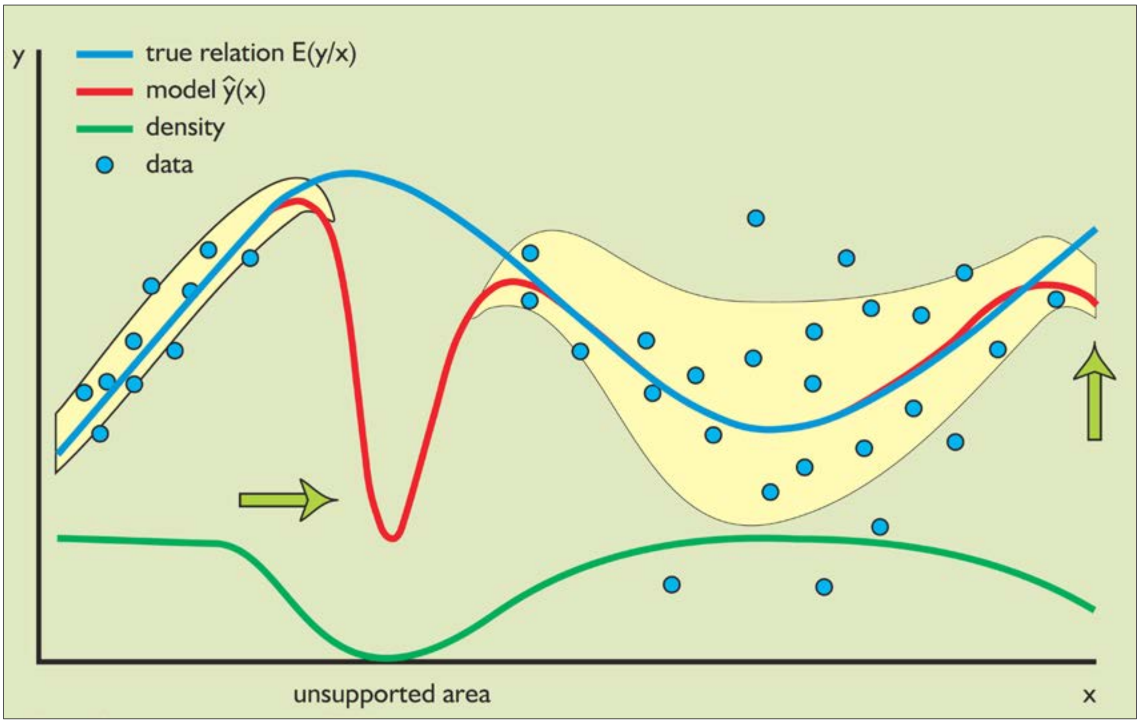
Exercise 6. Simulation versus optimization

Ask the learners to work in country groups, as appropriate, and to analyse the differences between the use of simulation and optimization models on climate adaptation plans in their countries. Learners then prepare and present an example of analysis of climate change adaptation from their countries using the suitable IWRM tool, and share their examples in small groups.

C. Data-based IWRM models

Models based on observed input and output data are used to abstract new information about the behaviour of the studied system. They serve as alternates for more process-based models in applications where the underlying relationships are complicated.

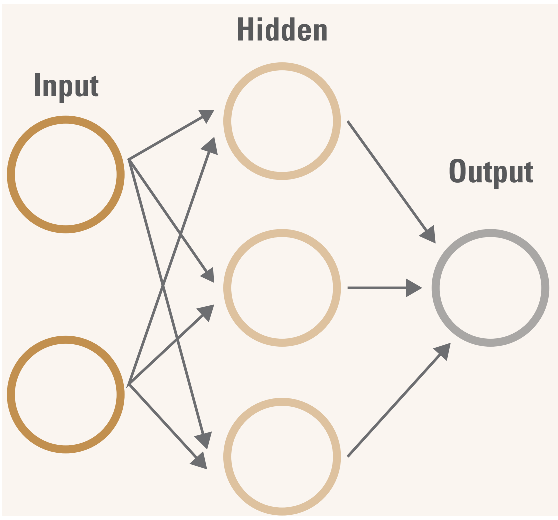
Figure 12. Representation of the data-based models



Source: Louks and others, 2005.

The optimization and simulation models used for IWRM describe, in mathematical terms, the interactions and processes that take place among the various components of the system. These process-based models usually contain variables whose values are determined from observed data during model calibration. These types of models differ from what are typically called black-box models, or statistical models. Statistical models do not describe physical processes; instead they try to convert inputs (such as rainfall, pollutants discharged to a river, inflows to a reservoir, pollutants entering a wastewater treatment plant) to outputs (such as run-off, pollutant concentrations in the downstream from a point of discharge to a river, reservoir

Figure 13. Representation of the artificial neural network



Source: Adapted from Louks and others, 2005.

Exercise 7. Developing an artificial neural network for flow routing

Ask the learners to work in country groups as appropriate and to develop an artificial neural network for flow routing sets of upstream and downstream flows. Develop the simplest artificial neural network that does an adequate job of prediction.

releases, pollutant concentrations in the effluent of a treatment plant) using any mathematical equation or expression that does the function.

The data-based IWRM modelling methods include genetic algorithms, genetic or evolutionary programming, evolutionary strategy and artificial neural networks. Each of these methods has many variations but all use computational methods based on natural evolutionary processes. The use of black-box statistical models, such as genetic programming and artificial neural networks, may be advantageous when for some reason a large number of model solutions must be obtained in a short period of time.

Data-based models are able to produce relatively accurate estimates within their calibrated ranges, but not outside those ranges. The bottom curve shown in figure 12 represents the relative density of data used in model calibration and the arrows point to where the model does not predict well (Louks and others, 2005).

An artificial neural network is an interconnected group of nodes, inspired by the vast network of neurons in a brain. In figure 13, each circular node represents an artificial neuron and an arrow represents a connection from the output of one neuron to the input of another.

D. Multi-criteria decision-making methods

IWRM systems typically include diverse economic, environmental and ecological aspects. They also serve a variety of purposes, such as flood protection, water supply, water drainage, navigation, recreation, hydropower production, waste reduction and transport. Performance indicators (or criteria) provide measures of the performance of a plan or management policy. There are a variety of indicators that one can use to judge and compare system performance. When conflicts between performance criteria exist, trade-offs must be considered. In the following we present multi-criteria decision-making methods to deal with these trade-offs in the political process of selecting the best decision.

Given the multiple performance criteria for multiple climate change adaptation alternatives, how can one determine the best decision, i.e. the best way to develop and manage climate change adaptation? The answer to this question will often differ depending on who is being

Table 11. Elements of the decision process in a multi-criteria decision method

Element of decision process	Multi-criteria decision analysis
Define problems	Stakeholders' inputs are incorporated at the beginning of the problem formulation stage.
Generate alternatives	Alternatives are generated through involvement of all stakeholders including experts.
Formulate criteria by which to judge alternatives	Criteria and sub-criteria hierarchies are developed based on experts and stakeholders judgment.
Gather value judgments on relative importance of criteria	Quantitative criteria weights are obtained from decision makers, experts and stakeholders.
Rank/select final alternatives	Alternatives are ranked or chosen using criteria scores and weights.

Source: Khalili and Duecker, 2013.

Exercise 8. Assessing flood vulnerability using the group decision-making method

Ask the learners to work in country groups as appropriate and to develop a group decision-making approach for flood vulnerability assessment. Each group should identify the concerned stakeholders, the criteria of flood vulnerability and their weight sets using the Delphi survey technique, because floods have a significant influence on society. The Delphi method is a structured communication method that relies on a panel of experts. The experts answer questionnaires in two or more rounds. After each round, a facilitator provides an anonymous summary of the experts' forecasts from the previous round as well as the reasons they provided for their judgments. Thus, experts are encouraged to revise their earlier answers in the light of the replies of other members of their panel. The learners will share their examples in small groups.

asked. There is rarely an alternative that suits every interest group or affected stakeholder. Multi-criteria decision-making methods are used to identify the efficient trade-offs among the objective values that each stakeholder seeks. These methods of multi-criteria analyses are not designed to identify the best solution, but only to provide information on the trade-offs between given sets of quantitative performance criteria.

Most multi-criteria decision methods consist of two main steps: (a) formulating data into a decision matrix; and (b) synthesizing matrix information and ranking alternatives. Multi-criteria methods utilize a decision matrix of criteria and performance scores to provide a systematic analytical approach to rank alternatives or select a single optimal alternative. Most methodologies include the formulation of data into a decision matrix, but each methodology synthesizes matrix information differently.

The use of group decision-making methods provides the benefit of better thinking and therefore, better decisions all around. Group decision-making is the process by which a group collective of stakeholders attempt to reach a required level of consensus on a given issue. This process is usually divided into two main components: the deliberation among members of the group and the aggregation of individual opinions into a single group decision (Kaner and others, 2007). Individual and institutional knowledge and the expertise of stakeholders are decisive factors for climate change adaptation in human settlements. However, stakeholders may have differing views, based on their personal experiences and areas of interest, such as economic, social, engineering, environmental and political issues (Lee, Jun and Chung, 2015). The group decision-making represents an opportunity to strengthen the capacity and effectiveness of the different involved stakeholders and to mainstream gender in IWRM to achieve a sustainable climate change adaptation in human settlements.

Table 12 summarizes elements of the decision process in a multi-criteria decision method. Details on the different multi-criteria methods can be found in Figueira and others (2005).

CH. 5

Implementation of Adaptation Measures

Implementation of Adaptation Measures

Sustainable adaptation to the impacts of climate change will require a mixture of actions at the sectoral, local, national and global levels. IWRM tools provide an opportunity for human settlements in Arab countries to better adapt to climate change.

Applying IWRM modelling methods to analyse climate change adaptation measures in human settlements can provide a shared vision of the best formulated plan or management policy. Reducing the frequency and/or severity of the adverse consequences of droughts, floods and excessive pollution are common goals of many planning and management climate change mitigation exercises. Other goals include the identification and evaluation of alternative measures that may increase the available water supplies and enhance the quality of water. Quantitative system performance criteria can help to judge the relative net benefits of alternative plans and management policies.

The inclusion of sustainability criteria among the more common economic, environmental, ecological and social criteria that are used to evaluate alternative development and management strategies for climate change adaptation may entail change in the way IWRM tools are developed and used. The anticipation of change—including climate change, change due to geomorphologic processes, ageing of infrastructure, shifts in demands or desires of a changing society, and increased variability of water supplies—is an essential aspect in the planning, design and management of sustainable systems.

Screening criteria

Selection and ranking of the appropriate IWRM criteria might differ along the particular institutional, social and economic conditions of cities in the Arab region. For example, cities

Box 4. Adaptive management

Sustainable IWRM systems are those designed and operated in ways that make them more adaptive, robust and resilient to an uncertain and changing future. They must be able to effectively operate under conditions of changing supplies, management objectives and demands.

Adaptive management in the human settlements sector is a process of adjusting management actions to new information on the current and likely future climate and socio-economic conditions. The limitations of current knowledge and experience should be considered in the use of IWRM systems in the context of adaptive management, which helps us to move towards realizing changing goals in the face of incomplete knowledge and uncertainty.

Table 12. Suggested criteria and their scoring scales

Criteria	Scoring scale (value between 0 and 100 where 0 is very low and 100 is very high)
(C1) Technical feasibility	
(C2) Cost	
(C3) Social acceptance	
(C4) Addition to adaptive capacity of the human settlement	
(C5) Indirect positive value	
(C6) Previous experience and local capacity for implementation	
(C7) Technology transfer of IWRM between Arab countries	

in the GCC countries consume much higher amounts of water per capita compared with those in the other Arab countries; yet high-cost desalination is the main source of water supply in the GCC countries. Tools of water rationing, public awareness-raising and applied water tariffs might be more appropriate in this subregion than in others, where water is also scarce but incomes are low.

In general, the suggested criteria and scoring scales showed in table 13 can serve as basis for training on screening options and tools of IWRM at the human settlement level.

Screening of adaptation measures

Several IWRM measures can be used for adaptation in human settlements in the Arab countries. The IWRM adaptation measures outlined in this module are as follows:

(A1) Water harvesting
(A2) Water demand management
(A3) Reuse of grey water
(A4) WFP tools
(A5) NRW reduction
(A6) Adaptation of urban planning policies
(A7) Wastewater treatment and reuse
(A8) Water tariffs
(A9) Managed groundwater recharge – aquifer recharge and recovery
(A10) Desalination by renewable energy

These measures are of clear value for enhancing climate change adaptation across human settlements in Arab countries.

Selection of climate change adaptation options

As previously mentioned, adaptation decision-making can be informed by various tools, methods and approaches. The use of a decision support system is a means to compare different possible interventions.

Table 13. Multi-criteria analysis matrix for adaptation in human settlements in the Arab countries

	C1	C2	C3	C4	C5	C6	C7
A1	x_{11}	x12	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}
A2	x_{21}	x_{22}	x_{23}	x_{24}	x_{25}	x_{26}	x_{27}
A3	x_{31}	x_{32}	x_{33}	x_{34}	x_{35}	x_{36}	x_{37}
A4	x_{41}	x_{42}	x_{43}	x_{44}	x_{45}	x_{46}	x_{47}
A5	x_{51}	x_{52}	x_{53}	x_{54}	x_{55}	x_{56}	x_{57}
A6	x_{61}	x_{62}	x_{63}	x_{64}	x_{65}	x_{66}	x_{67}
A7	x_{71}	x_{72}	x_{73}	x_{74}	x_{75}	x_{76}	x_{77}
A8	x_{81}	x_{82}	x_{83}	x_{84}	x_{85}	x_{86}	x_{87}
A9	x_{91}	x_{92}	x_{93}	x_{94}	x_{95}	x_{96}	x_{97}
A10	x_{101}	x_{102}	x_{103}	x_{104}	x_{105}	x_{106}	x_{107}

An important principle is that there is no single method/approach/tool that suits all circumstances of adaptation decision-making. Adaptation methods have conditions of applicability, and the preferences of stakeholders might be affected by decisions that might be overlooked in practice. The specification of the problem and the available 'inputs' to the decision process should inform the choice of policy.

Based on the criteria and the adaptation options discussed above, the evaluation of each of the adaptation options *A* according to each criterion *C* is represented by a vector $x_i = [x_{i1}, x_{i2}, \ldots, x_{i7}]$. The multi-criteria analysis matrix can be constructed (table 14) and the adaptation options can be screened and ranked. The adaptation options can be ranked using participatory decision-making during the training (Kaner and others, 2007).

Adaptation planning at the sectoral and local levels

Utilities and establishments responsible for important services and infrastructure in the human settlement systems of the Arab region must begin to assess potential climate change impacts and their vulnerabilities. They should devise plans accordingly to mitigate these impacts. Sustainable adaptation decisions should be made to avoid the costly abandonment or retrofits of infrastructure before the end of its useful life span.

The proposed measures to address adaptation presented in this module cut across several sectors of human settlements. Key climate-sensitive sectors in Arab cities include water, marine, energy, transport, communications and health. Each relevant utility and establishment should prepare adaptation plans for their sectors. In drawing up these sectoral plans, three basic steps must be included:

- A clear understanding of the impacts of climate change on each sector;
- Actions to equip decision makers with skills and tools;
- Integration of adaptation into policy at the sectoral level in Arab human settlements.

Policy decisions taken at sectoral level directly affect activities within the individual sector, and, potentially, may also affect other sectors indirectly. Therefore, cross-sector engagement must often occur as part of the adaptation process to ensure that interdependencies are understood and effectively considered in policy and planning processes. Sectoral level decision-making will also cut across local-level decision-making and this too must be taken into account.

For example, water utilities in Arab countries have initiated a research project on developing diagnosis and strategies to reduce NRW, under the supervision of the Arab Countries Water Utilities Association (ACWUA), a non-governmental, non-profit association established in 2009 to build capacity of staff of water and wastewater utilities in the Arab region. More information on ACWUA projects is available from http://www.acwua.org/projects.

Exercise 9. Identifying lead departments and agencies for sectoral adaptation plans

Ask the learners to work in country groups, as appropriate, and to identify the lead departments and agencies for sectoral adaptation plans in their countries. The learners will share their examples in small groups.

Climate change impacts are evident at the sectoral and local levels. Locally tailored policies and responses are thus required along with sectoral adaptation planning. Through their role as municipal leaders and service providers, local authorities have an important role to play in planning forward and taking climate change adaptation actions.

Local authorities are subject to increasing demand from many residences to improve service performance. Adaptation plans at the local level may have implications for neighbouring local authority areas and may require adaptation options that stretch beyond individual administrative areas. Therefore, in developing and analysing potential climate impacts and adaptive solutions, local authorities may opt to take a larger geographical approach by working with adjoining local authorities. Working together can also be a practical and cost-effective way for local authorities to share lessons learned, knowledge, experience and resources.

At the local level, the cities represent dense and complex systems of interconnected services. Therefore, they face a growing number of issues, the adverse effects of climate change with an impact on the frequency, intensity and location of floods that drive disaster risks. The above-mentioned adaptation measures could serve as an example of policies that can be developed to address risk drivers to make cities more resilient and liveable. In this regard, the United Nations Office for Disaster Risk Reduction (UNISDR) has launched the Making Cities Resilient campaign that targets mayors and local governments. More information is available from https://www.unisdr.org/we/campaign/cities.

Local adaptation strategies should develop and express a vision for a wel-ladapted local community that is resilient to the impacts of climate change, through:

- Determining an area’s vulnerability to climate risks;
- Identifying, prioritizing and costing adaptation actions;
- Developing and implementing a comprehensive action plan;
- Ensuring that climate change impacts and risks are embedded into all decision-making.

Finally, the process of devising sectoral and local adaptation plans must be open, transparent and inclusive. Interested organizations and stakeholders at the sectoral and national levels must be given early and adequate opportunities to contribute to the process plan preparation. In this regard, there is also a need to mainstream gender in the process of making adaptation plans; especially if there are service providing projects, women should be consulted.

Adaptation planning at the national level

The primary responsibility for developing national policies and programmes on climate change adaptation remains with national governments. Adaptation planning at the national level provides a strategic policy focus to ensure that adaptation measures are adopted across different sectors and local levels to reduce the vulnerability of human settlements in Arab countries to the negative impacts of climate change. The aim of adaptation planning at the national level is to ensure that an effective role is played by all stakeholders in putting in place an active and enduring adaptation policy regime, and in developing and implementing sectoral and local adaptation action plans, which will form part of the comprehensive national response to the impacts of climate change. Sectoral plans will be prepared by the relevant department or agency and will be adopted by the relevant minister.

National governments in Arab countries play a principal role in key areas affected by climate change, either because of the public nature of the services provided, or through the formulation of policies and associated legislation. Given the widespread nature of this involvement, it will generally be more efficient to insert adaptation considerations into the existing institutions, and correct any existing regulatory inefficiencies that risk being exacerbated by climate change.

Strong policy and planning coordination among the several sectoral and local authorities will be crucial in the delivery of adaptation planning at the national level. The national adaptation planning challenge cuts across key economic sectors and, consequently, a wide range of policy areas. To be addressed successfully, and as cost effectively as possible, adaptation

Box 5. Disaster databases

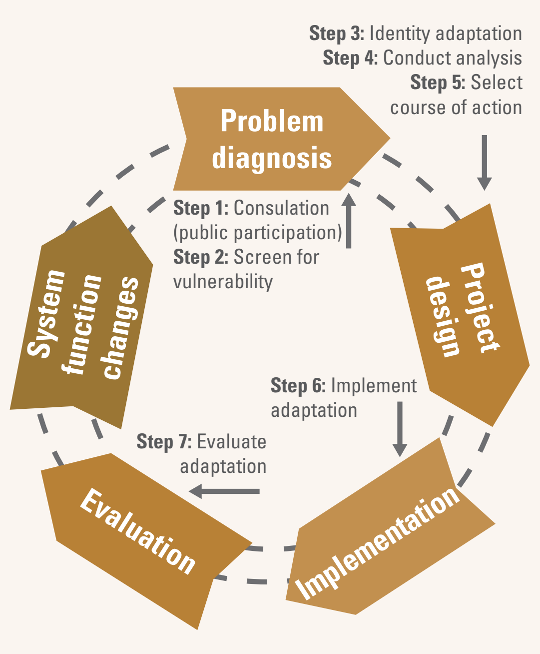
UNISDR is supporting a global initiative to build national disaster databases with a well-defined method. It uses for this purpose DesInventar, a free open source methodology and software. It permits the homogeneous capture, analysis and graphic representation of information on disaster occurrences and losses. Accounting for losses will allow countries to monitor progress against reducing disaster losses and impact targets, and can be used as a powerful disaster risk reduction tool. More information is available from the DesInventar website: http://www.desinventar.net/.

Access to significant information and understanding of disaster risks at the local level are an initial step to reduce losses. Better data collection and more detailed information about exposed areas, vulnerable people and coping capacities allow better risk assessment and disaster preparedness (UNISDR, 2015). Due to the growing importance of understanding current and evolving disaster risks, the programme on improved assessment of risk generates evidence to support local governments to integrate resilience into local development planning. The aim is to make investment and local development planning risk-informed and provide stakeholders with information on costs and impacts (mortality/morbidity) of water-related disasters at the city level.

issues and priorities must be integrated across the full scope of economic and development decision-making. In fact, adaptation policies should follow an integrated form of assessment that has the following benefits at the national level:

- Engages all stakeholders across all sectors, ranging from government to civil society;
- Integrates scientific methodologies, traditions and standards into interdisciplinary analysis to bridge the gap between science and policymaking;
- Links impact assessment to vulnerability assessment;
- Conducts analysis and assessment across relevant geographic and time scales;
- Recognizes and takes into account regional specificities;
- Accounts for scientific uncertainty and seeks to reduce it through objective methods.

Figure 14. Process of the adaptive planning cycle



The following are basic questions to inform the process of adaptation planning:

- What are the need and motivation/justification for adapting (while recognizing uncertainty)?
- What are the options for change/innovation?
- How can one prioritize and select between the options?
- What roles are undertaken by whom, including who pays for what?
- How and when is it to be evaluated?

Figure 14 shows a suggested framework of logical sequence of how adaptation measures/projects/retrofits might be approached and evaluated.

There is a need to establish national risk and disaster management strategies that have mainstreamed the gender component, through empowering women and enabling community participation and other means.These strategies have to be put into action as a precautionary procedure while responsibilities are distributed and institutions and individuals' capacities are built.

CH. 6

Measuring and Reporting Progress of Climate Change Adaptation in Human Settlements

CH. 6

Measuring and Reporting Progress of Climate Change Adaptation in Human Settlements

> Adaptation plans should be updated and improved over time as more information on impacts becomes available and as knowledge of dealing with adaptation issues increases. While uncertainty is a concern that will affect decision-making in the short term, it cannot be allowed to prevent early adaptation planning and action to mitigate changing climate impacts.

An indicator framework for climate change adaptation in human settlements

Monitoring will help policymakers to measure adaptation to climate change and determine where successful adaptation is occurring and where policy action may be needed to

Figure 15. Indicators used in the RICCAR vulnerability assessment

EXPOSURE

- Runoff
- Number of days with precipitation > 10 mm
- Number of days with precipitation > 20 mm

SENSITIVITY

Population

- Population density
- Share of agriculture labor force as part of total labor force
- Share of children and elderly of the total population
- Share of agriculture in GDP
- Refugee population
- Migrant population

Natural

- Land use/land cover
- Degradation of vegetation cover
- Livestock density
- Wetland areas
- Soil erodibility

Manmade

- Floodprone areas
- Urban extent
- Road network
- Areas under cultural heritage protection
- Wastewater treatment facilities

ADAPTIVE CAPACITY

Knowledge and Awareness

- E-government development
- Tertiary enrollment
- Adult literacy rate

Technology

- Number of scientific and technical journal articles
- Information and communication technologies

Infrastructure

- Transportation:
  - Density of road network
- Water and sanitation:
  - Areas served by dams
- Environment:
  - Environment performance index

Institutions

- Governance
- Areas under nature protection
- Disaster risk reduction commitees

Economic resources

- GDP per capita
- Official development assistance

Equity

- Female-to-male literacy ratio
- Years lost due to disability
- Migrants/refugees index

Source: RICCAR vulnerability assessment framework.

encourage and strengthen adaptation. The intention of the indicators framework is to assess trends over time and to understand the nature, extent and effectiveness of adaptation responses. The indicators will be of interest to decision makers and implementation entities at sectoral, local, national and global levels.

The identification of adaptation indicators should be reached through consultative processes in view of responding to the interests and priorities of policymakers and other stakeholders. A set of indicators are used in the RICCAR vulnerability assessment for the human settlements sector, which covers exposure, sensitivity and adaptive capacity (figure 15).

The potential use of MDG+ and SDG indicators for climate change adaptation

In September 2015, the United Nations Sustainable Development Summit led to the adoption of the 2030 Agenda for Sustainable Development, which includes 17 Sustainable Development Goals (SDGs) that aim to guide global action on the achievement of a common set of development objectives for the following fifteen years. The SDGs are the outcome of an advisory process that engaged governments, experts and civil society in global, regional and national dialogues on their development priorities. The SDGs replace the eight Millennium Development Goals (MDGs), which were formulated based on the declaration emanating from the Millennium Summit in September 2000. They present a broader set of goals aimed at achieving universal access to basic needs and services for all, and targets that place emphasis on considering the needs of women and vulnerable groups.

The inclusion of a goal dedicated to human settlements (SDG-11) indicates the recognition of the international community of their significance to achieve sustainable development. It is important to mention that there are many other Goals, targets and indicators which explicitly address issues related to human settlements sustainability such as those related to poverty (SDG-1), health (SDG-3), education (SDG-4), water (SDG-6), sustainable consumption and production (SDG-12), oceans, seas and marine resources (SDG-14) and ecosystems (SDG-15). Progress towards the sustainable development of human settlements depends on the integration of human settlements issues across the entire SDG framework.

The United Nations Statistical Commission established the Inter-Agency and Expert Group on Sustainable Development Goal Indicators in March 2015 to prepare a global indicator framework for monitoring progress towards the achievement of the 17 SDGs and their 169 targets. The resulting framework includes over 220 indicators, with at least one indicator identified to measure progress related to each target (United Nations, Department of Economic and Social Affairs, 2016). The SDG indicators will serve to measure progress towards sustainable development and to help ensure the achievement of the SDG targets. The indicators and their associated data records will be the basis of monitoring progress towards the SDG targets at the national, regional and global levels.

At the regional level, the MDG+ Initiative was launched by the Arab Ministerial Water Council in 2010 to establish a regional mechanism for monitoring and reporting on access to water supply and sanitation services in Arab countries. This Initiative provides country-level data from national monitoring teams on 10 regional indicators and 25 sub-indicators related to drinking water, water supply, sanitation, wastewater treatment and reuse. The first MDG+ Initiative report includes data records on indicators from 11 Arab States (League of Arab States, ESCWA and ACWUA, 2015). The

Figure 16. MDG+ Initiative indicator framework for water supply

		Water supply indicators						
	Data sources	Served population	Average water consumption	Continuity of supply	Water quality	Distance to source	Tariff structure	Affordability
Piped water supply systems	Service providers or regulators	Indicators´ values						

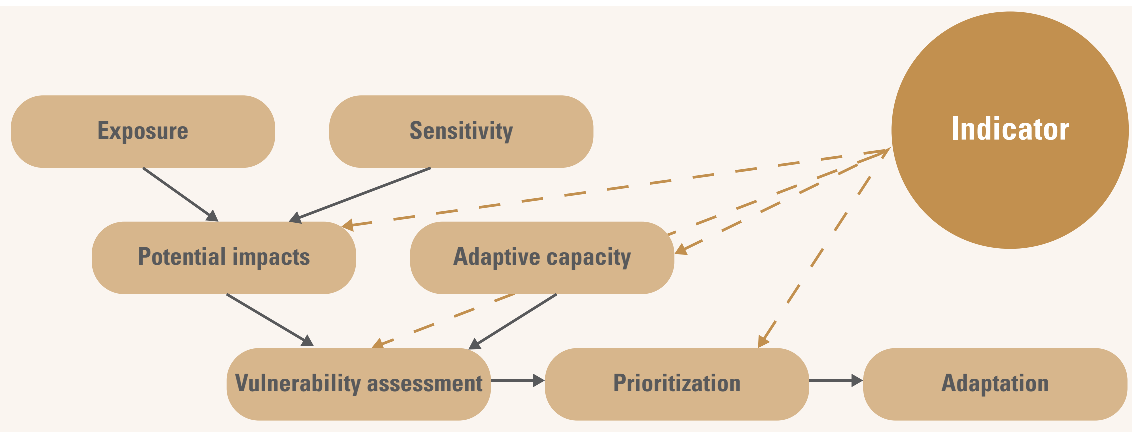
Source: Karnib, 2016.

Figure 17. MDG+ Initiative indicator framework for sanitation

		Sanitation indicators						
	Data sources	Served population	Treated wastewater	Treatment type	Reuse utilization	Reuse type	Tariff structure	Affordability
Sewerage systems	Service providers or regulators	Indicators´ values						

Source: Karnib, 2016.

Figure 18. Indicator-based approach for assessment of human settlements vulnerability and adaptation to climate change



Exercise 10. Selected SDG indicators

Ask the learners to work in country groups, as appropriate, and to identify the SDG indicators that can be used for the assessment of human settlements vulnerability and the adaptation to climate change in their respective countries. Then, ask learners to prepare and present the identified indicators that are relevant for their countries. The learners will share their examples in small groups.

second MDG+ Initiative report includes data records for 18 Arab States (League of Arab States, ESCWA and ACWUA, 2016).

Figures 16 and 17 present the MDG+ Initiative indicator framework for water supply and sanitation, respectively. The MDG+ indicators can be used to inform the assessment of human settlements vulnerability and adaptation related to water supply and sanitation.

The climate change adaptation indicator framework should be designed to work across diverse themes and sectors. It should also aim to integrate with other relevant indicator frameworks, for example that of the SDGs, the MDG+ Initiative and other regional initiatives.

Next Steps

Some additional key questions for articulating a vision for future climate change adaptation in human settlements by applying IWRM in the Arab region are:

- What processes are needed to stimulate political will for climate change adaptation in human settlements?
- How can sufficient capacity be built at the national and local levels to ensure successful implementation of climate change adaptation?
- What multi-level governance structures are needed to support the implementation of climate change adaptation?
- How can the means of implementation of the SDGs, in particular with respect to the targets and indicators related to human settlements issues, be harnessed to promote the implementation of climate change adaptation?
- What regulatory frameworks are needed at the national level for an effective implementation of climate change adaptation?
- What actors and institutions are drivers of change that can encourage implementation of climate change adaptation?

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ENVIRONMENT

Climate Change Adaptation and Ecosystem-Based Management
Using Integrated Water Resources Management Tools

AGRICULTURE

Climate Change Adaptation in Agriculture, Forestry and Fisheries
Using Integrated Water Resources Management Tools

HEALTH

Climate Change Adaptation in the Health Sector
Using Integrated Water Resources Management Tools

HUMAN SETTLEMENTS

Climate Change Adaptation in Human Settlements
Using Integrated Water Resources Management Tools

ECONOMIC DEVELOPMENT

Climate Change Adaptation in Economic Development
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